# Electronic Engineering

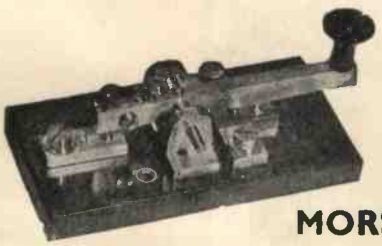
INCORPORATING ELECTRONICS, TELEVISION AND SHORT WAVE WORLD

*PRINCIPAL CONTENTS*




1/6D OCT., 1941

# For H.M. Services



There is a great interest in equipment for training operators, particularly for Service requirements. Although supplies are limited, Webb's are making every endeavour to reserve supplies for members of the Forces, Schools, etc. Below are details of some of the lines which can be delivered speedily but numerous other lines are generally available.

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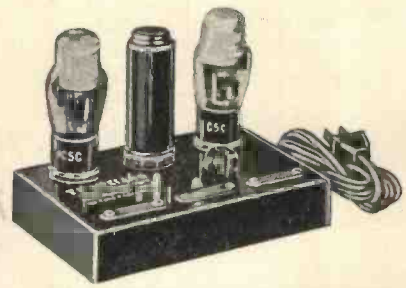

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Audio Oscillator suitable for feeding one to two pairs of headphones complete with line cord for 230-volt A.C. mains giving 1,000 cycle note, complete with valves, 45/-.

**HEAVY-DUTY "SCHOOLS" MODEL AUDIO OSCILLATOR, giving outputs to feed 20 or 50 pairs of telephones or alternatively several loudspeakers, is now available at £7 10s. 0d.**

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This is a machine consisting of photocell, the ray to which is broken by printed tape. The output from the cell is amplified and triggers a sensitive relay, making the instrument capable of keying at any speed from 5 to 50 words per minute. It should be used in conjunction with an audio oscillator as illustrated. Price of Mac Auto complete with one tape (approximately 2,000 words), £9 4s. Tape Puller for feeding the above, £3 17s. 6d.

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# Electronic Engineering

PROPRIETORS: HULTON PRESS LTD.,
Editor: G. PARR.

TELEPHONE: CENTRAL 7400

TELEGRAMS: HULTONPRES LUD LONDON.

No. 164 Vol. XIV

OCTOBER - - - 1941

EDITORIAL, ADVERTISING AND PUBLISHING OFFICES, 43-44, SHOE LANE, LONDON, E.C.4

## CONTENTS



# Plastics

THE average man does not realise to what an extent plastics are forming part of everyday life, so unobtrusively are they replacing the familiar wood and metal.

In the electrical industry we are more often reminded of the increasing uses of plastic materials and note the gradual disappearance of the ebonite panel or the metal meter case from the laboratory and the introduction of new coverings for wire.

Incidentally, conservatism apparently still demands that the cases of meters should be black, but it might be worth considering fitting, say, high tension voltmeters with red cases as standard. Possibly there will be a B.S.I. colour code for meters in a few years time, with gold bands to indicate sub-standard accuracy.

It is generally thought that plastics are of recent origin, but celluloid, the father of them all, was made in 1865. Bakelite, the first of the new insulating materials of the plastic type, dates from 1910 and the bakelite moulding from 1916. After the last war the development of thermo-plastics in this country proceeded rapidly until twenty years later Great Britain and U.S.A. between them were producing over 40,000 tons of thermo-setting resins yearly. The plastics industry at the present time can compare with the rubber industry, and the demands of the present war have enormously accelerated its growth.

No other materials can claim so many desirable properties as plastic materials. They are incorrodible, practically unbreakable, light, adaptable to nearly all manufacturing processes, and although they do not resist heat, this restriction on their uses is a minor one compared with the variety of applications which can be found for them.

**FREQUENCY MODULATION**

**Commencing in the November issue a series of six articles on this important subject will be published under the following headings:—**

1. **General Nature of the System.**
2. **The Advantages and Disadvantages of Frequency and Phase Modulation.**
3. **Methods of Achieving Frequency and Phase Modulated Transmission.**
4. **Reception of Frequency or Phase Modulated Transmission.**
5. **Prevention of Amplitude Change and Conversion of Frequency or Phase Modulation to Amplitude Modulation.**
6. **Particular Circuits for Conversion to Amplitude Modulation.**

**The author of the series is Dr. K. R. Sturley of the Marconi School of Wireless Communication whose book "Radio Receiver Design" is shortly being published by Messrs. Chapman & Hall.**

In the July issue of this journal* appeared a review of a small book on plastics written by two prominent members of the industry. In the concluding pages they paint an optimistic picture of the citizen of the future surrounded by plastics from the cradle, using plastic lenses and false teeth in middle age and finally being put away in an everlasting plastic coffin. However depressing the last thought is, there is no doubt that the plastic age is ousting the wood and metal age for many purposes and its advent will be accelerated by the urgent need for replacements after the war.

At the present time the interest of radio engineers is centred on plastics of the polystyrene type for their valuable properties in ultra-high-frequency work. Distrene, perspex, trolitul and diakon are now familiar component materials in modern short wave apparatus. In high voltage work, types of vinyl resins have a breakdown voltage of over 25kv. per millimetre, and are being increasingly used for flexible coverings for cables and wires.

In view of the particular interest which plastics hold for radio manufacturers and engineers at present, we have invited one of the authors of the book mentioned above to contribute a short series of articles to this journal and the first will appear shortly.

* p. 327.

# The Generation and Amplification of Microwaves

By C. E. LOCKHART

### Negative Grid Valves—Part 3

**The discussion of negative grid valves is concluded this month with a review of the salient features of the valves tabulated in Table II of last month's article as well as a number of other valves. The series will be resumed in December.**

## Transmitting Triodes

### 1. Filamentary Radiation Cooled

**Standard 3B/250**

This is a 300 volt 25 watt triode, the production version of the smallest of the three double-lead-out U.H.F. triodes developed by the Western Electric Co.[26, 27] and has the highest operating frequency of any existing negative-grid triode. In appearance it is identical with the illustration in Fig. 6, Part I. The limit of oscillation is reached at a frequency of the order of 1,800 Mc/s. (*See* Fig. 9) Part II. The filament is intended to be operated on a current basis. Diameter of bulb 2 in.

**Western Electric 316A, Standard 4316A and Mullard T.Y. 04.30**

This 450 volt 30 watt valve is the original W.E. "door-knob" with 100% ratings down to 60 cms. (500 Mc/s) which was later improved in the double-lead-out series. The variation of performance with frequency is given in Fig. 9 from which it will be seen that the limit of oscillation is reached at a frequency of the order of 750 Mc/s. diameter of bulb 2.11/16 in.

**R.C.A. 1628**

This is a 1,000 volt 40 watt triode with 100% ratings down to 60 cm. (500 Mc/s) and is illustrated on Fig. 7, Part I. It is provided with double lead-outs to the grid and anode and has a double helical filament with a centre tap in order to minimise the effect of filament lead inductance. Bulb diameter 1.1/16 in.*

**Western Electric 304B, Standard 4304B, R.C.A. 834 and Mullard T.Y. 1-50**

A 1,250 volt 50 watt triode with 100% ratings down to 300 cm. (100 Mc/s). This type developed by Western Electric Co. was one of the first valves commercially available to be capable of generating microwaves. The alternative versions are very similar in appearance and characteristics. The R.C.A. 834 is illustrated on Fig. 11, Part II, while the performance of the 4304B is shown on Fig. 9. The limit of oscillation is reached in the region of 400 Mc/s. Maximum bulb diameter 2.5-2.7 in.

The **Osram D.E.T.12** has very similar characteristics.

* The caption under this figure in the last issue should have read: R.C.A. 40 watt ultra short wave triode with 100% ratings down to 60 cm. (500 Mc/s).

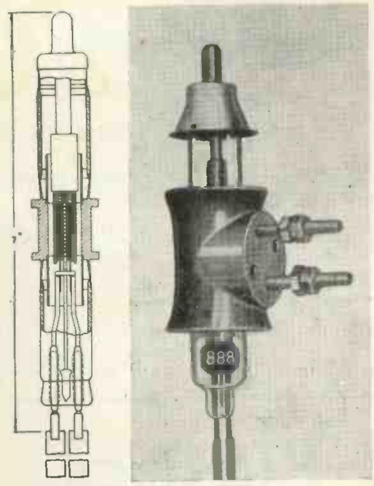



**Fig. 14. External and sectional views of R.C.A. 888 3000 v. 1000 W. water-cooled triode with 100 per cent. ratings down to 130 cm.** (*From R.C.A. Review*, 1937.)

**Western Electric D. 156548**

This 500 volt 50 watt triode is another model of the W.E. double-lead-out series and a larger edition of the 3B/250 developed for use in radio altimeters.[26, 27, 41] Very little information is available on this valve and the curve shown dotted in Fig. 9 is an estimate from the three points available. The filament is intended for operation on a current basis. The valve is illustrated in Fig. 6, Part I and has a maximum bulb diameter of 11 in.

**Western Electric 356A**

A 1,500 volt 50 watt triode with C.C.S. 100% ratings up to 300 cm. (100 Mc/s) and reduced ratings at lower wavelengths. An all-glass construction with a ceramic wafer at valve pins, a centre-tapped filament (5 volt 5 amps.), and an amplification factor of 50. Maximum operating anode current 120 mA. Power output: 100 Mc/s 75 watts; 150 Mc/s 50 watts.

**R.C.A. 826**

This is a 1,000 volt 60 watt triode with 100% rating down to 120 cm. (250 Mc/s) with double grid and anode lead-outs and a centre-tapped filament in order to minimise the effect of filament lead inductance. The valve is illustrated on Fig. 13, Part II and has a bulb diameter of 2 in.

**Osram A.C.T. 7**

A 2,500 volt 300 watt tungsten filament triode with 100% ratings down to a wavelength of 350 cm. (86 Mc/s) an efficiency of 30% is obtainable at a wavelength of 175 cms. (170 Mc/s). The valve has the following ratings for Class C Telegraphy service.

| | |
|---|---|
| Filament volts | 11 |
| Filament current (amps.) | 28 |
| Amplification factor | |
| Max. total cathode current (mA.) | 1,500 |
| Max. anode volts | 2,500 |
| Max. anode dissipation (watts) | 300 |
| Max. D.C. anode current (mA.) | 300 |
| Power output at 350 cms. (86 Mc/s) watts | 450 |
| Power output at 250 cms. (120 Mc/s) watts | 300 |
| *Inter electrode capacities.* | |
| Grid-anode | 9.1 $\mu\mu$F |
| Grid-filament | 8.8 $\mu\mu$F |
| Anode-filament | 0.7 $\mu\mu$F |

**Western Electric 357A**

A 4,000 volt 350 watt triode with C.C.S. 100% rating down to 300 cms. (100 Mc/s) and reduced ratings at lower wavelengths.

| | |
|---|---|
| *Design Characteristics.* | |
| Filament volts | 10 |
| Filament current (amps.) | 10 |
| Mutual conductance mA./V at Ia = 500 mA. | 9 |
| Amplification factor | 30 |
| Max. D.C. anode current (mA.) | 500 |
| Max. D.C. grid current (mA.) | 100 |
| Max. D.C. anode volts | 4,000 |
| Max. anode dissipation watts | 350 |
| *Interelectrode Capacities.* | |
| Grid-anode | 4.25 $\mu\mu$F |
| Grid-filament | 9.5 $\mu\mu$F |
| Anode-filament | 2.5 $\mu\mu$F |

The valve is illustrated in Fig. 12, Part II.

The chief constructional features of the 357A are heavy copper low-inductance leads sealed directly through the glass and shielded ceramic insulators which contact only one electrode.

### 2. Filamentary Water Cooled

**R.C.A. 887 and 888** [28, 29]

These valves are 3,000 volt 1,000 watt water-cooled triodes with C.C.S. 100% ratings down to 130 cm. (225 Mc/s). For their power the valves are very small in size (7 in. overall length), *see* Fig. 14. By making the lead-outs essentially a continuation of the electrodes and keeping the diameter of the enclosing glass

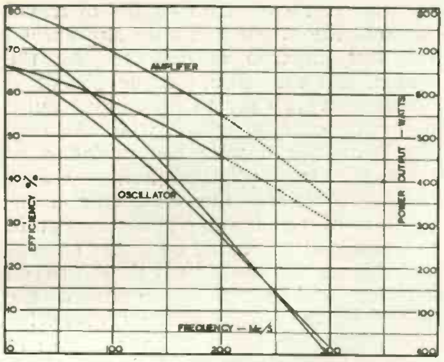



**Fig. 15. Performance curves of the R.C.A. 887 and 888 under Class C Telegraphy conditions, showing loss of power and efficiency, with frequency. The upper curve of each pair relates to the power output.**

cylinders very small the whole electrode system approaches the ideal for use with concentric line circuits.

The total length of the grid structure (the grid is made of tantalum) up to the point of external contact is less than 10 cm. The length of the tungsten filament structure to the point of external contact is also about 10 cm. The copper anode which is only an inch long is less than an inch in diameter.

In order to reduce transit time effects the grid to filament and grid-anode spacings have been made 60 and 90 thousandths of an inch respectively and the grid and filament are entirely self-supporting in order to remove all insulators. The glass portion of the envelope is shielded to prevent high voltage gradients. The valve is illustrated on Fig. 14 and performance characteristics as an oscillator and amplifier are shown on Fig. 15. The amplifier curve was taken experimentally up to 200 Mc/s, though the estimated performance is shown up to 300 Mc/s.

### General Electric Co. (U.S.A.) G.L. 8002 and G.L. 8002R

This remarkable 3,000 volt 1,200 watt water-cooled valve designed for Frequency Modulated and Television Transmitters has C.C.S. 100% ratings down to 200 cm. (150 Mc/s) and delivers 1,800 watts at this wavelength yet its overall length is only 4.11/16 in. and its maximum diameter $1\frac{7}{8}$ in. It will operate at reduced ratings down to 100 cm. (300 Mc/s). The G.L.8002 which is illustrated in Fig. 16, has three grid lead-outs and a centre-tapped filament to enable inductance effects to be minimised.

It is also available in forced-air cooling form as the G.L. 8002R with 3.11/16 in. diameter radiator milled from solid copper. While the characteristics are identical to the water cooled model, the frequencies for 100% ratings are slightly lower, the valve delivering 1,800 watts down to 250 cm (120 Mc/s) and operating at reduced ratings down to 150 cm. (200 Mc/s).

These valves are noteworthy as being the only design in this review capable of competing with an ordinary medium wave design of equal dissipation, owing to their high permissible input of 3 kW.

## Transmitting Beam Power Amplifiers

### I. Radiation Cooled

At was pointed out in the first part of this article triodes can be neutralised as amplifiers down to wavelengths of the order of 90 cm. (350 Mc/s). The neutralisation, however, operates only at the wavelength for which it has been adjusted, and is therefore inconvenient for use in equipments which have to cover a given wave-band. For this class of service a stable screened amplifier is desirable. The trouble of providing really low impedance connexions to the screening electrode has already been pointed out. However, by the use of a push-pull circuit and by mounting the two electrode structures in one bulb (in order to join the two screens and two cathodes with the shortest possible low impedance connectors) a big improvement can be realised. With this arrangement the voltage drop in the common connecting lead to the screen or cathode electrodes will be reduced as the fundamental and even harmonic components of the space current will tend to neutralise.[20, 24, 25, 27, 30, 31] In addition the push-pull circuit with the suitable electrode lead-outs made available by the mounting of the two electrode structures in one bulb enables efficient use to be made of parallel wire resonant line circuits.

**Fig. 16. This illustration shows the remarkably small size of the G.L. 8002, which is a 3000 v. 1200 watt water-cooled triode with 100 per cent. ratings down to 200 cm., at which wavelength it delivers 1800 watts. Inset : GL. 8002R.**

As in the case of a screened amplifier the screen dissipation becomes one of the main limiting factors to the output obtainable, it is imperative to align the control grid and screen grid in order to reduce the screen current to a minimum. Also in order to obtain the maximum anode circuit efficiency it is necessary to obtain the lowest possible " knee " voltage for the anode current-anode voltage characteristic. With the high peak anode currents required for Class C operation a better characteristic can be obtained with a beam tetrode type of design rather than with the suppressor grid of a pentode.

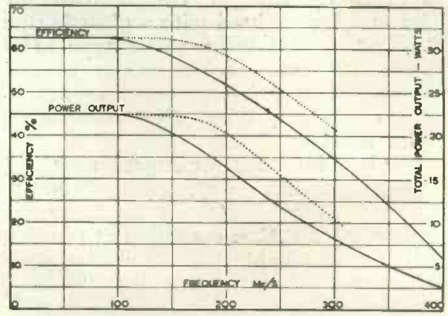



**Fig. 17. Performance curves for Class C Telegraphy service of R.C.A. 832, showing loss of power and efficiency with increase of frequency.**

The R.C.A. company have put on the market a number of such push-pull screened beam amplifiers, the first of these to be released being the

### R.C.A. 832

This valve which has a total anode dissipation of 15 watts for the two anodes is illustrated in Fig. 10, Part II. The two anodes are brought out at the top of the bulb and the two grids through the all-glass base together with the screen, cathode and heater connexions. The flat metal disk shield seen in the illustration provides a low impedance connexion between the two cathodes and also acts as an internal screen between the input and output electrodes.

As these valves had to be suitable for use at high altitudes (in aeroplanes) the anode voltage, and therefore also the screen voltage, had to be kept low. This factor necessitated the use of comparatively small gaps. The grid-cathode spacing employed is of the order of ten thousandths of an inch. The 832 provides a stable amplifier with a reasonable power output down to wavelengths of the order of 120 cm. (250 Mc/s) the loss of output with increase of frequency is shown in Fig. 17. From these curves and the information provided on Table II it will be seen that for an anode voltage of 400 and a total anode current of 90 mA. a grid R.F. drive of 124 volts peak-peak between grids will provide a power output of $22\frac{1}{2}$ watts up to a frequency of 150 Mc/s. For these curves the anode voltage was kept constant at 400 up to 250 Mc/s, at higher frequencies it was progressively reduced to the order of 360 volts at 300 Mc/s and 300 volts at 400 Mc/s. The input power to the anodes was, however, suitably reduced above about 150 Mc/s in order not to exceed the maximum rated anode dissipation ($7\frac{1}{2}$ watts per anode).

### R.C.A. 815

This 500 volt 25 watt total anode dissipation push-pull beam tetrode is an appreciably cheaper design than the 832 and 829. Fitted with a glass button type stem and large wafer type octal base with metal shell it has an overall length of 4.9/16 in., and a bulb diameter of 2.1/16 in. *See* illustration Fig. 18.

Mainly intended for Amateur (ICAS) service it has 100% ratings up to 200 cm. (150 Mc/s), it is, however, suitable for C.C.S. operation at reduced inputs, *see* Table II. The design is characterised by a very low "knee" voltage (of the order of 30 volts) which accounts for the high efficiencies obtained.

**R.C.A. 829**

A 500 volt 40 watt total anode dissipation push-pull beam tetrode with C.C.S. 100% ratings down to 150 cm. (200 Mc/s). This valve which is illustrated on Fig. 19 also has a low "knee" voltage when considered in conjunction with the higher operating peak anode current. The bulb diameter is 2.1/16 in. and the overall length 4.5/16 in.

**2. Forced Air Cooled**

The only screened beam power amplifier of this type with 100% ratings below 100 cm. (300 Mc/s) and an output comparable with that of the group of triodes in section (e) is the

**R.C.A. 827R**

This 3,500 volt 800 watt forced air cooled thoriated tungsten filament beam power amplifier illustrated in Fig. 20 is of special construction with 100% rating down to 90 cm. (110 Mc/s).[32]

The basis of the construction is the use of a Kovar metal header in place of the more usual glass stem. This header serves as a very low inductance connexion for the screen which is mounted on it by means of a continuous conical support. In practice the screen is maintained at ground potential to R.F. by providing a continuous connexion round this header and this provides very effective shielding at the higher frequencies. Two lead-outs are provided for the control grid.

Fig. 18. The R.C.A. 815 push-pull beam tetrode, having a max. total anode dissipation of 25 watts for ICAS service at an anode voltage of 500. Ratings are 100 per cent. down to 300 cm. Bulb diameter 2".

Fig. 19. R.C.A. 829 push-pull beam tetrode, with max. total anode dissipation of 40 w. at 500 v. Ratings are 100 per cent. down to 150 cm. Bulb diameter 2".

Both the control and screen grid consist of parallel vertical wires just under 4 cm. long in the form of a squirrel cage and the wires are aligned to reduce the screen current.

In order to reduce the electron transit time effects the grid-filament, grid-screen and screen-anode spacings have been made of the order of 50, 120 and 360 thousandths of an inch respectively. At a 100 Mc/s with the peak positive grid voltage present under carrier conditions of Class C plate modulated telephony, this results in transit angles of 14, 5 and 32 degrees respectively.[32]

A thoriated tungsten double helical filament is employed and owing to the close spacings the grid has to be coated with zirconium in order to reduce the tendency toward grid emission. In order to reduce dielectric losses all the electrodes have been made self-supporting.

The valve operates at high efficiencies, at 20 Mc/s the efficiency is of the order of 70%, while even at 110 Mc/s, efficiencies of the order of 56% have been measured.[32]

The diameter of the radiator is 4.21/32 in., and the length of the valve excluding flexible connectors 5.13/16 in.

## Frequency Multiplication

No review of negative-grid amplifiers would be complete without a consideration of the possibility of extending the wavelength range by the use of frequency multiplication.

