Electronic Engineering

INCORPORATING ELECTRONICS, TELEVISION AND SHORT WAVE WORLD

PRINCIPAL CONTENTS

Plastics in the Radio Industry. Part I
Frequency Modulation. Part I
Rhodium Contacts
A Photo Cell Controlled Lift
Electronic Aids to Industry. Part III (Measurement)
Review of Progress in Electronics. Part VIII

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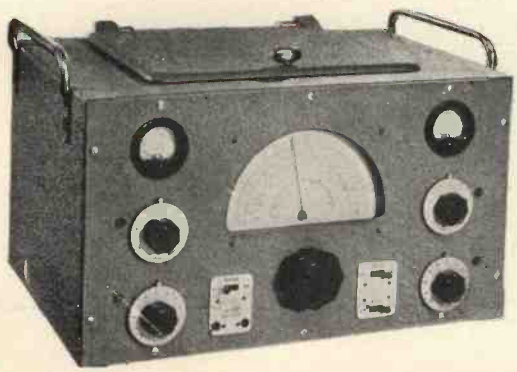

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Salvage

THE recent appeal for salvage of waste paper brings up again the question of what to do with the amount of technical literature which the average engineer accumulates during the course of years to form his own personal reference library.

Some are fortunate in having a works library which they can use as their own, and keep a minimum of private data, but the majority have a collection started in student days and gradually increased until it fills several shelves, not to mention the periodicals and manufacturers' catalogues which are allowed to pile up in cupboards.

A careful owner will usually bind periodicals to which regular reference is made, but the bulk is allowed to accumulate dust waiting for a turnout that seldom comes.

How much of this data is worth retaining? It is unfortunate, but inevitable that in the usual technical publication each ounce of meat in the shape of articles of direct interest to the reader is accompanied by several ounces of bone in the form of general interest. An analysis made by DR. HOLMSTROM of yearly articles on a specific subject (not electronic) showed that a hundred were found in some twenty specialised journals, a further hundred distributed among 120 journals dealing with related subjects, and a third hundred scattered among no less than 720 journals which only occasionally dealt with the subject in question.

The useful matter in this case averages about 1 in 3. While few engineers subscribe to more than three or four technical publications, the proportion in any specific journal will probably be the same.

In catalogues and technical booklets the waste material must be even higher, since they tend to "date" more than textbooks or periodicals. It is interesting to look through a catalogue of 1930 and note that power valves were slightly higher in price than they are now, but the reader might query whether the description of the valves is not given in a textbook on the shelves.

The demand for paper scrap is an excellent reason for a wholesale sorting out of literature and an inquiry into how much dead wood is being carried in duplicate information stored away in files. This note is not to advocate a wholesale scrapping of years of accumulated notes, but rather to suggest an opportune compressing and sorting of useful data—a task which will profitably employ the black-out hours and benefit the community at the same time.

The question of how to classify personal data is one which can be left to a later time. Apart from the standard methods of reference which are found in libraries and filing systems, which are generally more suited to a wide range of subjects, many engineers have their own ideas on the most useful way to file and cross-reference data on their own particular work, and we would be pleased to hear of any methods which experience has shown to be useful.

Proc. I.R.E. Abstract.

In the March, 1941, issue of *Electronics and Television*, as this journal was formerly called, an abstract appeared under the heading "Valves for Extremely High Frequencies" which was taken from the paper by B. J. Thompson and G. M. Rose (R.C.A. Mfg. Co) of the same title.

The Secretary of the Institute of Radio Engineers, in whose proceedings the article first appeared, has pointed out that the omission of the date (1933) in the abstract gives the erroneous impression that the work described is of recent years.

We regret the annoyance caused to the authors by the incomplete reference and have pleasure in printing this correction in view of the rapid developments which have taken place in valves for U.H.F. work, for which the staff of the R.C.A. laboratories are largely responsible.