Frequency multiplication appears at first sight such a simple method of reducing the minimum operating wavelength of a given valve, as by maintaining a reasonably high wavelength for the applied signal the problem of excessive input loading is largely eliminated. Two factors, however, limit the possibility of any improvement being realised.

(a) For efficient frequency multiplication it is necessary to provide a sharp narrow pulse of anode current. As explained earlier the anode current starts as soon as an electron begins to travel towards the anode and only stops when the last electron is collected by the anode. At the lower frequencies it is comparatively easy to produce a pulse of anode current whose width is very small compared with the period of a cycle of the applied signal. Under these conditions the harmonic components of the input signal present in the anode current can be made reasonably large. As the transit time between cathode and anode is increased the width of the anode current pulse becomes a larger and larger percentage of the period of the applied signal. This spreading and flattening of the anode current pulse reduces the amplitude of the harmonic components faster than it does that of the fundamental component of the input signal in the anode current.

(b) Due to capacity loading of the anode tuned circuit the possible reduction in wavelength for a given valve is limited. The higher anode load resistance required by frequency multiplication also results in a higher percentage of the available power being dissipated in the tuned circuit.

The above limitations of frequency-multiplication for extending the operating range should not however be confused with the possible improvement in stability that can be obtained by its use at somewhat longer wavelengths.

*Small figures refer to the bibliography given on p. 414 in last month's issue.

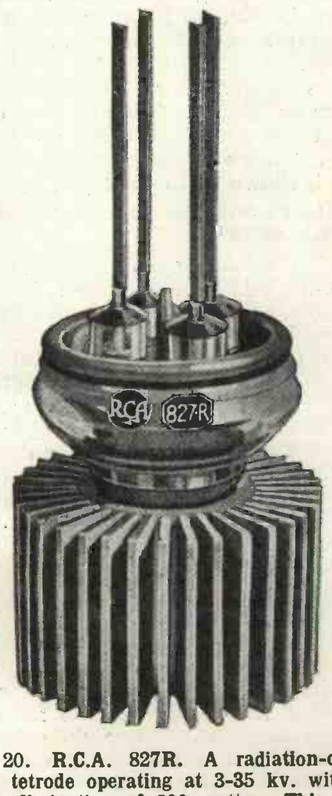
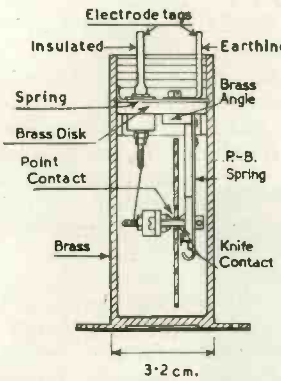


Fig. 20. R.C.A. 827R. A radiation-cooled beam tetrode operating at 3-35 kv. with an anode dissipation of 800 watts. This valve has 100 per cent. ratings down to a wavelength of 90 cm. Max. diameter of radiators : 4.65".

# Quartz Crystal Holders

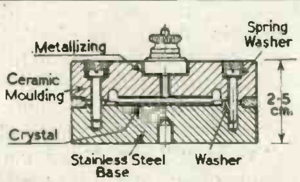
In a paper recently read before the Wireless Section of the Institution of Electrical Engineers, C. F. Booth (Radio Branch, P.O. Engineering Dept.) discusses some of the more important applications of the quartz crystal in tele-communications. The author points out that in order to take full advantage of the constancy obtaining in the equivalent circuit of the crystal due consideration must be given to the holder design and that very little information is available on the subject. For this reason the following sketches of typical holders developed in the P.O. Research Dept. are reproduced with permission. *(J.I.E.E., Vol. 88, No. 2 Part III, p. 97.)*




## Holders for Bars, Range 50 to 100 kc/s

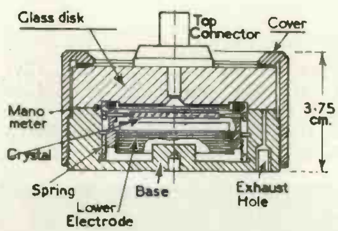
The design permits of an accurate nodal plane suspension of rigidly clamping the crystal and of hermetically sealing the holder and its chief application is for the mounting of standard and sub-standard bars. The electrodes are sputtered on the major surfaces of the bar, which is mounted between a knife-edge and a point of contact. The knife contact is located in a V groove, and the point contact rests on a countersunk hole in the opposite surface of the bar. In order to make the holder universal for varying sizes and types of bar in which the angle subtended by the nodal plane at the axis of the bar may differ, the knife-edge is arranged to be rotatable round the axis of the point contact.

The complete mounting system is contained in a heavy brass cylinder, 3.2 cm. diameter x 8 cm. high, and is securely locked in position.




## Type 2 Holder for Plates, 1,000 to 7,000 kc/s

The Type 2 holder comprises a circular metal bottom electrode, a thin metal spacer and a ceramic moulding. The top electrode takes the form of a metal film burnt on the under-side of the moulding; the film is continued through a small hole to the top terminal, which is inset and soldered to the film. The air gap is provided by making the thickness of the metal washer equal to the crystal thickness plus the size of the required air-gap, and the washer is shaped to act as a frame for the crystal.

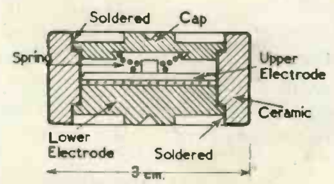



## Holder for Frequency Standards, 400-2,000 kc/s

In mounting a plate for a frequency standard it is desirable to employ nodal plane suspension with a double air-gap, and the holder should be sealed at a reduced pressure. These features are incorporated in the holder illustrated which is suitable for square plates in the frequency range 400—2,000 kc/s. The holder includes a circular metal base which carries the crystal carriage and bottom electrode and a glass disk. The top electrode is a sputtered gold film on the under-side of the disk, and connexion to the top terminal is made through a metal screw. The base and glass disk are clamped together by a metal shell which is threaded on the base. To permit the adjustment of the two air-gaps, the crystal mounting is in three separate parts—the bottom electrode, the carriage and the outer ring.

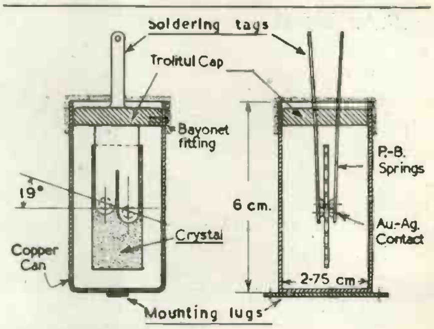
The circular bottom electrode is threaded and is screwed into the carriage. The latter is in the form of a ring, threaded inside and outside, and carries four bosses set at 90° intervals for the crystal clamping screws. The outer ring is internally threaded and is screwed on to the carriage. The crystal is securely clamped on the carriage by four pointed screws set in the carriage bosses, engaging in tiny holes in the plate. Variation of the lower air-gap is accomplished by rotating the bottom electrode with respect to the carriage and of the top air-gap by rotating the carriage and bottom electrode together in the outer ring.

To seal the holder hermetically the top electrode terminal and screw connector are sealed in the glass disk, and a seal is employed between the contact surfaces of the disk and the base. The holder is evacuated to the required degree of vacuum through a fine hole in the base and a corresponding hole in the glass disk which opens inside the holder. When the evacuation process is complete the disk is rotated to seal the hole in the disk. The holder is 7 cm. in diameter and 3.75 cm. high (excluding the top electrode), and is suitable for square and circular plates, the maximum sizes being some 3.3 cm. square and 4.6 cm. diameter respectively.




## Holder for Plates, 7,000-20,000 kc/s

The insulation between electrodes is obtained with a ceramic ring. The bottom electrode is a metal inset soldered into the ring, and the top electrode is held in contact with the crystal by means of a spring. A top cover-plate soldered into the ring ensures that the holder is effectively sealed.




## Crystal-Resonator Holder

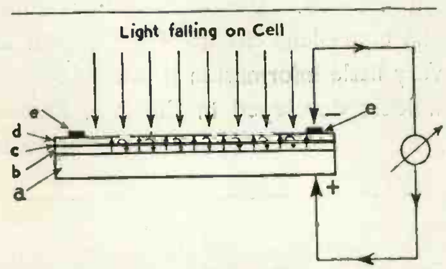
The holder shown was designed for the crystal elements used in the crystal filters associated with the London-Birmingham coaxial cable.

The plate is clamped between four hemispherical gold-silver contacts riveted on two split phosphor-bronze springs, the springs being split to allow of the automatic alignment of the contacts, and set at 19° to the base. The springs are moulded in a Trolitul base which is mounted in a spun-copper container. Brass lugs soldered to the base of the copper case enable the holder to be mounted on the vertical panel so that the major crystal surfaces are horizontal. The holder is compact and accommodates all the crystals, the external dimensions of the case being 2.75 cm. diameter, 6.0 cm. long. The mounting system allows the series resonant frequency to be adjusted to within 5 cycles per sec. of the specified value and permits the final frequency-adjustment, obtained by lapping the Y dimension, to be accomplished while the crystal is mounted. The contact pressure is adjusted so that normal jars and vibrations do not cause the crystal to move relatively to the contacts. The holder is sealed against the atmosphere by flooding the top with sealing compound.

# The Selenium Barrier Layer Photo-Cell

By Dr. G. A. VESZI
(*Laboratory of Evans Electroselenium, Ltd.*)

MODERN selenium barrier-layer cells, possessing as they do high sensitivity combined with high stability, have not only replaced their less-perfect predecessors in almost every scientific and industrial application but their development has also created many new possibilities of far-reaching importance. Many thousands of selenium barrier-layer cells are being used the world over to-day for objective photometry, in light meters, photo-exposure meters, photo-electric colorimeters, spectro-photometers and many other scientific and industrial devices. Still more useful applications are certainly possible, and it is worth mentioning that British-made cells of first-class quality are now available on the market that compare most favourably with the best cells made in Germany or the U.S.A. before or during the war.




**The photograph shows a representative collection of Selenium cells. Fig. 1.** *Above*: **Section through cell showing (a) metal base-plate (b) selenium layer (c) barrier layer (d) transparent metal layer (e) collecting ring.**

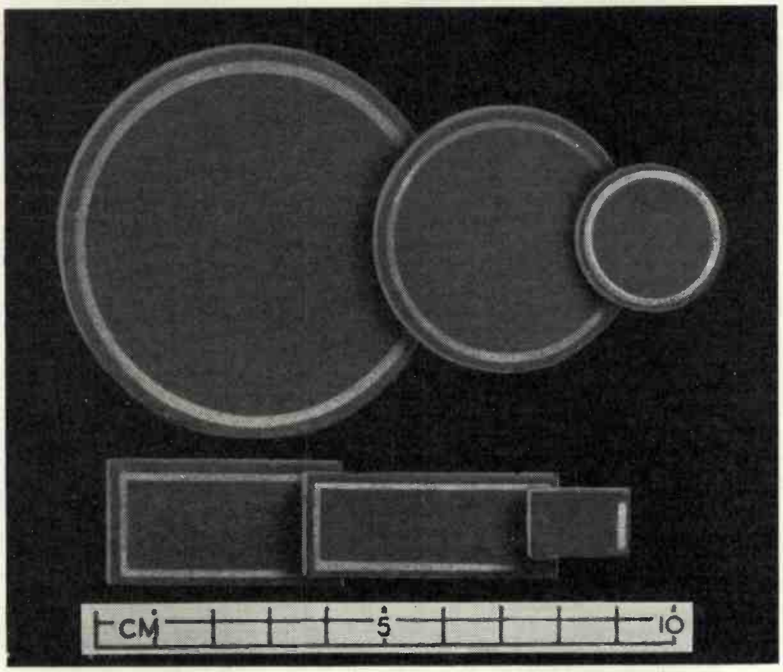
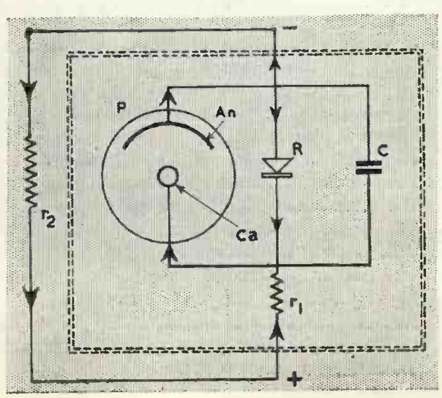



**Fig. 2.** *Below*: **Equivalent circuit of selenium cell. P—Bulb-type photo-cell: C—Cathode: An—Anode: R—Rectifier: C—Condenser: r—resistance of selenium layer: $r_2$—load resistance. Direction of electrons indicated by arrows.**




The construction of the selenium barrier-layer photo-cell is remarkably simple and robust, considering it is a device for transforming light into electrical energy. As shown in Fig. 1, the cell consists of a metal base-plate, usually steel, covered with a thin layer of selenium in its metallic, crystalline state. The selenium surface is covered with a very thin transparent metal layer, usually deposited by cathodic sputtering. When light falls upon the cell surface, it penetrates this top layer and sets free negatively charged electrons from the selenium surface. These in turn pass across the barrier-layer and accumulate a negative charge on the top metal layer. Thus the selenium and with it the base-plate are the positive and the very thin transparent metal layer on the top surface of the cell the negative pole of the "photo-element." To facilitate the collection of current and to protect the top metal layer from mechanical damage a more robust collecting ring (frame or strip) of low electrical resistance is applied. The remaining surface of the cell is then covered with a transparent protective film of lacquer or varnish. The finished cell does not look very different from a flat, thin metal disk or plate bearing a silvery coloured surround. Cells can withstand quite an amount of rough handling, but it is inadvisable to subject them to high temperatures. For this reason spring contacts are employed, and no attempt should be made to solder on contact wires, even with Wood's metal.

To get a clear understanding of the characteristics of a selenium barrier-layer cell it is useful to study an equivalent circuit. It may be assumed that light falling upon a cell penetrates the top layer and liberates surface electrons from the selenium. These cross the barrier-layer and accumulate on the top electrode. If the cell is coupled to an external load resistance, some of the electrons will flow across the latter and return through the base-plate to the selenium. Others, however, will choose the shorter way and will fall back directly to the selenium surface right across the barrier-layer. These conditions may be represented by a bulb or emission type photo-cell shunted by a resistance, the latter representing the paths of backward-flowing electrons. As to the nature of this shunt resistance, the following may be observed: every selenium cell of the barrier-layer type is also a selenium rectifier of quite good efficiency. Its resistance to the passage of a negative current in the direction from the selenium to the top contact is many hundreds of times greater than in the opposite direction. The electrons set free by light from the selenium surface cross the barrier-layer to reach the top electrode in the "reverse" or "non-conducting" direction of a selenium-metal rectifier combination, and conversely electrons falling back directly through the barrier-layer are travelling in the "forward" or "conducting" direction. This somewhat unexpected result suggests the assumption of a selenium rectifier in the "forward" direction as shunting resistance in the model. The "forward" resistance of such a rectifier combination, however, is not constant, and depends upon the voltage in a manner indicated by the current-voltage diagram of a selenium rectifier reproduced in Fig.

3. Up to some 0.2 volts, the resistance is fairly high. From this point it commences falling rapidly, and at about 0.5 volts it is only a few per cent. of its initial value. Bearing in mind the shape of this diagram and the equivalent circuit shown in Fig. 2, the broad outlincs of the characteristics of selenium barrier-layer cells given later will be understood.

In Fig. 4 the open circuit voltage (e.m.f./foot candle) diagram of a modern selenium barrier-layer cell is shown. Attention is directed to the sharp bend at 0.2 volts. A rapid increase in back current slows down any further increase in the voltage if the illumination is increased further.

In Fig. 5 the current output/foot candle diagram is given for a 45-mm. cell at different load resistances. The higher the load resistance the nearer the curve approaches that of the e.m.f., and the lower the load resistance the nearer the line approaches linearity.

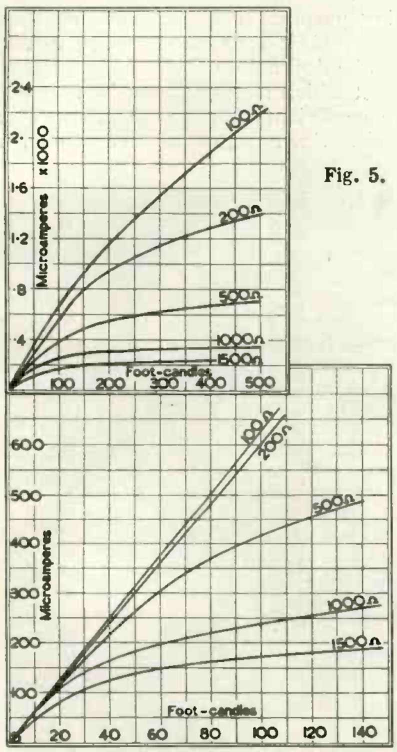



Fig. 5.

From the diagram it may be seen that for this cell size a 100-ohm load resistance is almost a short circuit up to about 100 foot candles. From the practical point of view, Fig. 5 shows clearly that a low resistance meter has to be used to obtain linearity over a wider range as is desirable for light meters, and a high resistance meter if a somewhat logarithmic sensitivity distribution is required as for exposure meters. In this connection, a further point is of interest. For a multiple-range instrument operating with shunts, these cannot always be calculated on a simple basis, as their inclusion in the circuit alters the total load resistance and with it the light/current characteristic of the cell. Simple calculation is

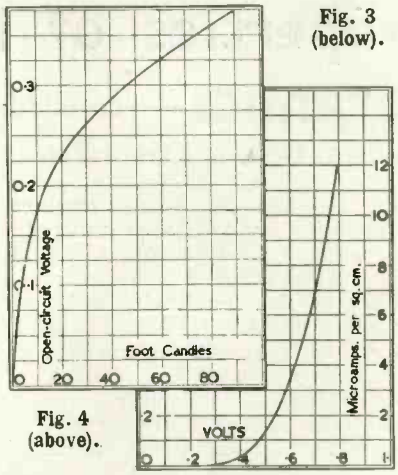



Fig. 3 (below).

Fig. 4 (above).

only possible if, by altering the total load resistance, the total external current given by the cell remains practically unchanged.

Fig. 6 shows the current output for different active cell areas for two illumination intensities and two load resistances. So long as the voltage drop is low, i.e., at low current (illumination intensity) values and at low resistance loads, the current is almost proportional to the cell area. Here again, for moderate load resistance values, the curves almost coincide for small active cell areas.

To the user of this type of cell, the latter diagrams show that for use with moderate meter resistances, best value will be obtained by purchasing large-size cells. On the other hand, there is no point in using large cells for high illumination intensities even with medium resistance meters.

As to the stability of modern cells of this type, their life should be practically unlimited with reasonable care. Fig. 7 gives an idea of what a really well-made cell can withstand. This shows stability tests on six cells, first measured at about 40 foot candles with a 100-ohm meter, then short circuited with clamps and exposed to an illumination of about 500 foot candles, resulting in an average short circuit current of at least 3 milliamperes. No precautions were taken against quite considerable heat produced by this illumination intensity. From

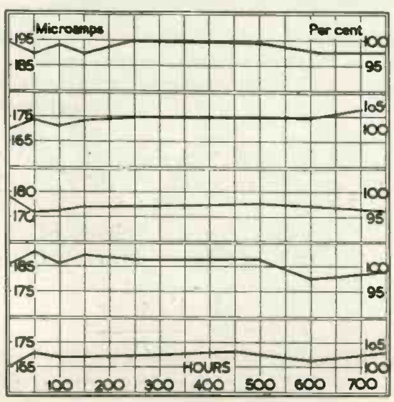



Fig. 7. Life test on typical cells.

time to time the cells were taken off test, allowed to cool to room temperature and remeasured at the test illumination of about 40 foot candles with the 100-ohm meter. This severe test is not likely to be encountered in the course of normal use, and the maximum variation after 750 hours was for all practical purposes nil—actually never more than 5 per cent. On some cells these tests were continued to 1,000 hours with like results.

To conclude, the following two observations may be found useful. It is clearly impossible to characterise a cell with one figure alone. However, it may be said with safety that the sensitivity of a good cell should be about 0.6 microamperes per foot candle per square centimetre of effective cell area, measured with a 100 to 200-ohm meter at about 10 foot candles. The second point is that a really good selenium barrier-layer type photo-cell should be a good rectifier—that is to say, it should be free from internal shorts and leakages which would cause an unnecessarily excessive loss in current. A well-made cell of, say, 25-mm. diameter should not pass more than 15 to 35 microamperes in the dark if 1.5 volts direct current are applied in the " non-conducting " direction (positive on the front contact). For larger cells the maximum value should be increased proportionately. If the current is considerably higher, say, three times higher, there is usually something very much wrong with the cell.

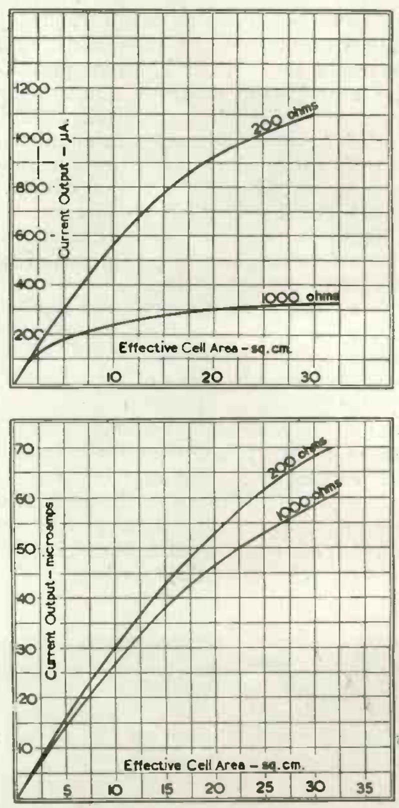
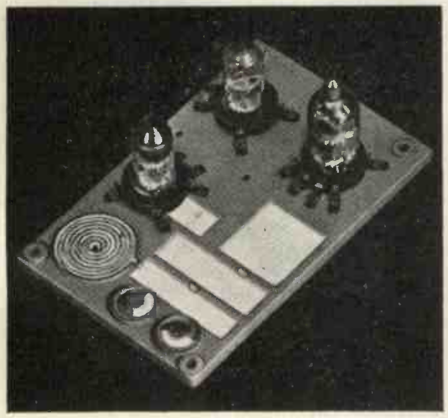



Fig. 6. Output curves for two valves of illumination.

# The Electrical Properties of High Frequency Ceramics—*concluded*

By DR. ING. E. ROSENTHAL



ANOTHER great advantage of ceramic material is the fact that it can be covered by a silver or other precious metal coating by burning on a suspension of silver oxide in an organic medium at temperatures of 750° C. to 800° C. The great advantages adhering to burnt-on metal coatings have been described by Britton,* and the question will now be dealt with as to which of the various ceramic materials is most suitable as condenser material under the different conditions prevailing. The main differences between the various types of ceramic high-frequency bodies suitable for the manufacture of condensers lie in their different permittivity and in the different temperature dependence of their permittivity. The permittivity of rutile bodies is about 80; that of magnesium orthotitanate between 14 and 16, and that of clinoenstatite bodies about 6. As a consequence, for higher capacitances rutile bodies are more suitable. The capacitance of a rutile body condenser is about fourteen times as great as that of a capacitor made of a clinoenstatite body, if the dimensions are exactly the same. Condensers having the shape of a small tube are, for example, made of a clinoenstatite body for a capacitance ranging from 10 to 250 pF, and of rutile bodies for a capacitance ranging from 100 to 2,000 pF, the thickness of the dielectric being, as a rule, somewhat greater in the case of rutile bodies than in the case of clinoenstatite bodies. For smaller capacitance values condensers having the shape of a disk or small cap are manufactured. Of even greater importance than the figure for the permittivity is the different temperature coefficient of the permittivity which the various dielectrics possess. In many cases a slight positive temperature coefficient is desirable, or, at least, not disadvantageous. In other cases, a permittivity having a temperature coefficient as near as possible to zero is required, but more often a negative temperature coefficient of the permittivity is of special advantage.

Radio and television engineers have become conscious of the ever-increasing importance of greater circuit stability and the importance of making the frequency of the circuit independent of the temperature.

Most circuit components have a positive temperature coefficient and use of a capacitor having the proper negative temperature coefficient makes it possible to reduce the temperature drift of the whole circuit to a negligible value.

The temperature coefficient of the capacitance $C_x$ expressed in terms of the $\mu\mu F$ per $\mu\mu F$ required is given by:

$$\alpha = \frac{2\Delta f}{f_t} \cdot \frac{C_0 + C_x}{C_x}$$

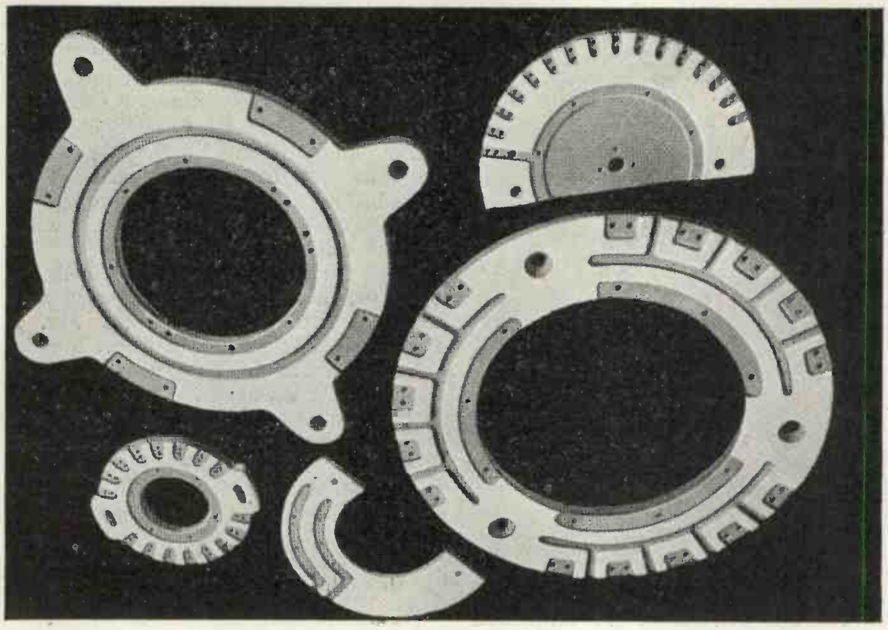
where $C_x$ is the value of compensating capacitance

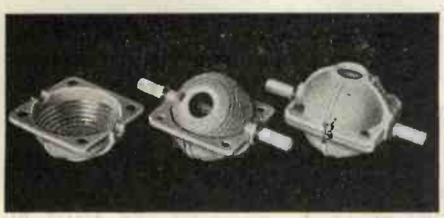
$C_0$ is the circuit capacitance including strays

$\Delta f$ is the drift in c.p.s. due to the change in temperature, and f is the frequency in c.p.s.

The apparent change in capacity $\Delta C$ which causes the drift in frequency $\Delta f$ is assumed small compared with the total capacitance of the circuit. $\alpha$ is also assumed constant.†

The temperature coefficient of the total capacitance of the circuit and especially the temperature coefficient of the capacitance value that is required for compensating purposes may not be a constant figure and it may therefore in certain cases be desirable to have a special component which may regulate the temperature coefficient of the capacitance of a circuit. Such a temperature coefficient regulator has been developed (Fig. 6), and it consists of a base of clinoenstatite material (a) on which a disk made of a rutile body (c) is arranged, and in a similar way another disk made of a clinoenstatite body (b) is arranged on the other side of the base. The thickness of both the rotary disks is in the same ratio as their dielectric constant. Both





**Photographs showing oscillator using condensers and coils of metal burnt on to ceramic material (head of column), ceramic parts for wave-change switch also with burnt-on coatings (above), and variometer made entirely of ceramic material with burnt-on metal coatings (foot of column).**

* *Electronic Engineering*, July, 1941, p. 301.

† Sherwood: *Electronics*, Sept., 1940.

surfaces of the base-plate and the surfaces facing this base are ground very accurately, and at the upper and bottom surface of both the rotary disks silver coatings are provided. The coatings of the upper and bottom surfaces of the base are connected and are facing each other. The coatings of both rotary disks are electrically connected by the central pin, but they do not face each other but are placed at an angle of 180° to each other. Both rotary disks are firmly coupled by the central pin and they change their relative positions to the base together if the central pin is turned. The capacitance of the component is constant and only the temperature coefficient of their permittivity is changed by turning the coupling disks.

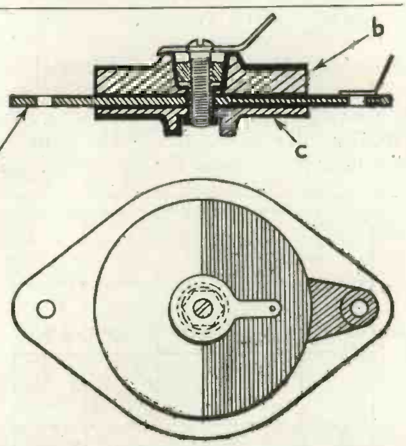



**Fig. 6. Condenser designed for compensating for temperature coefficient. (a) Clinoenstatite base. (b) Disk of rutile body, the metal coating of which is in electrical contact with that of c, a Clinoenstatite.**

In addition to the component described above, other regulators of the temperature coefficient have been designed which, without changing the capacitance, change only the temperature coefficient of their permittivity.

Ceramic trimmer condensers to vary the capacitance have been designed and manufactured and have been described on various occasions.*

Fig. 7 illustrates the temperature dependence of a clinoenstatite body condenser (a) of a rutile body condenser (b) and of a capacitor aggregate composed of both types (c).

There are, of course, instances where condensers having a temperature coefficient as small as possible are required, and for these purposes condensers of the magnesium orthotitanate type are most suitable. Compared with mica (whose permittivity is also practically independent of the temperature), low-loss ceramic condensers are less sensitive against higher temperature, and against electrical discharges or flash-overs which may occur in certain instances, and the power factor is more constant in humid atmospheric conditions. For all purposes where a small temperature coefficient of

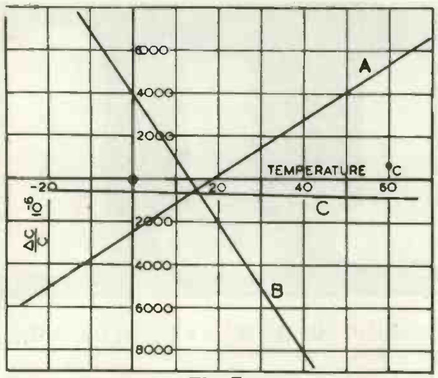



**Fig. 7.**

the permittivity is required, especially for higher tensions than 500 volts, condensers made of the magnesium orthotitanate type offer the best solution.

The temperature variation of the oscillatory circuit is, of course, not only caused by the temperature dependence of the permittivity of the condenser and other components, but also by the alteration of the dimension of the coils which changes with increasing and decreasing temperatures and causes alterations of the coil inductance. Coils the inductance of which is practically independent of the temperature can be wound on a coil former made of a ceramic material which possesses a very small thermal expansion, i.e., a low-loss material of the cordierite type.

Coils can be manufactured by burning on the ceramic coil former a silver coating into which a spiral of the desired pitch may be ground, and by this means coils can be produced which practically do not change their dimensions with rising or falling temperature, since the thin metallic coating follows elastically the alterations of the dimensions of the ceramic coil former. Consequently, the metallic coating has practically the same heat expansion as the ceramic former, and if the heat expansion of the ceramic material is very small, a coil former can be produced the inductance of which is practically independent of the temperature.*

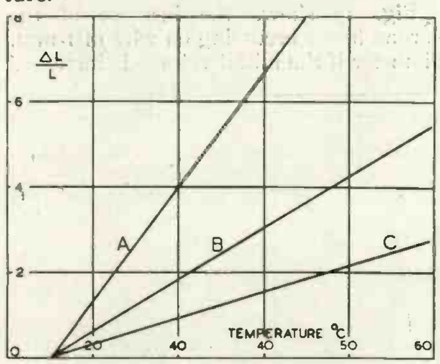
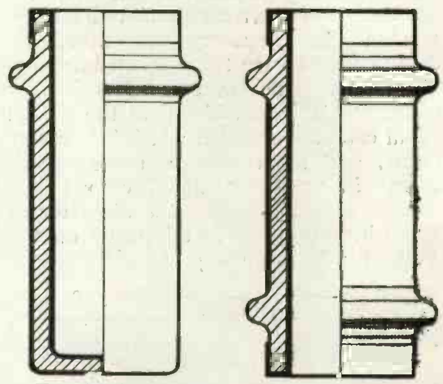



**Fig. 8.**

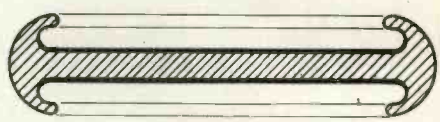
Fig. 8 shows the variation of the inductance of three types of coil, with temperature, (a) being a coil consisting of a ceramic coil former of the clinoenstatite type, the wire being wound in the usual way; (b) a coil consisting of a coil former of the same type of ceramic material where the coils are formed by burnt-on metal coatings; and the third (c) being a coil former of a cordierite body with burnt-on metal coils. The improvement is demonstrated by the fact that the temperature coefficient is $40 \times 10^{-6}$ for coil (a) and $8 \times 10^{-6}$ for coil (c).

In case of condensers for higher voltages the edges of the metal coatings have to be screened by means of suitably shaped ceramic edges to avoid discharges and flash-over. These protruding edges or ribs can at the same time be used to prevent corona losses which would occur in the case of high frequency and high voltage, a part of the surface of the rib facing the electrode being covered by the metal coating giving a curved edge having a large radius. It is not possible to shape mica condensers in a similar way.

For voltages between 1,000 and 5,000 tube-shaped condensers, the edges of the metal coatings being screened by ribs, are a very suitable design. The tube shape can be modified into the shape of a bottle with cylindrical walls, one end of the tube being closed (Fig. 9 below).

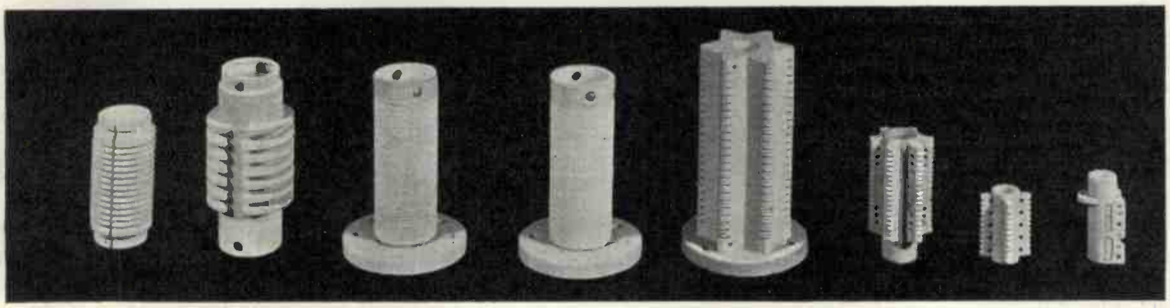


For higher voltages from 15 kv. test and onwards, disks of ceramic low-loss materials are used, both surfaces being covered by metal coatings and the edges of both coatings being again screened by ribs projecting on both ends of the ceramic plate (Fig. 10 below).



For very high voltage, as for instance in the case of condensers for current carrier telephony on high-tension overhead lines, capacitor units for 60 kv working and 2,200 pF have been designed. For use in transmitters a number of condenser plates are united on a frame possessing a base or end-plates made of low-loss ceramic material. Such a frame may contain ten condenser plates of about 20-cm. diameter of the clinoenstatite type material, and such an aggregate designed for 12 kv test voltage may have 5,000 pF capacitance for 300 kva.

*See footnote col. 2, p. 438.



**A set of coil formers in ceramic material. On the left is a former for an H.F. choke.** (*Messrs. Bullers, Ltd.*)

If rutile bodies having a dielectric constant of about 80 are used as a dielectric, the corresponding design is suitable only for 6 kv high-frequency test voltage, since the dielectric strength of rutile bodies against puncture is somewhat smaller, but the capacitance amounts to 50,000 pF owing to the higher dielectric constant. Rutile body condenser plates are as a rule somewhat thicker because owing to the low plasticity of the rutile bodies it is difficult to manufacture very thin disks.

Not only in the design of high-tension high-frequency capacitors but also for the design of other components for high-tension high-frequency apparatus, the corona losses have to be taken into consideration. This source of loss is very often not fully considered in the design of all components where such losses may occur, and the results of some experiments in measurement of corona loss and its dependence on the diameter of the wire (or other metal parts) on the voltage and frequency are of interest.

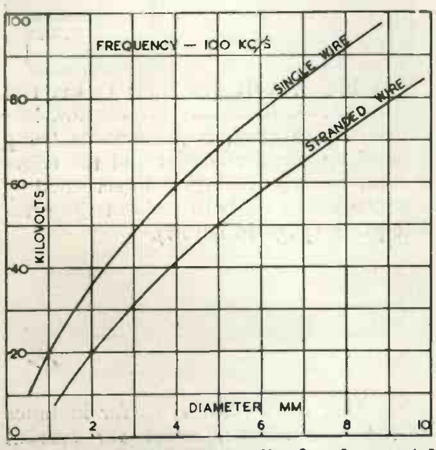



**Fig. 11. "Initial Voltage" of a horizontal aerial showing variation with diameter.**

Fig. 11 shows how the "initial corona voltage" increases with the increasing diameter of the wire, the frequency being 100 kc/s. The initial voltage is higher in the case of a plain wire as compared with a stranded wire. In the case of a plain wire the corona losses start at 10 kv if the wire diameter is 0.3 mm., and start at 100 kv only if the diameter is 10 mm. The gradient of the rise of the curve decreases with increasing wire diameter and an increase of the wire diameter above a certain value will cause only a small increase in the "initial corona voltage." The experiment was carried out on a horizontal aerial 10 metres high.

Curve 12 shows the increase of the corona losses in watts per metre if the voltage is raised above the initial voltage of 20 kv to 25 kv, and demonstrates how the corona losses increase by 1.2 kw/m if the initial voltage of 20 kv is increased by 5 kv.

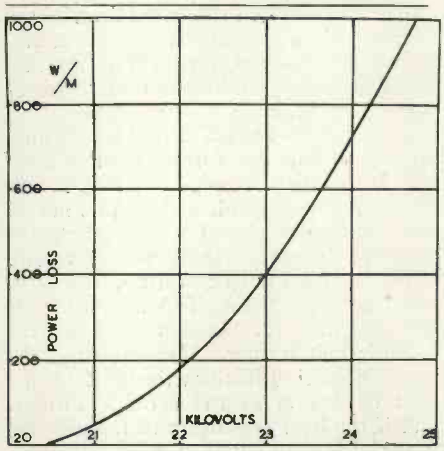



**Fig. 12. Corona loss on a 10m. horizontal aerial 1mm. diameter.**

Fig. 13 shows the increase of the corona losses occurring on wire of 1-mm. diameter if the initial voltage is increased by 100, 200, 500 volt steps at increasing frequencies.

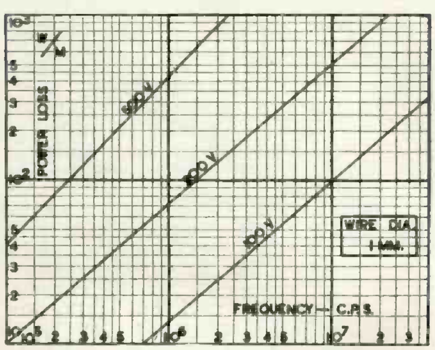



**Fig. 13. Variation of Corona Loss with frequency for increasing initial voltage.**

Fig. 14 shows which diameter has to be chosen for the aerial to avoid corona losses at a given voltage.

It is of course not sufficient to choose the right diameter for the aerial, but also no other metal parts carrying high-frequency high-tension should have a smaller diameter than the smallest diameter permissible for the aerial. This

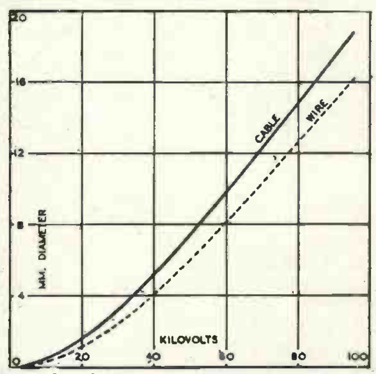



**Fig. 14. Aerial wire diameter required to avoid Corona loss.**

refers also to the edges of the metal coatings of high-tension insulators and capacitors for these frequencies.

It would, of course, be very difficult to reinforce the edges of metal coatings to such a degree as to get the same thickness as provided for the wire, but it is possible to achieve the same effect by extending the metal coatings over a portion of the screen or rib. For instance, very heavy corona losses would occur on high-tension aerial insulators

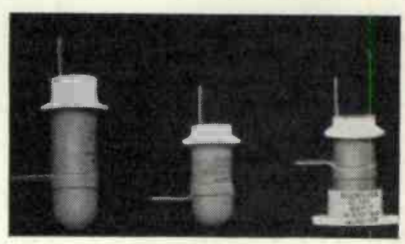


**Fig. 15. Typical metal coated High-tension High-frequency Ceramic Condensers showing the protruding ribs for reducing Corona losses at high voltages.** (*Dubilier Condenser Co.*)

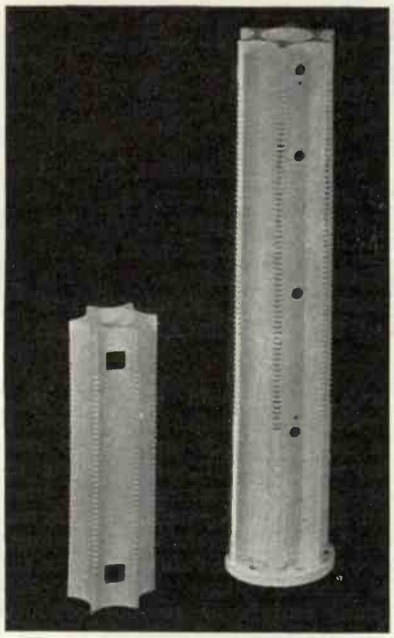


Fig. 17. Long ceramic coil-formers.

between the metal attachment and the insulator surface if no metal coatings were provided on the insulator surface adjoining the metal attachment. The metal coatings should have an edge of a similar radius to that of the cable attachment which can be achieved by providing a suitably shaped rib of ceramic material to be covered by the metal coating.

The electric field distribution plays a much more important part in the case of high-frequency high-tension insulators than in the case of 50 c.p.s. high-tension insulators. This fact is not yet fully realized in high-frequency high-tension insulator design.

The designer of high-tension insulators for power transmission can calculate the dry flash-over and the flash-over under rain if he knows the surface creepage distance and the " protected " surface creepage distance (i.e., the creepage distance which in case of rain remains dry and consequently an insulator by the protection of ceramic sheds and ribs). But in the case of high-frequency high-tension insulators, the ionization of the air caused by the corona discharges plays the same part as the rain does in the case of transmission line insulators: it makes the insulator surface conductive. This could not be prevented, but only be made worse by projecting sheds or ribs. To prevent corona discharges at unnecessarily low voltages it is necessary to obtain an equal field distribution over the whole insulator surface.