Plastics in the Radio Industry

I. Nature and Types of Plastics

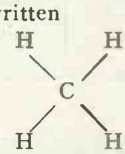
by

E. G. COUZENS, A.R.C.S., B.Sc., and W. G. WEARMOUTH, Ph.D.
(Messrs. B. X. Plastics Ltd.) (Messrs. Halex Ltd.)

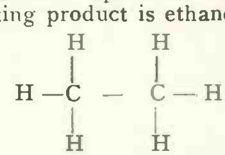
"PLASTICS have come to stay" is a statement which is peculiarly applicable to the Radio, Telecommunication and Electrical Engineering industries. This happy state of affairs is partly due to the extremely valuable co-operation shown by these branches of engineering even during those difficult stages of the early development of plastics. Indeed, some of the radio firms studied these problems with such industry that they now own their own factories in which they manufacture from plastics radio components of all kinds. The great usefulness of plastics to the radio world is also partly due to the fact that a large percentage of the better-known plastics have good insulation properties, while at the same time the materials are available in a wide variety of forms, extending from lacquers on the one hand through rubber-like materials to the hard and rigid bakelite type resins on the other.

All the materials discussed contain carbon which has the useful property of being able to link up chemically with other elements such as hydrogen, and the so-called hydroxyl group, denoted by (OH). It can also line up with other carbon atoms.

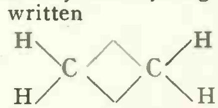
Carbon is often denoted by —C—, the four strokes denoting four combining bonds, and hydrogen by H—, the single stroke representing one combining bond. It is seen that four hydrogen atoms are therefore required to satisfy completely the combining capacity of one carbon atom. The resulting molecule is written



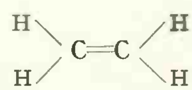
which is the symbol for methane. Similarly two carbon atoms require six hydrogens for complete saturation, and the resulting product is ethane, written



It is possible to get two carbons linking up with only four hydrogens to give ethylene, written



and one bond on each of the carbons is left unsatisfied. It is more usually written



and the double bond, i.e., free or unsatisfied combining bonds with carbon represents a weakness. It is not surprising, therefore, that such a material shows a readiness to link up with other materials which can satisfy the unmated bonds on the carbon atoms. Ethylene is, therefore, a very reactive compound, and it actually forms the starting material for certain synthetic resins, in particular "Alkathene" which consists of many ethylene molecules linked up with one another.

This process of linking is called polymerisation and many carbon compounds having this double bond in their structure can be made to polymerise forming resinous materials.

Thus, the molecules of styrene $C_6H_5-CH=CH_2$ (note the double bond) will link up with each other to produce polystyrene—a word which means literally "many styrenes." This building up proceeds through many stages and by suit-

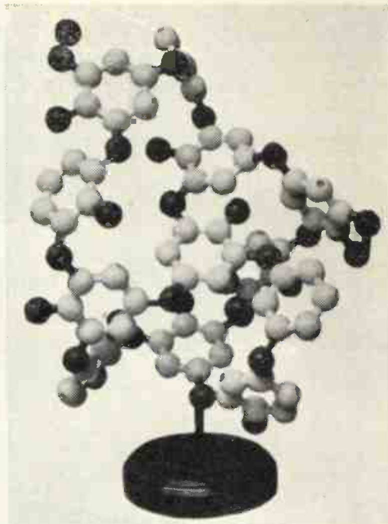


Fig. 1. Phenol Formaldehyde. Model illustrating the cross linked structure of the P.F. resin molecule. The chain to the left is seen to be cross linked at each end with the central chain which is itself linked to a complex on the right. The original phenol unit in the form of a hexagon is linked in each case to its neighbour by a (dark) carbon atom derived from formaldehyde. ***(By courtesy of Dr. N. A. de Bruyne.)***