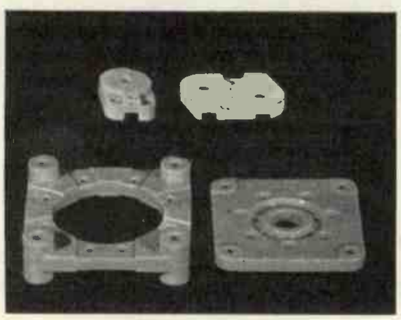


Fig. 18. Ceramic valve holders and (above) parts for trimmer condensers.

To obtain an equal field distribution over the surface of a high-frequency insulator, it is necessary (apart from avoiding ribs or sheds having a small radius or sharp edges) to accumulate the insulating material next to the electrode. Ribs provided in the middle of the aerial are not the best design, since they deteriorate field distribution and have practically no influence on the flash-over voltage of high-frequency insulators. In case of very high frequencies they definitely decrease the flash-over voltage. Quite different considerations than in the case of the design of high-tension insulators for 50 c.p.s. have to govern the design of high-tension high-frequency insulators, and the arrangement and shape of the ribs. They should be provided near the electrode or metal attachment which carries the voltage. Such considerations apply to both high-frequency high-tension support insulators and aerial or strain insulators. For instance, a support insulator taking into consideration the general rules mentioned above, and illustrated in Fig. 16, possessing a height of only 6.2 cm. (without metal parts), has a flash-over of 33.8 kv, whereas a support insulator of the size standardized for low frequency possessing the normal rain shed of a height of 15 cm. (without metal parts) has a flash-over of 15 kv at 100 kc/s—an astonishing improvement.

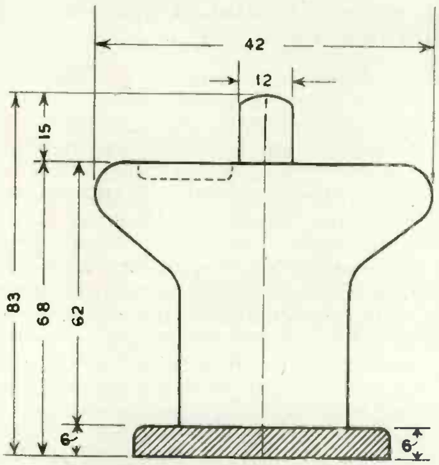



Fig. 16. Sketch of modern H.F. high-tension insulator.

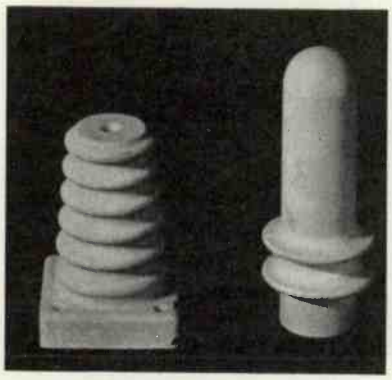


Fig. 19. H.T., H.F. stand-off insulator and shell for condenser (see also Fig. 15).

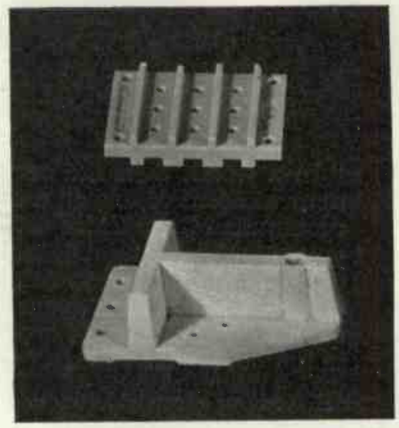


Fig. 20. Typical ceramic pressing for instruments.

The same considerations have, of course, to be applied with regard to the design of other high-frequency high-tension insulators.

In conclusion, the writer expresses his thanks to the management of Messrs. Bullers, Ltd., who put at his disposal most of the photographs published, and to Mr. Coursey, of Messrs. Dubilier Condenser Co., who supplied the photograph of the condensers.

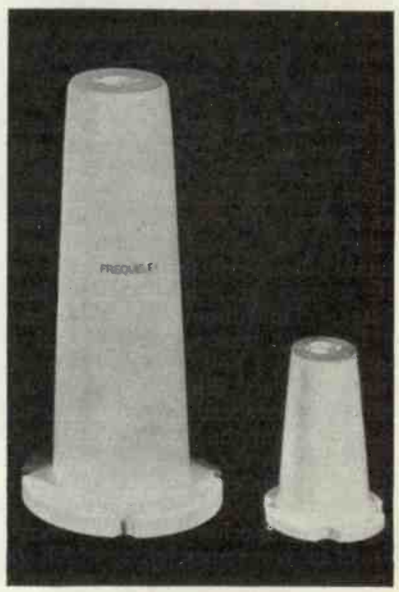


Fig. 21. Stand-off insulators for H.F. transmitters.

# Review of Progress in Electronics

## VII.—Electrical Conduction in Gases

By G. WINDRED, A.M.I.E.E.

**" In a word, then the act of ionisation in gases appears to consist in the detachment from a neutral atom of one or more negatively charged particles, called by Thomson corpuscles. The residuum of the atom is, of course, positively charged, and it always carries practically the whole mass of the original atom. The detached corpuscle must soon attach itself in a gas at ordinary pressure, to a neutral atom. . . . It is because of this tendency of the parts of the dissociated atom to form new attachments in gases at ordinary pressure that the inertias of these parts had to be worked out in the rarefied gases of exhausted tubes."—R. A. Millikan in his book " Electrons," Cambridge, 1935.**

THE study of electrical conduction in gases has developed in very close association with investigations of the properties of the electron itself and the other basic constituents of matter. These combined studies represent one of the most extensive and important chapters in the history of pure science, and in addition have made possible a very large part of modern electrical engineering practice. It is interesting and instructive to reflect upon the fact that the immense variety of modern electrical apparatus employing the principles of gaseous conduction has grown from purely academical studies, pursued without thought of practical application or financial gain.

### *Early Researches*

The idea that electricity, like matter, might have an atomic or discontinuous structure is fairly old, having been suggested by Maxwell and later by Weber. As long ago as 1881, Helmholtz stated the idea clearly in a lecture at the Royal Institution. The motion of fundamental units of electric charge associated with current transfer in electrolytes was introduced by G. Johnstone Stoney in 1874, several years before any researches had been carried out on the nature of these particles, to which in 1891 he first gave the name of " electrons."

The so-called cathode rays emanating from the cathode of an electrical discharge in gas at low pressure received the attention of many investigators towards the close of the nineteenth century. In 1892 Hertz[1] made the important discovery that the rays were able to pass through very thin films of matter. This discovery was taken up by Lenard,[2] who used a special discharge tube and passed the rays through a very thin opening so as to study their properties outside the tube. He found that the penetration was dependent upon the mass of the material rather than its chemical composition.

This work was soon followed by Röentgen's epoch-making discovery of X-rays in November, 1895, which gave a powerful stimulus to research on the conduction of gases. The late Sir Joseph Thomson[3] and his collaborators, working in the Cavendish Laboratory at Cambridge, found that a gas subjected to the action of X-rays became conducting, whereas in the normal state it behaved as an insulator. At low gas pressures, an appreciable time was required for restoration of the normal properties of the gas after the X-rays were cut off. The conducting property disappeared when the gas was passed through a plug of glass wool or cotton wool, or between metal plates maintained at a sufficiently high potential difference. The first result showed that the conductivity was imparted by some agent which could be removed from the gas by filtering; the second that this agent must have the nature of an electric charge. The observation that loss of conductivity after the removal of the rays required a definite time for its completion led to the view that the rays must " ionise " the gas, thus producing charged particles of opposite polarities which disappeared by the process of recombination when the rays were stopped. On this view, which has since remained unchanged, the loss of conductivity when the gas was passed through or otherwise subjected to a sufficiently strong electric field could be ascribed to the passage of the positive particles (ions) to the negative electrode and of the negative particles (electrons) to the positive electrode.

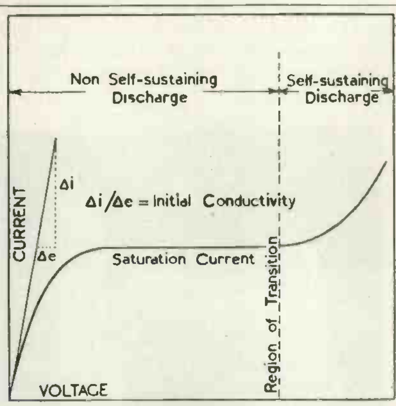



**Fig. 1. Characteristics of gas discharge, showing region of transition.**

This simple theory gives a satisfactory explanation of the observed fact that a conducting gas does not obey Ohm's law. If a sufficiently strong electric field is applied, the transference of ions and electrons to the respective electrodes is so rapid that the number which are able to recombine is very small. If the field itself does not cause ionisation, the process will not be augmented by an increased field and the current will consequently have a saturation value, independent of the applied voltage. This is a characteristic feature of gaseous conduction over a definite region.

These discoveries gave rise to an important series of investigations on the mobilities and coefficients of diffusion of gaseous ions, leading to the discovery that the negative ions in gases ionised by X-rays carry on the average the same charge as is carried by the equivalent ion in electrolysis. This work lies somewhat outside the scope of our present subject matter, as it refers to measurements on the properties of individual particles taking part in the process of conduction rather than the phenomena associated with conduction itself. It will be sufficient to mention here that in 1897 Sir Joseph Thomson[4] established definitely that the cathode rays carried a negative charge. He also made the first exact determination of the quantity e/m, representing the ratio of charge to mass of the particles comprising the cathode rays. Thomson called these particles " corpuscles," but the name " electron " has since become common usage.

Subsequent work on the passage of electricity through gases resulted in the classification of different phenomena and the recognition of three principal forms of conduction or discharge :—

1. The non-self-sustaining discharge, relying for its continuance upon supplementary effects for producing ionisation, as by means of photoelectric or thermionic emission or X-radiation.
2. The self-sustaining discharge, independent of separate means of excitation, and in which the mechanism of discharge formation is inherent.
3. The arc discharge, capable of occurring in various forms, but always luminous and characterised by a high current.

All types of discharge involve the fundamental processes of production, movement, and final absorption of particles such as electrons and ions which act as a means of conveying the current. Although attempts have been made, with considerable success, to formulate mathematical theories concerning the various phenomena of gaseous conduction, the subject is at present more suited to experimental investigation. Probably the best accounts of modern theory and experiment are those by Wheatcroft,[5] Darrow,[6] Seeliger,[7] and Engel and Steenbeck.[8]

## *Non-Self-Sustaining Discharge*

If a gaseous space between two electrodes contains carriers of electric charge (ions and electrons) a current will flow through the space when a potential is applied to the electrodes, owing to the movement of the carriers under the action of the resulting electric field. A continuous flow of current can take place only if the carriers whose charges are absorbed by the electrodes are continuously replaced. This replacement can be effected by any source of ionisation, whether photoelectric or thermionic, and with increasing field strength the production of carriers begins to balance their absorption and recombination. The attainment of this condition corresponds to a state of saturation in the current flow, as shown in Fig. 1. This condition is maintained with increasing field strength until a stage is reached where ionisation by collision causes a rapid increase in the number of carriers.

During the stage of the discharge corresponding to low electrode potential the current is lower than the saturation value. The rate of change of current in the region of zero is a measure of the initial conductivity of the discharge path, which is of the order of $10^{-13}$ reciprocal ohms per cm. for gaps between plane electrodes in air and much less for normal gases at low pressure. The saturation value of the current is dependent upon the intensity of ionisation, and is also proportional to the volume of gas between the electrodes as well as the gas pressure. If these values are high, the free path which an electron is able to traverse before making an ionising collision is short, and if the electric field is sufficiently high to impart the requisite electron velocity, a number of such collisions may be made during the passage of an electron between the electrodes.

## *Self-Sustaining Discharge*

As the electrode potential increases to the stage where ionisation occurs freely, positive ions are produced in the gas and move towards the cathode, which they may strike with sufficient force to eject the further electrons necessary for maintaining the discharge. In this case, no outside means of excitation are necessary, and the discharge is said to be self-sustaining. The electrons ejected from the cathode by ion bombardment travel to the anode, producing on their way further positive ions and electrons, and the discharge is maintained through this cumulative action so long as sufficient potential is maintained between the electrodes. The transition to this form of discharge is accompanied by an increase of current beyond the saturation value, as shown in Fig. 1.

There are several forms of self-sustaining discharge, corresponding to different gases, gas pressures and electrode arrangements. The initial form is known as a dark discharge, but with increasing current density luminous effects occur, and a "glow discharge" develops.

*The glow discharge.*—It is found that as the discharge current is increased, the characteristic changes considerably and the dark discharge is replaced by the glow discharge. It is not possible to differentiate sharply between these two forms of discharge, but the curve in Fig. 2 shows the change of characteristic relative to current and voltage for a discharge between plane electrodes

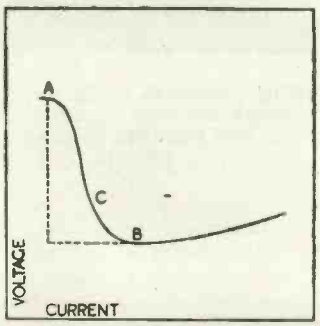



**Fig. 2. Change of characteristic from dark to glow discharge.**

commencing with a very small value of current. At an early stage of the characteristic a drop in the electrode voltage commences as shown at A. After a subsequent stationary condition represented by point B, a further increase of the discharge voltage occurs. The glow discharge is fully developed at point B, but the conditions corresponding to a point such as C with a lower current and higher voltage are also considered as belonging to the glow discharge. Occasionally the change of voltage from condition A to B is sudden, as represented by the dotted vertical line, in which case it is possible sharply to define the condition of glow discharge.

The development of the discharge represented by the curve is accompanied by changes of luminosity. In the case of small currents the discharge has practically no luminous effects, although absolute darkness is not general owing to the ionising action of the carriers. As the current increases the luminosity also increases, and at the same time moves to different parts of the discharge space.

*Development of the arc discharge.*—Further increase of current between the electrodes results in a further change of the discharge characteristic, and this time the conditions are characterised by low voltage drop, considerably below the values corresponding to the glow discharge.

Since the arc discharge may take place with very low voltage it is evident that the mechanism by which the carriers are produced in this case must be more effective than in the case of the glow discharge. There is a wide variety of types of arc discharge, representing different arc phenomena, but all these are characterised by the intensiveness of the carrier-producing process, giving rise to considerably higher current densities than the previously considered forms of discharge.

It is instructive to consider the manner in which an arc discharge may develop from the glow discharge. It may be assumed, for example, that a D.C. source is applied to two small electrodes in such a manner as to produce a glow discharge in a gas, and that the electrodes are of a material such as tungsten, which does not readily vaporise. It is further assumed that the discharge can be varied between wide limits by means of an external resistance.

As the current is increased, the first indication of change in the discharge is only a slight alteration in the region of the cathode, and the electrode voltage remains constant. Further increase of current leads to an increase of the voltage drop, and eventually the voltage reaches a maximum as shown in Fig. 3. It is here that a considerable change occurs in the conditions. The energy absorbed by the cathode due to the movements of the carriers causes heating which leads to the emission from the cathode of thermionic electrons, as well as those resulting from ion bombardment. This action results

(*Continued on page 465*)

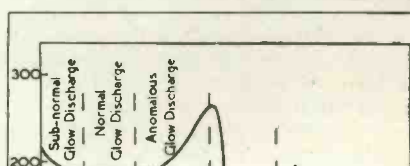



**Fig. 3. Change of voltage characteristic with variation of discharge current.**

# The Application of Electronics to Industry

## II. Control Devices

### by John H. Jupe

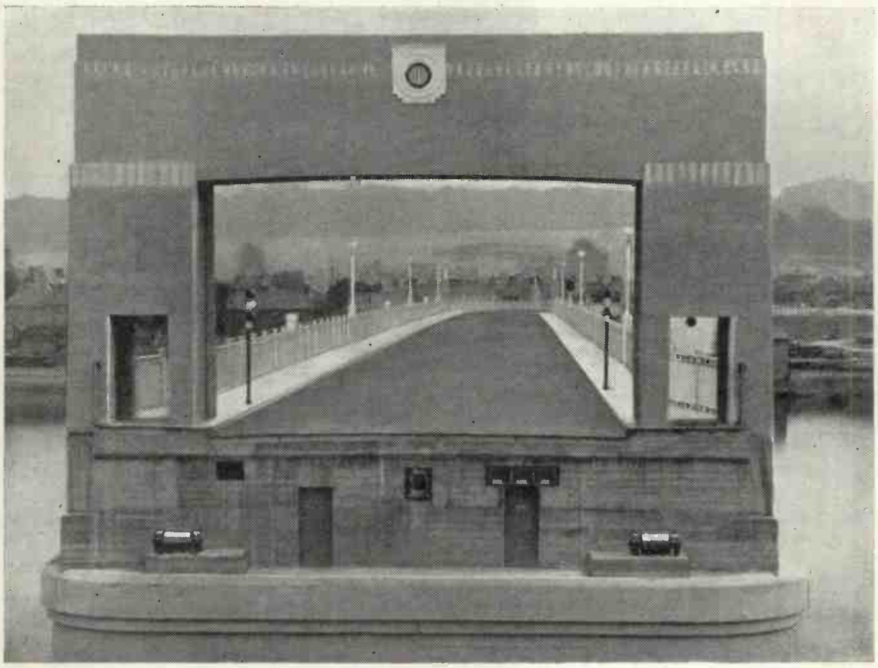
BESIDES providing us with means of measuring, the various forms of electron tubes also enable us to control industrial, scientific and domestic operations which would, in some cases, be otherwise very difficult to handle. In fact, the majority of electronic applications may be said to come under the heading of " control."

This may be considered as either a form of measurement, using arbitrary standards set by commercial usage or requirement, or it may be a means of making work simpler or easier. It is hard to pick an industry which cannot make profitable use of electronic control in some process or other, and as a typical example the printing, paper and pulp trades provide an excellent illustration.

In these trades a well-known electrical engineering company made an analysis of the various inquiries received regarding the installation of electronic plant, with the following results:—

| | |
|---|---|
| Devices to measure paper opacity | 30% |
| Illumination control ... ... | 20% |
| Alarms for paper breaks ... ... | 16% |
| Cutting on a printed mark ... | 15% |
| Counting cartons, logs, etc. ... | 14% |
| Colour measurements ... ... | 5% |

And these results show that control uses are in the majority.



A striking photograph of the swing bridge at Kincardine-on-Forth, showing the roadway seen through the shore abutment. The alignment of the bridge in the closed position is controlled by a photo-cell installation actuated by the lamp box seen above the doorway on the right. *(By courtesy of the General Electric Co., Ltd.)*

Consider the various registering applications such as overprinting sheets with additional matter or cutting on a definite mark, as in the case of wrapping machines. Without a device such as the photo-cell it would be almost impossible to guarantee perfect results because any adjustment would depend on some kind of assumption, such as paper size or distance moved, but with the introduction of electronic control this is eliminated and if the article is not exactly in the correct position operation of the machine beyond that stage does not take place. Consequently, creepage errors, common with certain types of mechanical control, are non-existent (Fig. 2).

Weighing and measuring are other uses for the photo-cell with very wide industrial application, and a variation of this form of control can be adapted to ensuring that articles are all facing one way. Another development of such " batching " mechanisms is in the field of apparatus for automatically sorting radio resistors to predetermined values by means of a cathode-ray tube.

Gas discharge tubes are another branch of the electron art of great use to the manufacturer; in fact, it is hard to point to an electrical device which is so rapidly gaining ground as the discharge tube. This is partly due to the considerable amounts of power which may be controlled using very slight changes in the "trigger" circuits. Some of the highest pressure boilers in the world make use of such equipment in the fuel and water pump circuits.

For the electrical engineer, a specially interesting use of electronic control is with synchronous motors, and by using " thyratrons " as frequency changing devices it is possible to run these motors as variable speed machines. At least one set with a maximum output of 400 horse power has been in operation.

For remote control, the various carrier current systems using valve oscillators stand as reliable pieces of engineering equipment, and when applied to electrical machinery these and other electronic devices have one immense advantage over other methods of control. It is the fact that any such apparatus may be so built into the controlled machinery circuits so that it is an integral part of them, with the result that failure is often eliminated. A fine example of this is in phase failure protection equipment.

The usual methods of arranging for such indications are by relays using a rotating disk, multi-coil relays depending on phase relation of currents and voltage relays connected in a network of reactors, etc., so as to respond to abnormal conditions. Apparatus of this nature has several drawbacks but suitable electronic equipment will furnish similar protection with greater reliability and in some cases with very little additional cost. An instance of this would be alternating current lift motors controlled by contactors passing direct current through their field coils and obtaining this from rectifying valves. Here the same valves could be arranged to provide incorrect phasing interlocks and, although it is not suggested that there is any great demand for such plant, it shows how electronic equipment can be made an inherent part of other circuits, avoiding the use of relays in this case for phase protection.

In welding plant, ignitron tubes have been applied with great success and when controlled by electronic timing gear provide better results than any other form of control. The apparatus is silent in operation, there are no contactors carrying heavy currents and requiring contact replacements, the timing is positive, and interlocks are easy to provide.

These few instances show but little of an immense field and one which can provide export as well as home markets. There is, however, one important point

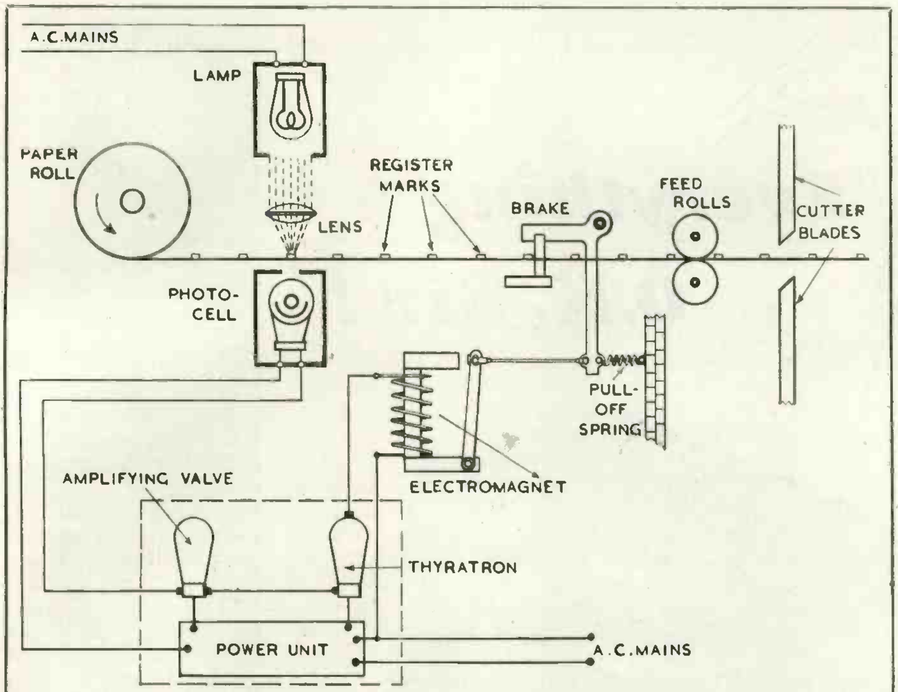



**Fig. 2. A method of ensuring accurate registration in printing or cutting paper by the use of a brake actuated by a photo-cell and thyratron controlled magnet.**

to be taken into account by the manufacturer of electronic equipment and also the industrialist planning in his own research laboratories. That is the fact that almost every job is a special one. Mass production of such equipment is impossible, as each machine, process and article made has problems of its own. But this should not deter the electrical engineer, who, if he will but study the problems of other trades, need not be short of work. Building pieces of apparatus one at a time can be as profitable as turning out twenty thousand an hour, and by passing the control of processes into the electron tube much greater uniformity is achieved in the finished product and, as is well known, uniformity is often a good measure of quality.

Another valuable aspect of electronic control is the economic one and much can be learnt by the consideration of how much inspection is necessary for a finished product. This will often suggest the remark, " If only we had a machine to . . . " and to a trained engineer there is often an immediate visualization as to how an electron tube could be made to do it. Such consideration is worth while, and in the case of an article costing 4.68 shillings per thousand to inspect, the installation of an electronic sorting machine brought this down to 0.02 of a shilling per thousand.

Appended is a list of other applications of the electron in control devices and, although by no means exhaustive, it gives some indication as to what may be achieved.

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| *Process or Quantity Controlled.* | *Electronic Principle.* |
|---|---|
| Flaw detection. | Resonant circuit inspects for change in permeability. |
| Perforation. | Photo-cell seeks for pinholes. |
| Volume control. Telephone. Radio. | Special thermionic valve circuits. |
| Skew control. | Photo-cell views threads in weaving machinery relative to fixed guide. |
| Heartbeats. | Cathode-ray cardiograph. |
| Metal detection. | Resonant circuit inspects goods for eddy current loss. |
| Motion limits. | Capacitance operated relay. |
| | Photo-cell operated relay. |
| Regulation (electric). | Thermionic valves used to regulate voltage or resistance of supply in terms of load. |
| Electro-plating control. | Photo-cell views plating and measures " goodness " in terms of reflectivity. |
| Sheet reversing (rolling mills). | Capacitance, permeability or photo-cell trigger to reverse motor. |
| Over and undervoltage. | Neon and other gas-filled tubes. |
| Germination of plant seeds. | Exposure to X-rays, before planting. |
| Vulcanization of rubber. | Grid condenser plates of oscillator embedded in rubber. Combined sulphur content measured in terms of dielectric constant. |
| Viscosity. | Rate that steel balls fall through oil measured with photo-cell or permeability change. |
| Cosmic-ray research. | Electron tube acting as trigger. |
| | Gas on point of ionization caused to become conductive by rays. |
| Fluorescent powders for advertising devices. | Stimulated by ultra-violet light. |
| Ship steering gear. | Photo-cells operated by light beam moved by compass card. |
| Metal surfaces. | Electron diffraction camera. |
| Detection of gases. | Heat conduction from hot wire unbalances thermionic circuit. |
| Block-making for printing. | Photo-cell automatic engraving machine. |
| | Photo-cell grading of negatives in three-colour process. |

# DATA SHEETS XII, XIII & XIV

Electronic Engineering

## The Inductance of Single Layer Solenoids

DUE to skin and proximity effects at high frequencies the current in a single layer inductance coil crowds towards the inside radius of the turns, so that the effective radius of the coil is reduced. Unfortunately no expressions for calculating the inductance with this current distribution exist and the inductance of a coil is computed on the assumption of uniform current distribution across the cross-section of the wire. Inductance formulæ for single layer coils are therefore only strictly accurate for a D.C. or very low frequency current. They are, however, used extensively for the design of H.F. coils as other sources of error such as variations in the diameter of coil formers and differences in winding pitch limit the accuracy of calculation in any case.

The most widely used accurate formula for single layer coils is that due to Professor Nagaoka which gives the value of the "Current Sheet" Inductance as :—

$$L_s = 0.00987 D^2 n^2 l K \text{ microhenries} \quad (1)$$

$$= 0.00987 D N^2 \left( \frac{D}{l} K \right) \text{ microhenries} \quad (2)$$

where K is a factor which depends only on the ratio $D/l$ and is plotted on Data Sheet 12.

The term "Current Sheet" Inductance implies a coil wound with infinitely thin tape lying edge to edge with an infinitely small separation. While a closely wound coil with thin insulation approaches the ideal fairly closely, the presence of appreciable insulation (or air space) between turns has to be corrected for.

This correction is applied by subtracting an inductance $\Delta L$ from the value of $L_s$ obtained by equations (1) or (2) where

$$\Delta L = 0.006283 D n l (A+B)\ \mu H. \quad (3)$$

$$= 0.006283 D N (A+B)\ \mu H. \quad (4)$$

The Factor "A" is only a function of the ratio $S = d/p = dN/l$ and is plotted on Data Sheet 13. Likewise the Factor "B" is only a function of the total number of turns in the coil and is plotted on Data Sheet 12.

The complete expression for the inductance can therefore be written in the form :

$$L_0 = L_s \left( 1 - \frac{\Delta L}{L_s} \right) \mu H.$$

$$= L_s \left[ 1 - \frac{2l(A+B)}{\pi D N K} \right] \mu H. \quad (5)$$

In order to reduce the labour involved in determining whether, or what order of, correction is necessary for any required accuracy of result Data Sheet No. 14 has been prepared.

**SYMBOLS**

- D = Diameter of coil between wire centres in cms.
- d = Diameter of bare wire in cms.
- $l$ = Np = length of coil in cms.
- N = Total number of Turns.
- n = $N/l$ = turns per cm.
- p = $l/N$ = pitch of winding in cms.
- $L_S$ = "Current Sheet" Inductance in $\mu$H.
- $L_0$ = D.C. Inductance in $\mu$H.
- K = Nagaoka's Factor.
- A & B = Correction Factors for spaced windings.
- $x$ = Percentage by which $L_S$ is higher than $L_0$.
- S = $d/p = dN/l$.
- X = $0.0157\, x (D/l) K$.
- Y = $(A+B)/N$.

If we designate by "$x$" the required accuracy in per cent., *i.e.*, the value of $\Delta L/L$ as a percentage, then

$$\frac{x}{100} = \frac{2l(A+B)}{\pi N D K} \quad (6)$$

$$0.0157 x \frac{DK}{l} = \frac{A+B}{N.} \quad (7)$$

For any given value of "$x$" the value of $X = 0.0157x(D/l)K$ can be plotted with $d/l$ as the variable. Similarly for any given value of $S = d/p = dN/l$ the value $Y = (A+B)/N$ can be plotted with N as the variable.

The factor X for values of $x = 1\%$ to $10\%$ for a range of $d/l$ values from 0.2 to 20 has been plotted on Data Sheet No. 14. On this sheet also is plotted the factor Y for values of S=1.0 to 0.5 and for a range of total turns N from 4 to 200. This Data Sheet may be used in either of two ways : (a) We can determine the minimum number of turns or minimum turns per centimetre that must be used for the result given by equations (1) and (2) to be within the accuracy specified by the chosen value of "$x$" (b) We can estimate directly by how many per cent. the value of $L_s$ given by equations (1) and (2) will be higher than the correct value $L_0$ of equation (5) and make the correction if required.

Thus for example we may require to know the minimum inductance for which we can use equation (2) with a coil having for performance reasons a ratio $D/l$ of 2 ; S = 0.7 and a diameter of 5 cm. If the calculation is required to an accuracy of say 2% then from Data Sheet 14 we find that X = 0.033 and as we have to make $X \geqslant Y$ at least 15 turns must be used. (For 1% accuracy at least 31 turns would have had to be used).

$$L_s = 0.00987 \times 2 \times 5 \times 225 \times 0.525\ \mu H.$$
$$= 11.65\ \mu H.$$

For any inductance value higher than this the accuracy will be better than 2%. An alternative problem is to calculate the inductance of a coil 5 cm. in diameter wound with 20 turns of No. 16 S.W.G. wire in a length of 5.0 cms.

$$L_s = 0.00987 \times 1 \times 5 \times 400 \times 0.6884\ \mu H.$$
$$= 13.61\ \mu H.$$

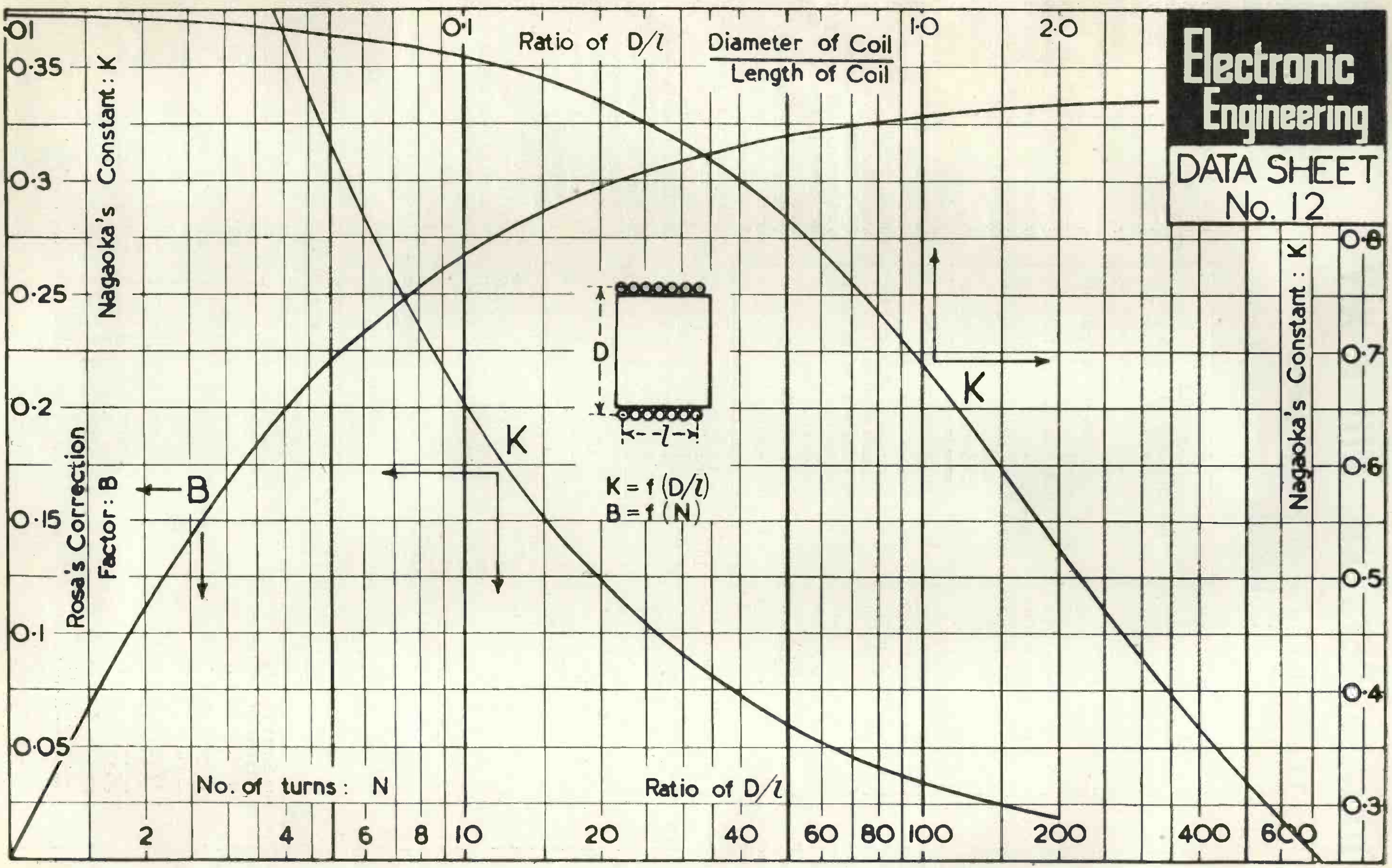
Now p = 5/20 and d = 0.1626 ; therefore S = 0.1626 × 4 = 0.65. From Data Sheet 14 we find that for N = 20 and S = 0.65 $D/l$ = 1 the value of $L_s$ given above would be about 1.9% high. From Data Sheets No. 12 and 13 we have

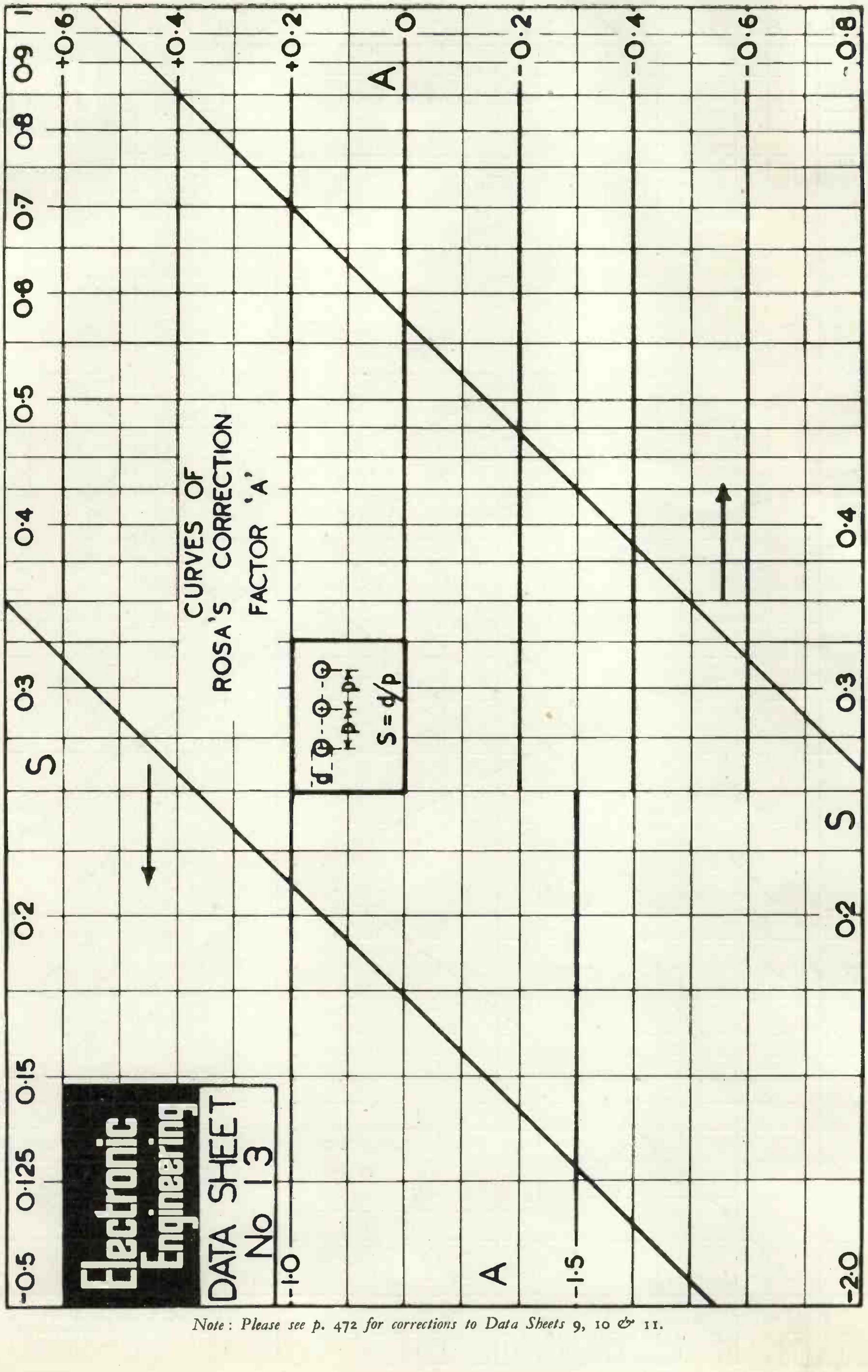
$$\Delta L = 0.006283 \times 5 \times 20 \times (0.1261 + 0.2974)\ \mu H.$$
$$\sim 0.266\ \mu H.$$

and $L_s$ was about 1.9% high.

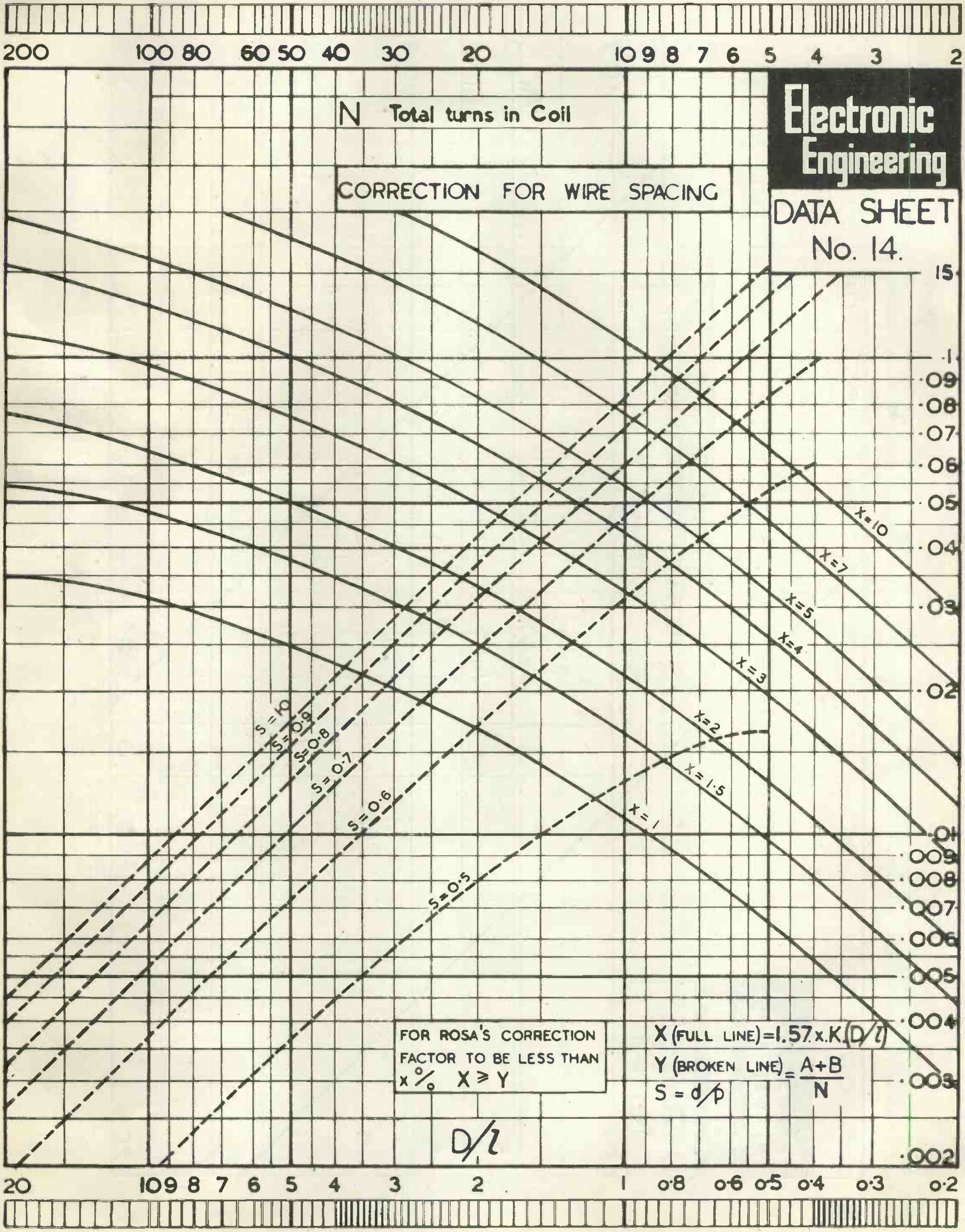
| S.W.G. | Diam. mm. | Theoretical Turns per cm. Length of Single-Layer Coil | | | | |
|---|---|---|---|---|---|---|
| | | D.S.C. | D.C.C. | E. & S.S. | E. & S.C. | Enamel |
| 12 | 2.642 | — | 3.3 | — | 3.4 | 3.6 |
| 14 | 2.032 | — | 4.2 | — | 4.3 | 4.7 |
| 16 | 1.626 | 5.8 | 5.2 | 5.6 | 5.3 | 5.8 |
| 18 | 1.219 | 7.7 | 6.7 | 7.5 | 6.8 | 7.8 |
| 20 | 0.914 | 10.1 | 8.4 | 9.7 | 8.6 | 10.2 |
| 22 | 0.711 | 12.7 | 10.1 | 12.1 | 10.4 | 12.9 |
| 24 | 0.559 | 15.7 | 12.3 | 15.3 | 13.3 | 16.2 |
| 26 | 0.457 | 19.2 | 14.1 | 18.7 | 15.7 | 19.9 |
| 28 | 0.376 | 23 | 15.9 | 22 | 18.5 | 24 |
| 30 | 0.315 | 26 | 17.6 | 26 | 21 | 29 |
| 32 | 0.274 | 30 | 18.9 | 30 | 23 | 33 |
| 34 | 0.234 | 34 | 21 | 35 | 26 | 39 |
| 36 | 0.193 | 39 | 24 | 40 | 31 | 46 |
| 38 | 0.152 | 46 | 26 | 49 | — | 56 |
| 40 | 0.122 | 54 | 29 | 58 | — | 72 |