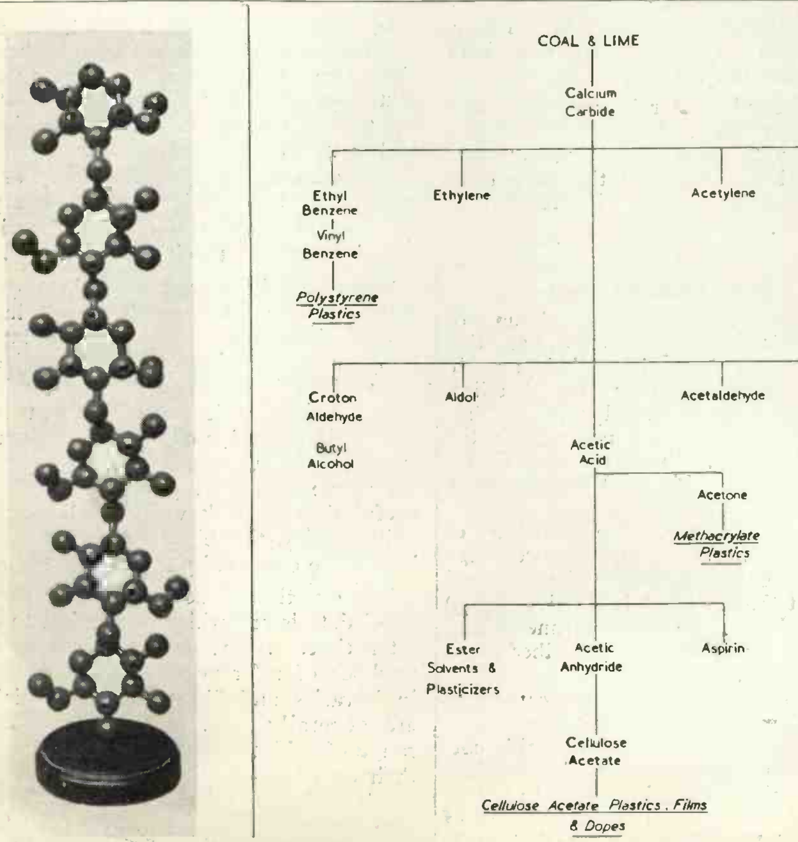


Fig. 2. The Cellulose Chain (left). A model showing composite carbon and oxygen hexagonal rings joined together by oxygens. Certain hexagonal atoms attached to the carbon atoms have been left out for simplicity. ***(By courtesy of Dr. N. A. de Bruyne.)*** **Right: "The Acetylene Tree."**

able control of the polymerising conditions polystyrene can be produced with a wide range of molecular sizes.

The outstanding characteristic of all these materials is the existence of very long chains formed by joining the simple units or monomers end to end. The illustration (Fig. 3) shows a model of a short section of such a polystyrene chain the full length of which may consist of 800 to 1,200 units and may be as much as five or six thousand. Well known materials which link up in the same way are vinyl chloride $CH_2 = CHCl$ (again note the double bond) giving polyvinyl chloride and methyl methacrylate from which Perspex* and Diakon* are made.

The physical property of thermoplasticity which is the outcome of long chain structure is characteristic of all these materials and by permitting plastic flow gives to these synthetic resins their special manipulative value.

The cellulose derivatives are produced in a slightly different manner. The previously mentioned materials can all be formed from chemicals produced synthetically. The cellulose compounds, as their names imply, are produced from cellulose. This is a natural product, although sufficient is known of its chemical structure to say that it is a polymerisation product—the polymerisation being carried out during the growth of the plant from which the cellulose is derived. The illustration (Fig. 2) shows a simplified model of a portion of a cellulose chain in which the resemblance to the resin structure can be traced though the linkage of unit to unit is through the agency of oxygen atoms. By chemical treatment of the cellulose, compounds such as cellulose nitrate, cellulose acetate and ethyl cellulose can be produced which when suitably processed are very tough, flexible and strong.

Cellulose nitrate plastic known as celluloid or Xylonite was originated by Parkes, by plasticising nitro-cellulose and camphor, in the middle of the 19th century and was the forerunner of the plastic industry as we know it to-day and though it is not so useful to the radio engineer as many other plastics, its study and manufacture laid the foundation of the plastic industry. Cellulose acetate suitably plasticised with high boiling point solvents produces the familiar "non-flam" celluloid of which Bexoid and Celastoid are examples and which with celluoid, also a long chain compound, shows characteristic thermoplasticity particularly utilised in the case of cellulose acetate for injection moulding.

A different type of resin of the utmost importance to the electrical industry is the compound of phenol and formaldehyde discovered by Baekeland and known as Bakelite. If two of the hydrogens in methane CH_4 are replaced by oxygen we get formaldehyde HCHO

*These are registered trade names.

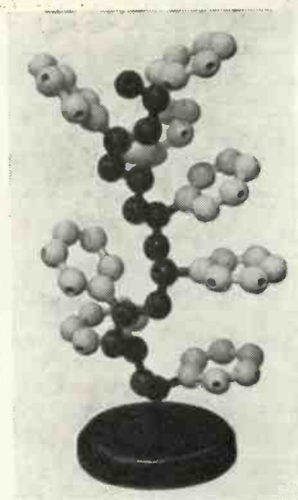


Fig. 3. Polystyrene. Model showing arrangement of the carbon atoms in a short section of the polystyrene chain. Note the hexagonal benzene rings attached to the (dark) main carbon chain.