# Electronic Engineering DATA SHEET No. 12






*Note: Please see p. 472 for corrections to Data Sheets 9, 10 & 11.*

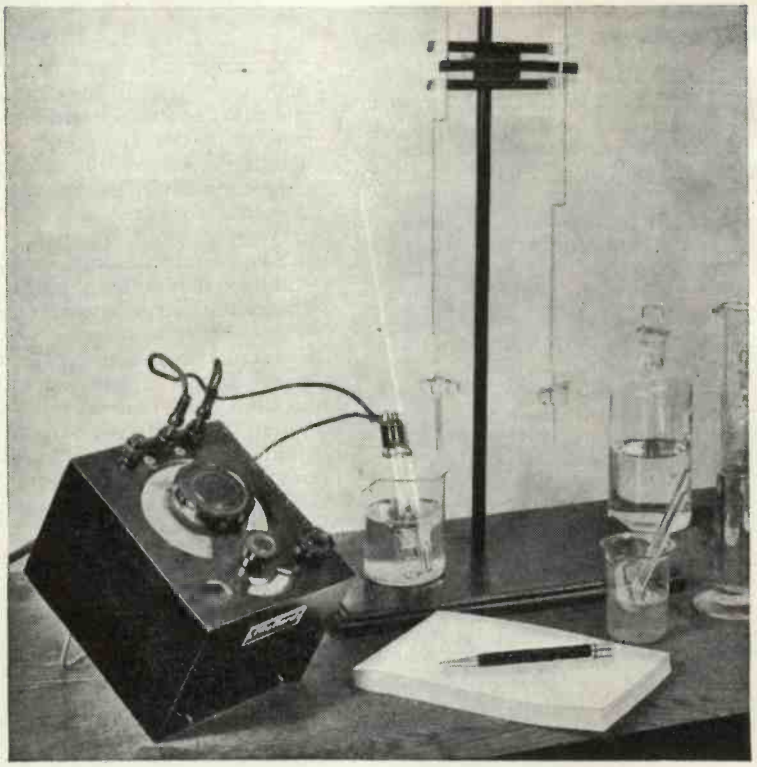

Electronic Engineering
DATA SHEET
No. 14.
N Total turns in Coil
CORRECTION FOR WIRE SPACING
200 100 80 60 50 40 30 20 10 9 8 7 6 5 4 3 2
15 ·1 ·09 ·08 ·07 ·06 ·05 ·04 ·03 ·02 ·01 ·009 ·008 ·007 ·006 ·005 ·004 ·003 ·002
X=10
X=7
X=5
X=4
X=3
X=2
X=1·5
X=1
S=1·0
S=0·9
S=0·8
S=0·7
S=0·6
S=0·5
FOR ROSA'S CORRECTION FACTOR TO BE LESS THAN x % X ≥ Y
X (FULL LINE) = 1.57 x.K.(D/l)
Y (BROKEN LINE) = A+B / N
S = d/p
D/l
20 10 9 8 7 6 5 4 3 2 1 0·8 0·6 0·5 0·4 0·3 0·2

MULLARD MEASURING APPARATUS

# ELECTRICAL CONDUCTIVITY OF SOLUTIONS

Determination of the electrical conductivity of a solution depends basically upon the accurate measurement of a resistance. In the Mullard Measuring Bridge Type GM.4140, described last month, we have the ideal instrument for measurement of resistances between 0.1 ohm and 10 megohms, and in order to extend its applications to cover the determination of conductivities, Mullard engineers have designed two pieces of auxiliary apparatus. These are **Conductivity Cell Type GM.4221,** Price £3 10s. 0d. and **1,000 cycle Oscillator Type GM.4260,** Price £7 10s. 0d.

These three instruments together render obsolete all the cumbersome apparatus previously associated with conductivity measurements—slide wire potentiometers, high frequency reed buzzers and insensitive headphone detectors. For further information send us a postcard, asking for a copy of our leaflet No. MV916 entitled "Measurement of Electrical Conductivity of Solution with the Mullard Measuring Bridge Type GM.4140."



The illustration depicts the use of the Mullard Conductivity apparatus for conductimetric analysis. Other applications include:—

Determination of the Ash content of sugar solutions.
Determination of the dissolved solids in water supplies.
Estimation of water content of alcohol.

***Let Mullard engineers help you to apply the new technique to your problems. Write to Dept. E.E.1 at the address below.***

THE MULLARD WIRELESS SERVICE COMPANY LIMITED

MEASURING APPARATUS SECTION

CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2

# The Technique of Receiver Measurements

By G. T. CLACK

## Part III—conclusion

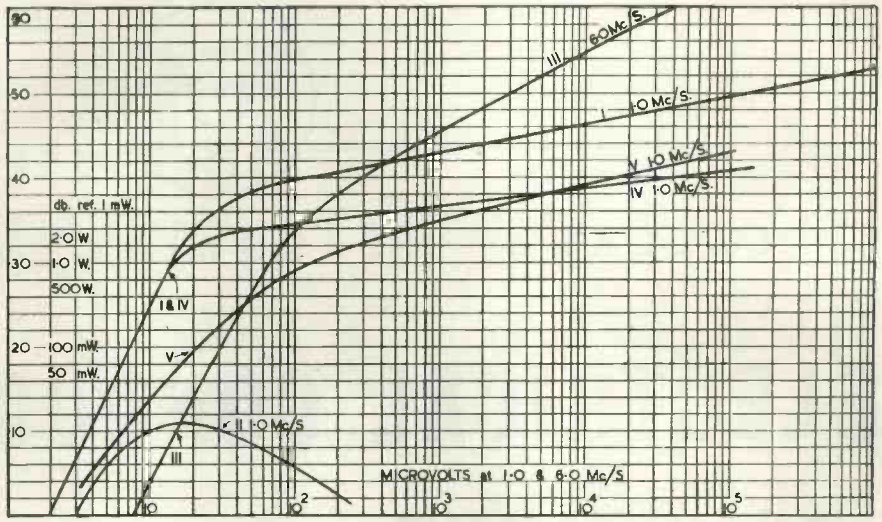



Fig. 15.—Curves taken from A.V.C. measurement on the receiver.

### R.F. Tests

HETERODYNE volts can be measured by inserting an 0-1 milliameter in the low potential end of the oscillator grid leak R3. As the valve manufacturers give an average figure for heterodyne volts, it is worth while measuring them over the whole frequency range of the receiver. The figure varies with different types of valves and may be anywhere between 6 and 12 volts peak. The voltage should not be allowed to fall too low, otherwise sensitivity will be affected. Should the heterodyne volts be too high or too low, then adjustments can be made to coils, grid leak, coupling condensers or anode potential to remedy any defect.

The general tendency is to parafeed the oscillator anode as shown in Fig. 1, and the value of R5 depends upon the type of valve in use, but may be anything between 25,000 and 50,000ω. The oscillator must be functioning when I.F. sensitivity tests are being carried out, otherwise the gain will appear to be better than it actually is.

Assuming that the signal and oscillator circuits are in order and details such an padding, alignment and optimum efficiency have been completed, then the R.F. signal generator is connected via a dummy aerial (Fig. 13) to the aerial and earth sockets of the receiver and an output meter coupled to the speech output winding as shown.

The input is modulated 30 per cent. at 400 c.p.s. as in previous tests and the sensitivity is that number of microvolts injected to produce the standard output. The frequencies at which this is carried out are tabulated below, but if required the sensitivity at a number of intermediate points can be measured to assist in plotting a complete curve (Fig. 14).

L.W. ... 160 200 300 kc/s.
M.W. ... 600 1,000 1,400 kc/s.
S.W. ... 6.0 11.6 17.75 kc/s.

The variation between the extreme ends of the bands should not be worse than about 3:1. In the case of the M.W. and S.W. bands, the aerial couplers were peaked at the H.F. end of the range and the effect of this is disclosed by a higher sensitivity there. The reverse was the case for the L.W. band and the curve gives proof of this.

To ascertain the aerial circuit gain, the standard modulated input is injected between the frequency changer grid and chassis at various radio frequencies and a record taken of the input necessary to produce the standard output. The ratio between these figures and those obtained by an overall R.F. sensitivity test at similar frequencies will indicate the gain of the aerial coil.

The following sample figures give an idea of the process:—

| Input to: | 160 | 200 | 300 | 600 | 1000 | 1500 | kc/s | 6 | 10 | 16 Mc/s |
|---|---|---|---|---|---|---|---|---|---|---|
| $V_1$ grid | 38 | 38 | 40 | 34 | 36 | 36 | | 42 | 28 | 23$\mu$V |
| A. and E. | 12 | 13 | 40 | 15 | 6 | 4.5 | | 26 | 16 | 12$\mu$V |
| Aerial coil gain | 3.15 | 2.9 | 0 | 2.25 | 6 | 8 | | 1.7 | 1.75 | 1.9 |

The coil gain at various frequencies is determined by the type of coupling used, i.e. whether high- or low-peaked primary with or without top-end coupling. The coils tested happened to have low-peaked primaries on the medium and high frequencies and a high-peaked primary on the lower frequencies. The gain for a given coil remains constant but the sensitivities at the grid of the frequency changer will vary with different makes and such figures can serve as a basis for comparing conversion efficiency provided the correct amount of heterodyne volts are maintained at the oscillator grid.

For medium- and long-wave frequencies the standard dummy aerial consists of a 200-pf. condenser, a 20-ohm resistor and an inductance of 20 micro-henries in series with each other and connected into the high potential side of the input. This dummy aerial represents what has been described as the average aerial. On S.W. frequencies this is replaced by a non-inductive 400-ohm resistor.

### A.V.C.

A.V.C. is plotted as a curve showing the relation between input and output.

The R.M.A. method of measurement calls for an input of 1 volt at R.F. with the volume control adjusted so that the receiver delivers a quarter of its nominal output. The input is then reduced in convenient steps and a record taken of the fall in output.

The only information obtained from this test is the point at which A.V.C. commences and the " slope " of the controlled portion of the curve, i.e., expressed as the change in input, in db, needed to obtain a change of 1 db in power output.

An improved method of measurement* which gives much more information is described herewith. The advantage over the conventional method is that it reveals many other facts (1) inherent receiver noise, (2) output at the point where A.V.C. commences, (3) delay volts too high or too low, (4) sensitivity of the receiver in microvolts input for any required output.

Another point is that some generators will not supply the 1-volt R.F. output as required by the R.M.A. specification,

* *See* M. G. Scroggie, " Radio Laboratory Handbook," and "The A.V.C. Characteristic," *Wireless World*, Vol. 44, No. 18, pp. 427, 428, 12th June, 1936.

whereas with the Scroggie method the most important information is gained using inputs between 1 $\mu$V and 1-10th volt.

The R.F. signal generator is coupled via a dummy aerial to the aerial and earth sockets of the receiver, and the desired signal frequency, modulated 30 per cent. at 400 cycles, injected. The change in power output is referred in decibels to 1 milliwatt, and plotted on 6-cycle log:linear paper against R.F. input up to 1 volt. As the curve is plotted on log paper the input in microvolts can be conveniently increased in steps of 3, 10, 30, 100, 300 and so on, as this will save measuring unnecessary intermediate points.

An A.V.C. measurement should be taken at a frequency near the middle of each range covered by the receiver, but if desired there is no reason why some other, perhaps more convenient, frequency should not be used.

With the gain controls set to maximum, adjust the input to the receiver until, say, 1 milliwatt is read on the output meter (Fig. 13); then this input in microvolts is plotted as the reference point, Odb, as in Fig. 15.

The input is then increased in small steps and the output change in db is read directly from the wattmeter. It is obvious that the L.F. stages will be hopelessly overloaded before any useful information is obtained, so it becomes necessary to reduce the L.F. gain when the output reaches a convenient level and to refer the previous reading in db to the new level before continuing. An example will clarify the process. For the receiver already mentioned an input of 2 $\mu$V produces 1 mW. output. Increasing the input in the previously mentioned order (×3, ×10, ×30, etc.) brought the output up in steps which were noted and plotted. When output was +30 db above 1 mW. (1 watt), the L.F. gain control was turned down, until the meter read 100 milliwatts, and referring to this level as +30 db, the test was carried on.

The gain must be reduced each time the output reaches 25 to 50 per cent. of its maximum in order to avoid overloading occurring in the L.F. stages.

As mentioned in previous tests, a current or voltmeter could be used in place of an output wattmeter. Current ratios measured in the output load resistance can be interpreted into db change in power output (Fig. 8). For an A.C. milli-ammeter the 1-milliwatt reference level is found by $I=\sqrt{W/R}=20$mA. for a 2.5$\omega$ load. In this instance, owing to the extremely low reference level it becomes impracticable to employ a voltmeter across the resistance, as the voltage is in the order of .05 volts. Connecting the voltmeter as in Fig. 5 solves this problem, and a 1-milliwatt level is indicated by a meter reading of 2.83 volts for an 8,000 $\omega$ anode load. The same procedure as for the wattmeter is used when + 30 db is reached.

The point at which A.V.C. commences

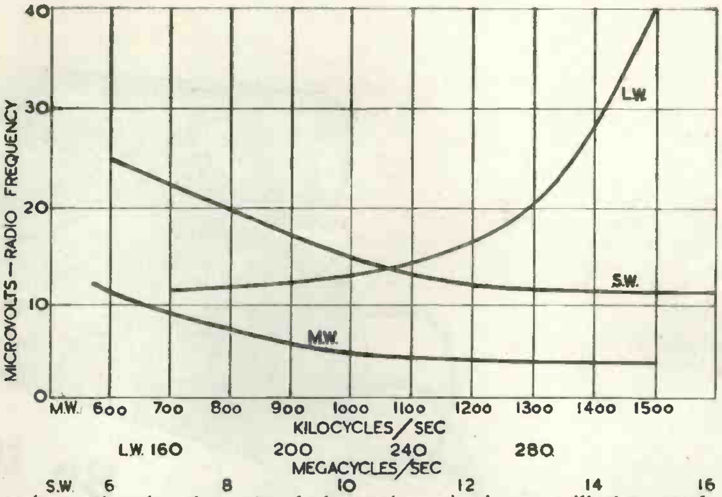



Fig. 14.—Sensitivity curves of receiver.

is shown by the sharp bend that takes place at about 20 $\mu$V input. Plotted also are points indicating the output power. By altering the delay voltage on the A.V.C. diode anode it is possible to arrange matters so that A.V.C. occurs before or after the maximum power output is obtained. In the case of curve I (Fig. 15) the A.V.C. becomes effective just as the maximum output is developed.

Invariably the delay is arranged so that the maximum output is obtained before A.V.C. takes full control, otherwise with a low L.F. gain there is a possibility that the maximum output will not be realized unless the carrier is very strong. This condition could be experienced if, for instance, $V_3$ and $V_4$ of Fig. 1 were replaced by a double diode output pentode and insufficient delay volts applied to the A.V.C. diode anode (V).

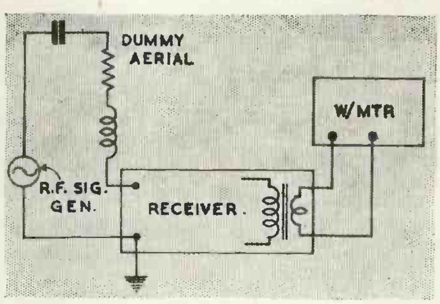



Fig. 13.—Connexions for sensitivity tests.

An improvement in the A.V.C. curve would result if the L.F. gain were reduced and the loss in sensitivity made up in either the I.F. or R.F. circuits, together with this an increase in the delay voltage. The effect would show itself as illustrated by curve IV in Fig. 15.

With the type of receiver in Fig. 1 it is inadvisable to employ A.V.C. on the control grid of the frequency changer V1 on short waves, as a variation in bias on this grid affects the coupling between R.F. and oscillator sections, which in turn detunes the oscillator frequency. This effect is very noticeable when the input signal fades, more so than when it increases. A change of even ten times in input will detune the oscillator frequency by 3 to 6 kc/s. in a high-frequency direction, and as the fading under bad conditions can exceed 100 : 1 it is possible that the use of A.V.C. on the frequency changer can cause fading to appear worse than it actually is. The low potential end of the S.W. aerial coil should be returned to earth and only the I.F. valve controlled (curve III).

Prior to taking the A.V.C. curve, a note should be made concerning noise level with zero input and maximum gain. Also it is as well to plot a curve showing increase in noise for an increasing unmodulated carrier (II) and the point where it tends to disappear. The average receiver should not show more than .5 to 1 milliwatt of noise with volume control up and aerial and earth terminals connected together and not more than 5 to 10 milliwatts of noise for an unmodulated carrier below A.V.C. operation. The total noise output (including hum) with 1-volt R.F. input on medium and long waves should not be more than 5 milliwatts.

Referring back to Fig. 12, curve II is the overall response of the receiver at 1,000 kc/s. The generator connexions are as shown in Fig. 13, but with an externally connected L.F. generator to supply the modulation frequencies from 50 to 10,000 cycles.

The input is adjusted to 20 mV at 30 per cent. mod., at 400 c/s and the L.F. gain control, R.14, set to give a convenient output, against which is plotted the response. The high input of 20 mV is to create a similar condition as would be met with local station reception.

The few preceding tests are sufficient for normal requirements, but a complete record of receiver performance would include many other tests, including padding, adjacent and remote channel selectivity, frequency stability, re-radiation, acoustic tests for sensitivity, output and fidelity, etc. etc.

A complete and detailed specification on testing and expressing performance of radio receivers can be obtained from the British Standards Institution, London, S.W.1.

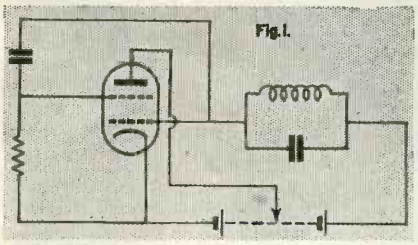
# A Note on the Use of Small Power Pentodes as Negative Resistance Oscillators

by E. LAWRENCE

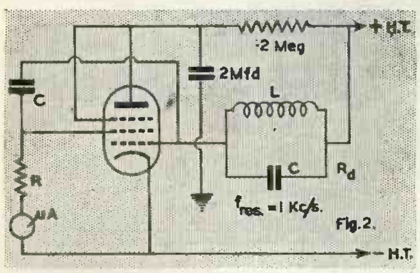
WITH little difficulty a small power pentode of the MP Pen, AC/Pen, Pen.A1 class used under the conditions described can be used to provide a ready and stable oscillator.

This note is based on a practical experiment using a valve having the following normal constants:—

- Heater, 4 volts 1 amp.
- Max. H.T. voltage, 250.
- Max. screen voltage, 250.
- Average anode impedance, 50,000 ohms.
- Average mutual conductance, 3 mA/V.




The familiar early tetrode circuit is shown in Fig. 1. Such a circuit is simple on paper only as its performance may be erratic due to ageing and even when very carefully set up the choice of operating bias is critical. The circuit shown in Fig. 2 suffers from no such difficulties.




The connections shown were decided after carrying out tests involving various electrode combinations, though the successful operation of the circuit is mainly due to a more important point, which is that oscillation does not commence until the valve emission is limited by a reduction of cathode heater temperature.

The most stable condition for this type of oscillator is found by inserting a micro-ammeter in series with the lower return lead of R and then slowly increasing the heater current until the meter reading is a maximum (this in most cases is some 50 micro-amperes and occurs when the heater has about two volts across it).

The choice of C and R is not critical when the circuit is used at high frequencies, but at the frequency of test, i.e., 1,000 c.p.s., it was found that a 10 per cent. increase in output took place if CR equalled the period of oscillation.

At 1,000 c.p.s. the period equals 0.001, and reasonable values to choose would be 0.01 mfd. and 0.1 megohm.

Tests were carried out to find the effect of varying electrode potentials, and to ascertain the oscillation threshold. The results are tabulated below:—

| H.T. Volts | Volts across LC. Circuit |
|---|---|
| Threshold of oscillation | |
| 48 | 4 |
| 72 | 11.5 |
| 96 | 15 |
| 120 | 20 |

Grid constant at + 120 volts.

| Volts (screen and anode) | Volts across L.C. |
|---|---|
| 3 | 5 |
| 6 | 12 |
| 9 | 16 |
| 12 | 19 |
| 24 | 27 |
| 36 | 30 |
| 72 | 38 |
| 96 | 40 |
| 120 | 41 |

As the output is across the LC circuit it is to be expected that the wave-form will be good, and this was confirmed by a measurement as under:—

Harmonics of 1,000 c.p.s.

| H.T. Volts | Total I (mA) | Second Harmonic % | Third Harmonic % |
|---|---|---|---|
| 24 | 3 | 2 | 0.6 |
| 100 | 3 | 0.3 | 1.0 |

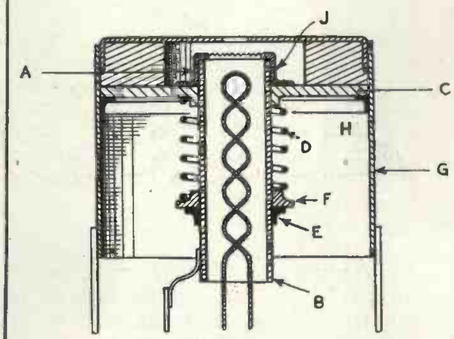
Frequency stability for variations in supplies is very good, and for H.T. and L.T. changes of some 15 per cent. the frequency changes no more than 1 part in 5,000.

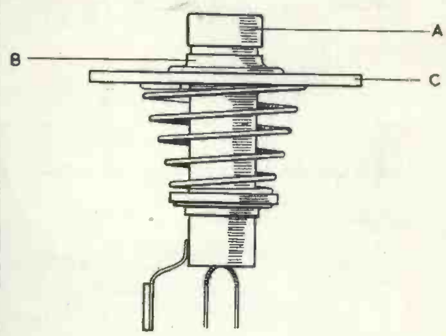
It is often important to know the available value of a negative resistance. This can be found approximately by increasing C until oscillation ceases, then L/RC at this setting gives the figure. For the case noted this proved to be some 3,500 ohms.

The circuit was also tried without any alteration other than changing the resonant LC values from 1 kc/s to 5,000 kc/s. The circuit went into oscillation readily and the volts across the particular coil used were in excess of 20.

## Cathode and Control Electrode Assembly for C.R. Tubes

THE familiar indirectly heated cathode consisting of flat end-cap coated with emissive oxides, terminating the cylinder housing the heater, needs to be maintained in accurate location relative to the control electrode despite temperature variations during manufacture and subsequent operation. A neat assembly for ensuring this is illustrated in the accompanying drawings, of which Fig. 1 shows a section through such a cathode assembled within its control electrode.




The flanged cathode A is first rigidly fixed to the cylindrical sleeve B. An insulating spacer C and cylindrical spring D are slipped over the sleeve, and the flange E is then moved into a position such that the spring is compressed slightly: to ensure that the spring does not contact the cathode sleeve the spacer C is shouldered as illustrated Heating of the spring by the sleeve is minimized by introducing a further insulating (e.g., ceramic) spacer F between the flange E and the spring. Spacer C fits inside the control electrode cylinder G, which supports the retaining ring H. The spacing between the emitting surface and the end-disk of the control electrode is determined by the thickness of the further insulating spacer J.

The modification shown in Fig. 2 is useful where it is desired to adjust the distance between the emissive surface of the cathode and the end-plate of the control electrode. In this case the cathode A is not itself flanged, but a separate flange is provided at the appropriate position to co-operate with the spacer C.—**R.C.A. Laboratories.**

# ABSTRACTS OF ELECTRONIC LITERATURE

## Thermionic Tubes

### A Method of Measuring Dynamic Characteristics of Valves

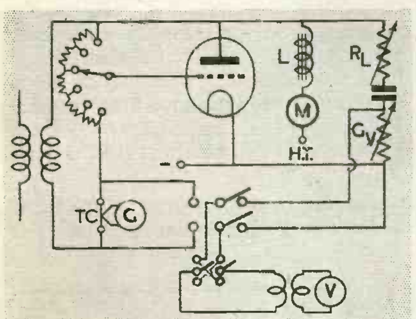
(*J. B. Maggio*)

A circuit which directly determines the dynamic characteristic by a method which is simpler, more rapid and more free from the inherent errors of the graphical method. A dynamic transfer curve is obtained rapidly and under operating conditions by direct measurement under A.C. conditions.

The desired D.C. and grid biasing potentials are applied to the valve and a pure sinusoidal driving voltage of carefully determined value applied to the grid.

The driving circuit consists of a tapped potentiometer of equal resistance steps, one of which is the heater of a thermocouple T.C. An oscillator applies a pure sinusoidal voltage to the potentiometer and its output adjusted until the galvanometer G connected to the thermocouple indicates that 1 volt peak is applied across the thermocouple. Under these conditions the steps of the potentiometer apply to the grid multiples of 1 volt peak from the bias voltage.

The alternating and direct components of the anode current are separated by a parallel circuit RL Gv, the inductance of L being sufficiently high to prevent flow of A.C. The A.C. component through RL Gv is measured by adjusting Gv until the peak voltage across it is 1 volt as compared with the voltage across the thermocouple in the grid circuit (see diagram).




A double-pole double-throw switch permits the peak voltmeter V to be thrown rapidly from one to the other, and a similar switch is connected so that either the positive or negative peaks may be read. The circuit may be used for measuring the transconductance from control grid to anode. As the load resistance is made small compared to the internal resistance of the valve, the voltage ratio from grid to anode approaches the product of transconductance and load resistance. By making RL equal to zero, setting the grid potentiometer to the 1-volt tap, and adjusting Gv until there is one volt across it, the voltage gain through the valve, or the ratio of anode to grid voltage, is unity, and the transconductance will be equal to one divided by the load resistance, which is Gv. Since the reciprocal of Gv is the conductance, which is read directly from the Gv dial, the transconductance is obtained directly. When the voltage gain has been adjusted to unity with the grid potentiometer on the 1-volt tap, the calibration of Gv is independent of the actual grid voltages.

—*Bell Laboratories Record*, Vol. 19, No. 9, May, 1941, page 281.

## Circuits

### An Ionization Gauge Circuit with a 'Magic Eye'

(*W. E. Parkins and W. A. Higinbotham*)

The special feature of this circuit is the use of a magic eye valve which incorporates two independently controlled shadow angles. One is used to set the ionisation gauge grid current to an approximate value, the other enables a balance to be made giving the ratio of the gauge plate to grid currents. This is a function of the pressure in the gauge, but is insensitive to changes in the grid current. Consequently, the pressure can be determined without the usual trouble in maintaining the grid current at some constant value.

—*Rev. Sci. Inst.*, Vol. 12, No. 7, July, 1941, page 366.

## Measurements

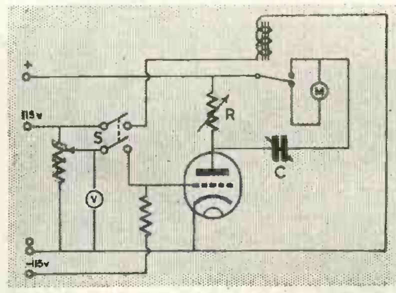
### A Simple Method for Measuring Steady Currents of Brief Duration

(*R. D. Bennett*)

A method which permits point to point measurement of the characteristics of substantially resistive elements, using ordinary indicating instruments, but requiring current duration so brief as to avoid dangerous heating effects. The method is particularly useful in the study of valve characteristics under overload conditions.

For the measurement of triode characterics the voltage divider which supplies Vg should have so much current carrying capacity that the value of Vg is not altered appreciably by the grid current and the current in Rg when S is closed, yet Rg should be small enough to keep the value from blocking when S is opened. The anode voltage actually applied is calculated from the quantity of electricity indicated by the instrument A and the values of R and C.

To obtain conveniently a grid voltage-anode current characteristic with constant anode voltage requires an anode power source of good regulation whose voltage can be adjusted. The source of voltage is adjusted to a value in excess of the voltage to be applied to the anode by an amount say Vx. R




is then adjusted for some convenient value of Vg, so that the drop in R is just equal to Vx. The drop in R is determined for any given combination by the value selected for C and the quantity going into C as indicated by A with the aid of its calibration. Once C and the corresponding deflection of A have been established, as new values of Vg are selected R is readjusted to give the same deflection of A with C kept fixed. Consequently the drop in R is always the same, namely Vx, the voltage applied to the anode is always the same and the anode current is quickly calculated from the value of R.

—*Rev. Sci. Inst.*, Vol. 12, No. 6, 1941, page 332.

### Use of a Cathode Ray Tube for Comparison of Capacities

(*R. H. Cole*)

A simple method is described for comparison of capacities. It consists of a circuit containing the unknown and standard capacities in series, the potential differences across them being applied directly to the vertical and horizontal deflecting plates of a cathode ray tube. Simple methods for calibration of residual circuit capacities and of the cathode ray tube are described. The method is capable of the accuracy of the order of 0.5% in the range 50 kc to 2 Mc and has the advantage that determination of the unknown capacity is unaffected by parallel conductance of the unknown.

—*Rev. Sci. Inst.*, Vol. 12, No. 6, June, 1941, page 298.

### Electronic Cup Anemometer

This instrument, which is manufactured by W. & L. E. Gurley, Troy, New York, is basically a rotating cup type of anemometer using electronic circuits and electric meters to indicate the rate of rotation of the cup rotor.

The head consists of a 3-cup rotor mounted on a spindle to which is attached a perforated disk, located within the housing. Rotation of the disk interrupts, without mechanical connexion, the oscillation of a small oscillator contained in the same housing and produces signals of frequency proportional to the rate of rotation of the rotor. By means of a five-wire shielded cable, power is transmitted to the head

(*Continued on page 466*)

# An Experimental Electronic Musical Instrument

By F. C. BLAKE

THE use of a zither harp as a generator has its limitations owing to the restricted frequency range available, and the rendering of musical compositions of an ambitious nature is not possible. As an experimental instrument, however, it has great possibilities and the following account of the author's constructional work may be of use to experimenters who have similar forms of instrument available.

A number of 1 in. steel panel pins were driven halfway home on the underside of a piece of batten the width of the harp, at suitable distances apart so that their heads coincided with the position of the strings when mounted over two fillets acting as spacers (Fig. 1). Each pin was then wound with approximately 100 turns of thin enamelled wire (about 36 s.w.g.) one end of each coil being soldered to a brass pin driven into the edge of the batten, the other end being soldered to a common busbar connexion made from thin strip brass. The batten was then screwed down in position over the harp, making sure that the pins did not foul the strings or were situated too far above or to one side.

By passing a small direct current through each coil in turn tapping from one brass pin to another the panel pins became weakly magnetised. Thus on activating the strings in some way, and connecting up suitable coils a number of alternating currents will be produced in the coils corresponding in frequency to the natural vibration of the string, plus a number of harmonics depending on the position of the coil armature. In this case it was arranged so that the point of excitation was roughly a quarter the length of the string. (Fig. 2).

*Exciter.*

An a.c. gramophone motor was mounted on a board (Fig. 3) with its spindle horizontal, at such a level that when an endless tape, driven by a pulley mounted on the spindle, and running over a similar reel mounted on a bracket at the opposite end, was moved by the motor, it set into vibration all the strings at the same time. This part was afterwards improved by sewing short lengths of tape in the form of a brush along the original tape at close and regular intervals, a little resin in powder form being pressed into the tape " brushes " with the aid of a thin knife.

*Keyboard.*

Some old piano keys were mounted in position on a baseboard. (Fig. 4). Springy brass strips were used as contacts, and were screwed to the keys as shown in the diagram. Owing to the wiping action the contacts kept quite clean, and apart from initial adjustment no trouble was experienced.

*Connexion to Amplifier.* (Fig. 5).

A good " quality " amplifier is needed, and one usually used for record reproduction was used, the connexion between the instrument and the amplifier was an output transformer from a moving coil speaker. It was found necessary to connect a " key click " filter across the secondary winding, and a condenser and resistance proved suitable. It was also found that owing to irregularities in magnetic flux in the panel pins, and their varying proximity to the strings, the strength of each note was not uniform, but by means of slight adjustments to the height of the pins over the strings the tones were fairly well balanced.

With this primitive device there is, of course ample room for improvement. For instance, an iron frame harp, screw-type coil armatures, and soft leather wheels running individually over each wire, are a few that suggest themselves. Again, the use of a separate " field " coil to energise each coil would constitute a great advantage over the simple system outlined above.

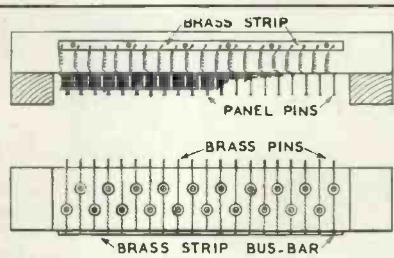



Fig. 1.

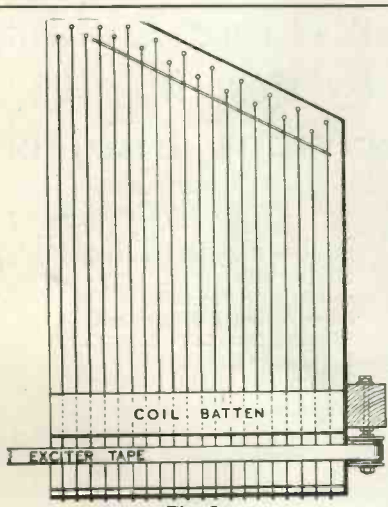



Fig. 2.

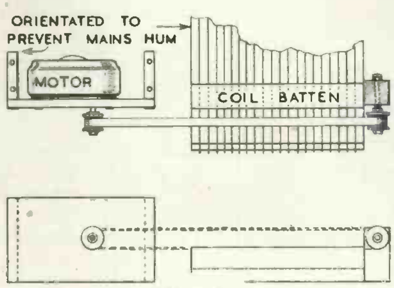



Fig. 3.

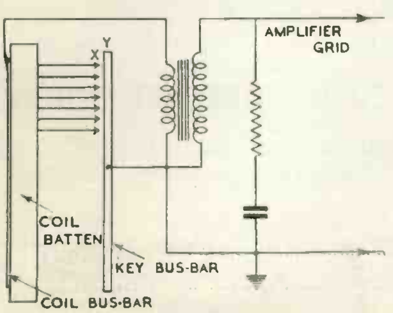



Fig. 5.

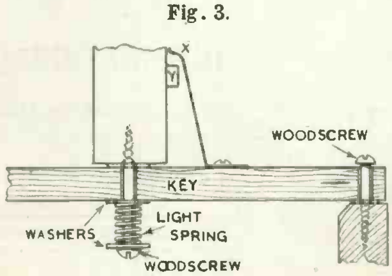



Fig. 4

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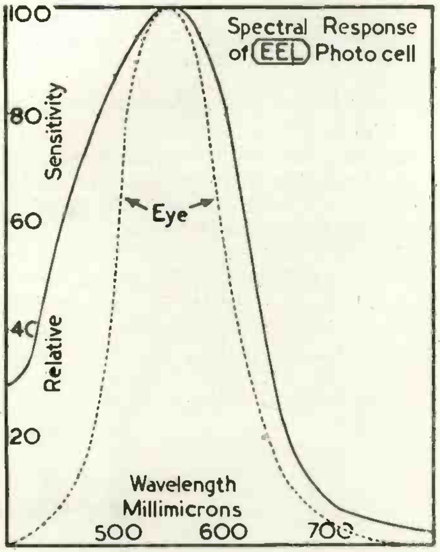


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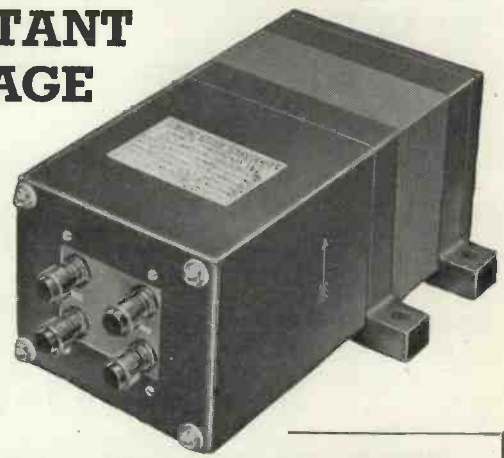

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# NOTES FROM THE INDUSTRY

### Absorptiometers

Messrs. Adam Hilger point out that instruments used for colorimetric methods of analysis are erroneously called "colorimeters" since they do not measure the colour, but the absorption of the substance. For this reason they prefer the word "absorptiometer" applied to the so called "photo-electric colorimeter."

Messrs. Wild-Barfield Electric Furnaces have been appointed distributors to the engineering industry for the Spekker photo-electric absorptiometer manufactured by Hilger. In some systems employed in photo-electric absorption measurements no provision is made for eliminating mains supply variations or for allowing for ageing of the photocell used. The Spekker meter is independent of voltage fluctuations and as the cell is used as a "null" indicator the accuracy is unaffected by changes during life.

Other features are a robust galvanometer, simple optical system and the fact that a standard solution need not be used to check every test solution. Solutions for a given test are prepared and measured on first use of the instrument and need be repeated only after long intervals. The accuracy is within 1%.

The instrument was first described in the *Jour. Sci. Inst.* 13, 268, and a booklet on its uses can be obtained from Messrs. Wild-Barfield, Watford By-pass, Watford.

### Soldering Pliers

Many users of soldering irons have had experience of the awkward job which demands a third hand or an assistant to hold the work. By making the soldering iron into a pair of pliers difficult soldering jobs are considerably simplified as the work can be gripped and heat applied simultaneously, leaving a hand free for manipulation.

"Acru" soldering pliers are manufactured by the Electric Tool Mfg., Co., 110 Great Ancoats Street, Manchester, 4, and are available in 75, 100, 125 and 150 watt sizes. Special shaped bits can be supplied. A particular feature is the air-tight element which has a two years' guarantee. Supplies in London can be obtained from Arthur's Radio, 150 Charing Cross Road.

### Moving Coil Microphone

The General Electric Co. announce a new microphone designed for message broadcasting systems and control centres. It is of the moving coil type mounted in a hardwood desk pattern cabinet measuring $6\frac{1}{4}$ in. high by $5\frac{3}{4}$ in. wide and is fitted with a D.P. key and internal terminal strip. The coil is of low impedance (15 ohms) and it is thus possible to use a long transmission line with the minimum of noise pickup. Copies of the leaflet describing it can be obtained from the G.E.C., Magnet House, Kingsway. Ref: B.C.S. 2282.

### Radio Textbooks

The National Book Council, of 3 Henrietta Street, W.C.2, have issued a leaflet No. 170 of recommended books on Radio and Telecommunications, compiled by Mr. Clarricoats of the R.S.G.B. The various sections are classified, and give a useful guide for students who are not aware of the range of textbooks available at the present time. There are one or two notable omissions, however, for example Zworykin's "Television," which is acknowledged to be a standard work, and which is obtainable through Messrs. Chapman & Hall.

The omission of some McGraw-Hill publications is probably excusable at the present time owing to the difficulty of obtaining them. What is now wanted, of course, is a list of textbooks with concise comments attached, but it will be a bold Book Council that undertakes its preparation.

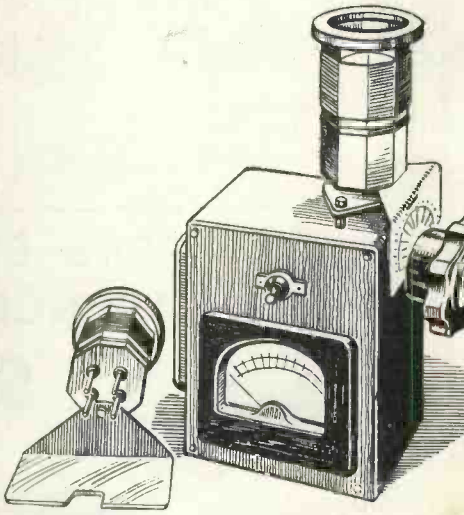
### The Television Society

The annual general meeting of the Television Society will be held on Saturday, October 4, at the Institution of Electrical Engineers, Savoy Place, S.W., at 3 p.m.

At the conclusion of the general meeting Dr. van den Bosch of Messrs. Vacuum Science Products will read a paper on "Recent Improvements in High-Slope Electron Multipliers" with special reference to the new high-slope "Augetron." Visitors are invited to this part of the meeting, and tickets can be obtained on application to the Secretary, Mr. J. J. Denton, 17 Anerley Station Road, S.E.20, or to the Editorial Dept. of this journal.

### Neat Method of Interchanging Scales

The sketch below shows a method of changing the scale to suit the coil in an absorption wave meter. The scale is cut from a small piece of thin metal and bent to the shape shown in the sketch. The bent end is fastened to the coil former as shown, and when the coil is in place the scale is automatically aligned in front of the condenser pointer. —**Q.S.T.**, July, 1941.



## Inverting the Characteristic of an Amplifier

It is sometimes necessary to compress the amplitude range of signals prior to transmission or recording and subsequently to expand the amplitude range to its original value. In order to avoid distortion, it is important that the expansion characteristic shall be the inverse of the compression characteristic, and a convenient arrangement for ensuring this has been devised by the Radio Corporation of America.

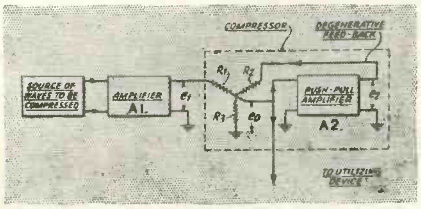



Fig. 1.

The principle is illustrated by Fig. 1. The source of signals which are to be compressed feeds an amplifier A1; the output voltage $e_1$ from which is applied across resistances $R_1$ and $R_2$ in series. A further amplifier A2, which is identical with the amplifier which is to be used for expanding the compressed signals, has its input circuit connected across $R_3$ and its output voltage $e_2$ is applied across resistances $R_2$ and $R_3$ in series. The compressed signal voltages $e_0$ are picked up across resistance $R_3$ and are fed to a further amplifier before utilisation.

Let it be assumed that the amplifier A2 is such that it provides an output voltage $e_2$ which is related to the input voltage $e_0$ by the relation

$e_2 = -\mathbf{m}\, e_0$ where **m** is a function of $e_0$.

If also $R_1$, $R_2$ and $R_3$ are equal in value, $e_0 = \frac{1}{3}e_1 + \frac{1}{3}e_2$.

Substituting for $e_2$, we have $e_0 = \frac{1}{3}e_1 + \frac{1}{3}(-\mathbf{m}\, e_0)$ or $e_0 = e_1/(\mathbf{m}+3)$

And, if **m** is large compared with 3, $e_0 = e_1/\mathbf{m}$, which is the desired relationship.

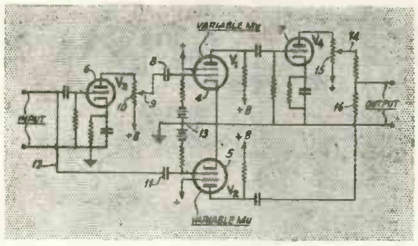



Fig. 2.

The amplifier A2 may be of any kind, but a convenient practical arrangement is shown in Fig. 2. This consists essentially of a pair of variable-mu valves $V_1$ $V_2$ arranged as a biased-back push-pull amplifier, to provide a characteristic as shown in the full line curve of Fig. 3. Phase inverting valves $V_3$ and $V_4$ are provided instead of transformers, but transformers may be used if desired. The inverted characteristic is shown in dotted lines in Fig. 3.

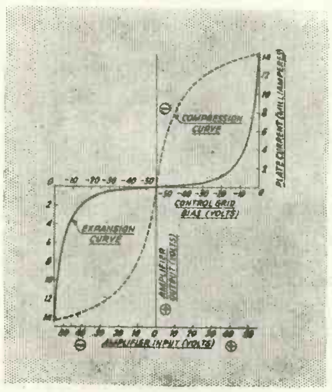



Fig. 3.

## Review of Progress in Electronics—*continued from p. 443.*

in an increase of current accompanied by a rapid drop in the discharge voltage, while the conditions change from those of a glow discharge to a fully developed arc. The greater the current flowing, the greater is the heating of the cathode, and consequently the greater the number of thermionic electrons produced.

The voltage between the electrodes of an arc discharge is related to the arc current and arc length in a somewhat complex manner owing to the fact that the total arc voltage is composed of the voltage drop in the arc itself as well as in the respective portions of the arc between the cathode and anode and the arc column. The relationships between these various quantities have been studied extensively by numerous workers as represented in the works listed in the accompanying Bibliography.

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# ABSTRACTS OF ELECTRONIC LITERATURE

(*Continued from page* 458)

and the signals are transmitted to the receiver where, by means of a suitable valve circuit, the signals are converted into a direct current which is read on a standard milliammeter with a scale graduated in miles per hour. The speed range is from 0 to 100 miles per hour.

—*Rev. Sci. Inst.*, Vol. 12, No. 7, July, 1941, page 373.

### A.C. Impedance of Chokes and Transformers

*(Rehfisch and Bissmire)*

Details are given of an instrument designed mainly for the measurement of A.C. impedance of chokes and transformers by a comparison method utilising a valve voltmeter. It is claimed to be quick and simple in operation and electrically robust, and to be most convenient for production checks.—A per cent. indicator is incorporated.—*Wireless Engineer*, July, 1941, page 266.

## Industry

### A Thyratron-Controlled Annealing Furnace

*(L. Tarnopol)*

In the circuit an alternating-current bridge and amplifier control the output of a thyratron which is in series with the Nichrome furnace winding. Alternating voltage in phase with the supply line is impressed on the bridge, and the output from the bridge consists of a component varying with the balance of the bridge, and another approximately constant component 90° out of phase with the impressed voltage.

The bridge is transformer coupled to a single stage audio-frequency amplifier which preserves the phase of the input voltage. This amplified voltage is used to bias the grid of a mercury vapour-filled thyratron whose anode is in series with the furnace winding and the supply line. Continuous temperature regulation is obtained rather than on and off control by this phase-shifting circuit.

—*Rev. Sci. Inst.*, Vol. 12, No. 7, July, 1941, page 368.

### Metal-Coated Plastics

Brief mention is made of a metal-spraying process for coating phenol formaldehyde mouldings, cast resin products and laminated materials with zinc, aluminium, copper or tin. It is claimed that the electromagnetic screening properties of the zinc film are approximately equal to those of tin foil of 0.02 mm. thickness. Several advantages are claimed including, saving of metal and space, reduction in weight and increase in strength and better adhesion than that obtained by galvanising.

—*Engineering*, August 22, 1941, page 125.*

### Silver Coatings on Non-Metallic Surfaces

*(Hepburn)*

This article describes methods of silvering non-metallic surfaces by simple immersion. The process is applicable to mica, celluloid and plastic materials generally and has the advantage that the whole surface area of an intricate shape is covered with a film of reasonably uniform thickness. Where a film is used as a base for subsequent electrodeposition the total thickness of the film can be accurately estimated. Brief mention is made of an optical method of determining the thickness of the silver deposit.

—*Met. Ind.*, August 8, 1941, page 90*

## Theory

### D.C. Amplified A.V.C. Circuit Time Constants

*(K. R. Sturley and F. Duerden)*

A theoretical examination of a D.C. amplified A.V.C. system with filter circuits in the grid and cathode of a valve showed that the overall time constant is very nearly equal to the sum of the time constants of the two circuits when the two time constants are widely different, *i.e.*:

$$T = RgCg + \frac{RkR'a}{Rk + R'a} Ck$$

where the suffixes g, k and a refer to grid, cathode and anode circuits respectively, and R'a is the sum of the valve slope resistance and any external anode circuit resistance (a valve used for audio frequency as well as D.C. amplification may have an anode load resistance). The actual time constant has greatest departure (+7 per cent.) from the formula given above when grid and cathode time constants are equal.

Experimental investigation with a triode and pentode D.C. amplifier indicated that errors occur in practice due to variations of the valve slope resistance Ra and amplification factor over the working range. A more correct expression for overall time constant is

$$T = KRg\,Cg + \frac{RkR'a}{Rk + R'a} Ck.$$

where K is a correction factor dependent on the variation of $\mu$ and Ra in R'a the average value of valve slope resistance over the operating range methods of calculating K (it is less than 1 for discharge and greater than 1 for charge) and Ra are given.

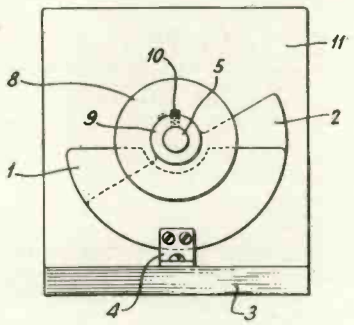
—*Wireless Engineer*, Vol. 18, No. 216, September, 1941, page 353.

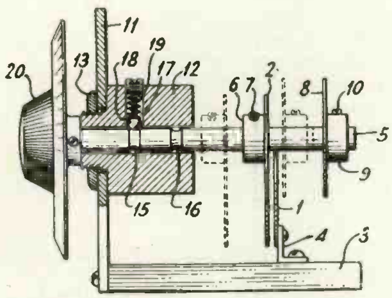
*Supplied by the courtesy of Metropolitan-Vickers Elec. Co., Ltd., Trafford Park, Manchester.

### Vernier Condenser

IT is possible to provide a compact vernier condenser unit having two ranges of capacity variation which can be operated by means of a single control and such an arrangement is shown in the accompany figure.

The stationary semi-circular condenser plate 1 is associated with a movable semi-circular condenser plate 2 to obtain the necessary large capacity variations. Stationary plate 1 is mounted upon an insulating base 3. Movable plate 2 is secured to a metal shaft 5 by means of a collar 6 and a set screw 7. A circular disc 8 is likewise secured to shaft 5 by means of collar 9 and set screw 10. The metal shaft 5 has two annular grooves 15 and 16. Shaft bushing 12 has an aperture 17 in which is located a spherical ball-shaped member 18. A spiral spring 19 normally keeps the shaft 5, by means of frictional engagement with ball 18, from moving horizontally through the bushing and yet allows it to be rotated for obtaining the necessary capacity variation. However, a sharp forward pull on knob 20 will move the shaft through bushing 12 until the ball drops into groove 16, thereby locating the condenser shaft in a new position. This new position which is indicated by dotted lines, provides a much greater clearance between the movable and stationary plates, thereby giving a much smaller range of capacity variation. The addition of the circular disc 8 makes it possible to change over from one range to the other at the mid-scale position without appreciably altering the capacity.—*R.C.A.*





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| **SP. 352** | 350-350 v. 150 m.a. 5 v. 2a, 6.3 v. 2 a, 6.3 v. 2 a... | 18/- |
| **SP. 806** | 315-0-315 60 m.a. 5 v. 2 a. and 6.3 v. 3 a. C.T.... | 8/6 |
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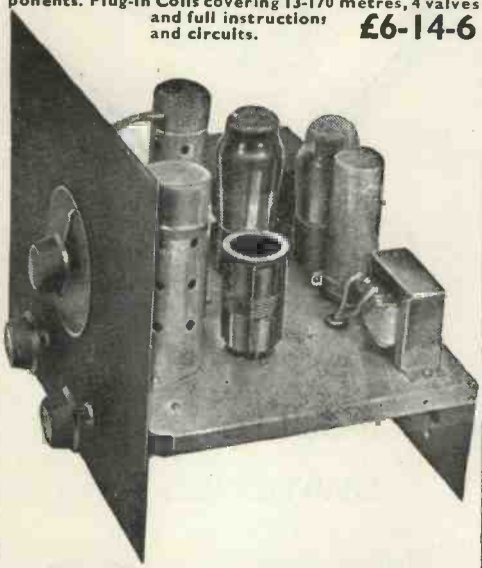

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Trolitul insulation. Certified superior to ceramic. All-brass construction. Easily ganged

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**Small Can Type,** 16 and 24 Med. 525 v.... 7/6
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4 Med. Wet, 320 v. ... 1/6

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**Microphone Transformers.** Suitable for all mikes. Tapped primaries, A, 20 and 40 :1; B, 30 and 60 : 1; C, 50 and 100 : 1. 6/6 each.
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CALLERS to: Jubilee Works, or 169, Fleet Street, E.C.4 (*Central* 2833), or 50, High Street, Clapham, S.W.4 (*Macaulay* 2381).

## Reducing Phase Shifts in Transformers

IT is well known that transformers introduce large phase shifts at high frequencies due to the action of the primary and secondary capacities and the leakage inductance between primary and secondary. Thus a lag of 360° is approached at very high frequencies between the primary input current and the secondary voltage.

If the leakage reactance could be short-circuited the maximum would become 90° lag. In transformers having ratios near unity, a condenser may be connected between primary and secondary points of like voltage and polarity and by short-circuiting the leakage reactance between these points for high frequencies, greatly improve the phase and attenuation characteristics.

The approximate equivalent diagram of a transformer energized through a valve at high frequencies is shown in Fig. 1a. This is seen to be similar to a low-pass filter driven from a resistance generator. At high frequency, the filter itself approaches 180° lag in phase while, since its impedance becomes capacitative, the voltage across the input to the filter (across $C_1$) is seen to approach 90° lag. Thus, 360° total lag is approached and, of course, the attenuation becomes very great. This condition is very undesirable in feedback circuits where phase delays of 180° in the whole feedback loop must be avoided if stability is to be obtained. If a condenser $C_2$ is shunted across the reactor L, as shown, then at very high frequencies the diagram becomes equivalent to that of Fig. 1b.

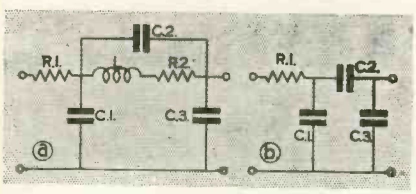


**Fig. 1.**

This is simply a capacity divider driven through a resistance and the maximum phase delay is 90° lag. Since capacitor $C_2$ shunts the inductance L and resistance $R_2$ in Fig. 1, a parallel tuned circuit is formed in series between the input and output at some frequency. If $C_2$ and $R_2$ are made large compared to L, the maximum impedance reached by their tuned circuit may be made negligible. If necessary, an additional resistance may be inserted in series with $C_2$ to limit the tuned impedance, but this will permit the circuit to go to 180° lag at infinite frequency instead of 90°. However, in practice, the resistance used may be made so small as to have negligible effect at any desired frequency.

A step-up transformer with one side common to the primary and secondary windings reduces at high frequencies to the equivalent of an auto-transformer with two parallel-connected primary windings. For ratios near unity, the leakage inductance of an auto-transformer is much less than that of the equivalent transformer. For instance, for 2:1 ratio the leakage of the auto-transformer is one-fourth that of the transformer. Such a step-up transformer is interposed between the last two stages of the audio-frequency channel illustrated by Fig. 2.

The channel of Fig. 2 includes a step-up transformer to the input circuit of the last amplifier stage.

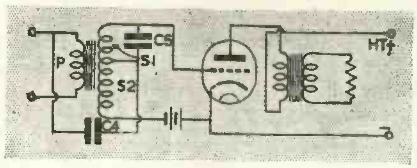


**Fig. 2.**

Substantially equipotential points of the primary and secondary windings are interconnected through a condenser $C_4$, and a condenser $C_5$ is connected across the section $S_1$ of the secondary winding or between the equal voltage point and the high-voltage terminal of the winding.

As previously indicated, such a transformer operated at high frequencies is the equivalent of an auto-transformer which exhibits a leakage reactance much lower than that of the usual two-winding transformer. If the winding section $S_1$ is sandwiched between the windings P and $S_2$, a great additional reduction in leakage inductance is realized. If the section $S_1$ is shunted by the condenser $C_5$ as shown, this winding section is substantially by-passed at high frequencies and the phase lag of the voltage applied to the input circuit of the amplifier stage cannot exceed 90°.

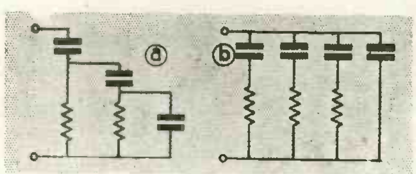


**Fig. 3.**

Resonance effects in this type of network may be controlled by connecting across $S_1$ various combinations of reactance and resistance such as that illustrated by Fig. 3a, in which the condensers and resistances become progressively smaller from left to right, or that shown in Fig. 3b. Such arrangements, of course, tend to reduce to negligible impedance at infinite frequency and to damp-out resonance with the inductances which they shunt.

This development is reported from the laboratories of the Radio Corporation of

# PATENTS RECORD

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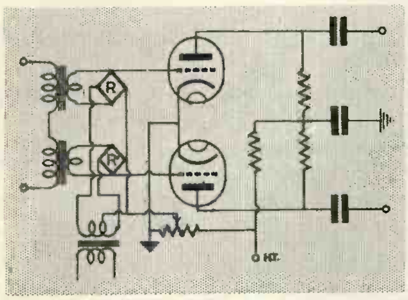
## RADIO AND COMMUNICATIONS

### Reception

A method, by means of an automatic contrast amplifier circuit, of compensating loss by increasing the volume of low notes when high audio-frequency interference is excessive.

—*Marconi Wireless Telegraph Co., N. M. Rust, J. D. Brailsford, A. L. Oliver, and J. F. Ramsay. Patent No.* 536,004.

A push-pull thermionic amplifier or oscillator provided with a feed-back circuit connecting its output terminals to its input terminal for feeding back in the push-pull mode, energy in negative phase in the case of an amplifier and a regenerative phase in the case of an oscillator. Also means for feeding back, energy in negative phase in the parallel mode for preventing spurious parallel mode oscillation.



—*Standard Telephones and Cables, Ltd., F. R. Hill and G. G. Samson. Patent No.* 537,300.

### Crystal Controlled Oscillators for u.h.f.

A circuit for generating an ultra-high-frequency in which a positive reactance at these frequencies is obtained in the feed back circuit including a crystal. This enables a crystal to control directly the generation of u.h.f., for example, of the order of 120-150 Mc/s which are harmonics higher than the fifth harmonic of the fundamental crystal frequency.

—*Standard Telephones and Cables, Ltd. (Assignees of W. P. Mason). Patent No.* 537,546.

### Transmission

This invention is to provide an electromagnetic relay particularly suitable for the opening and closing of circuits which operate at high potentials and which are desired to effect a rapid "make" and "break" of their contacts. The relay is specially suited for radio transmitter keying where other functions such as aerial change-over must be rapidly performed in an accurate preset order. The relay is not limited to this use only.

—*Marconi's Wireless Telegraph Co., Ltd., and A. J. Campbell. Patent No* 537,450.

## TELEVISION

### Video Frequency Signal-Transmitting System

The object of this invention is to provide in a television signal-receiving system, improved means for developing and re-inserting the background-illumination component in the video-frequency signal being translated.

The method adopted is a video frequency signal-translating system which comprises an amplifier having an input circuit which is adapted to have impressed thereon an unstabilised video-frequency signal having its background illumination represented by the peak value on the black side of its zero axis. An outlet circuit is provided for the amplifier and means are coupled to the output circuit for developing a unidirectional-bias voltage proportional to the peak value of the signal on the black side of its zero axis. The unidirectional voltage is then applied to the input circuit to reinsert the background illumination component in the signal translated. Preferably, adjustable means such as a voltage-divider resistor are included in the output circuit for selecting a portion of the signal-output voltage of the amplifier and the unidirectional voltage developing means comprised a diode rectifier coupled to the voltage divider resistor. An initial fixed-bias voltage may be applied to the input circuit of the amplifier and the unidirectional voltage developed by the rectifier may be applied in opposition to the fixed bias voltage.

—*Hazeltine Corporation (Assignees of J. C. Wilson). Patent No.* 537,599.

### Linear Thermionic Amplifying Systems

This invention relates to amplifying systems for amplifying modulated waves and more particularly to such systems which operate at comparatively high power and/or high efficiency and which are intended to give a socalled "linear" amplification of the modulated wave. A portion of the input energy applied to the amplifier and a portion of the output energy obtained are detected in separate rectifiers to obtain two different waves of envelope frequency which respectively represent the forms of the envelopes of the input and output waves. These two waves are then mutually opposed to yield a corrective control wave corresponding to the difference between them, which difference represents the envelope distortion which has been introduced by amplification at high efficiency. This control wave so derived is then applied directly to the amplifier in order to modulate it in such a manner as to reduce the distortion of the envelope produced. The present invention seeks to improve this arrangement by connecting a transformer between the rectifiers and the amplifier so that the control wave passes through it before modulating the amplifier.

—*Standard Telephones and Cables, Ltd. (Assignees of F. E. Terman). Patent No.* 537,558.

### Scanning Generators

Relates to the generation of saw-tooth wave-form electric oscillations such as are employed in the time base circuits of a cathode ray tube.

In the invention the charging circuit of the condenser includes a resistance and the anode-cathode circuit of thermionic valve having a control grid, the potential of which is controlled automatically by the potential drop across the resistor so that as the drop decreases with decreased charging current the control grid to cathode bias decreases tending to increase the charging current. The discharge of the condenser may be effected in any suitable known manner.

—*The British Thomson-Houston Co., Ltd. D. J. Mynall. Patent No.* 537,310.

### Cathode Ray Tube Improvement

The invention describes a circuit comprising a cathode ray tube with a control electrode to determine the intensity of the ray. Means for utilising the periodic deflecting voltage both for blocking during the return periods and for applying a substantially steady negative bias to the control electrode on any failure of the deflecting voltage.

—*Marconi's Wireless Telegraph (Assignees of W. J. Poch). Patent No.* 537,695.

## THERMIONIC DEVICES

### Control

An over-voltage protective device consisting of a bulb containing a gas at low pressure. The bulb contains two main electrodes, and an auxiliary electrode much nearer to one electrode than to the other. This is connected to the nearer main electrode by a high resistance. The nature and arrangement of the electrodes is such that the starting voltage when one main electrode is cathode is greater than 600 volts. The starting voltage when this electrode is anode is considerably greater.

—*General Electric Co., Ltd., and B. N. Clack. Patent No.* 535,842.

## INDEX TO ADVERTISERS

# A signal achievement

## THE EDDYSTONE "358"

## Communication Receiver

The Eddystone "358" Communication Receiver and its counterpart—the Model "400"—are landmarks in the development of Short-Wave Receiver design. The most advanced electrical technique and mechanical construction have been employed and no detail that will ensure reliability or enhance performance has been omitted. They are precision instruments of the highest calibre, ruggedly built, British to the core and capable of satisfying the most exacting requirements of present day operation.

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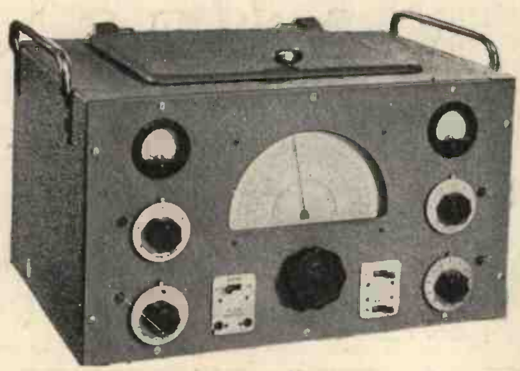

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Separate models of both the "358" and the "400" incorporate

**BAND-PASS CRYSTAL FILTER UNITS.**

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