(By courtesy of Dr. N. A. de Bruyne)

and this material reacts with phenol, written C_6H_5OH, to give resinous compounds—which are at first soluble and fusible, but which on heating become insoluble and infusible and are not thermo-plastic but thermo-setting. Fig. 1 shows a model illustrating the complicated structure of phenol formaldehyde in the final stage, where what is known as "cross-linking" with primary bonds produces the characteristic hardness and infusibility of Bakelite.

As will be seen from the attached list of plastics some of these Bakelite type resins which include compounds of cresol as well as phenol are available as coating solutions, others as powders for moulding. There are also laminated sheets and tubes which are prepared by coating sheets of paper or fabric with the resin and then pressing the treated sheets together between heated steel plates. The sheets made up from a paper base are more useful to the radio engineer because of their better insulating properties. These laminated materials can also be prepared with remarkable mechanical strength.

Urea also gives resins by combination with formaldehyde—known commercially as the "Beetle" type resins. These resins are also available as lacquers, moulding powders, laminated sheets and tubes and are thermo-setting.

As already indicated celluloid was first manufactured in the middle of the 19th century and was in fact the earliest plastic. The next great landmark was the invention of Bakelite about 1910—since then intensive research has been proceeding particularly in the direction of the production of completely synthetic materials derived from the simplest and commonest substances, as will be seen from the diagram (Fig. 2) known as the "acetylene tree."

It is during the past decade that such vitally important materials as polystyrene, polyvinyl chloride and methyl methacrylate have been commercially developed, the first two to the great advantage of the radio and electrical engineer. Since it is becoming increasingly possible to predict with certainty what type of resins will be produced in any given chemical reaction the plastics chemist is thus in the position of being able to produce resins to suit particular requirements and the active co-operation which has been so noticeable between the radio and plastics industries in the past should operate with increasing advantage to both parties in the future, as new resins with still more accurately controlled physical properties are produced.

Material.	Form.	Trade Name.	How Manipulated.	Strength.
Phenol Formaldehyde Resins.	1. Lacquers. 2. Powders.	Bakelite. Mouldrite. Nestorite. Rockite. Elo. Epok.	1. Used as Lacquers and insulating varnish. 2. Powders are moulded under heat and pressure in steel dies.	1. Coating is stable. 2. Very rigid and quite strong.
Phenol Formaldehyde Resin coated sheets.	Laminated sheet and tube.	Tufnol. Delaron. Paxolin.	Machined. Drilled. Turned.	Very strong.
Urea Formaldehyde Resins.	1. Lacquers. 2. Powders.	Beetle. Mouldrite. Rockite.	1. Used or coatings. 2. Powders moulded in steel dies.	1. Coating is stable 2. Very rigid and strong.
Urea Formaldehyde Impregnated Sheets.		As Phenol Formaldehyde Sheets.		
Polystyrene.	1. Powders. 2. Sheet, Rod and Tube.	Distrene	1. Moulded. 2. Machined, turned, can be shaped.	Quite strong in thick sections
Cellulose Acetate.	1. Powder. 2. Sheet, Rod and Tube. 3. Thin film.	Bexoid. Celastoid. Rhodoid.	1. Moulded. 2. Machined, turned and shaped.	Quite tough, and can be obtained in pliable form.
Cellulose Nitrate.	1. Sheet, Rod and Tube.	Xylonite. Celluloid (American).	Machined and turned or moulded.	Very tough.
Methyl Methacrylate Resin.	1. Powder. 2. Sheet, Rod and Tube.	Diakon. Perspex.	Moulded in dies. Machined and turned.	Quite strong.
Polyvinyl Chloride.	1. Powder. 2. Sheet, Rod and Tube.	Welvic B.X. Plastics "P.V.C." Chlorovene.	Machined and turned.	Very tough. Can be made in a flexible grade.

TABLE OF BRITISH PLASTICS

Colour	Copolymers	Ethyl Cellulose	Polyvinyl Chloride	Polyethylene	Poly Isobutylene	Polystyrene	Methyl Methacrylate	Cellulose Nitrate	Cellulose Acetate	Aniline Formaldehyde	Urea Formaldehyde Sheets	Urea Formaldehyde	Phenol Formaldehyde Sheets	Phenol Formaldehyde	Trade Name	Lacquers	Compression Moulding Powders	Injection Moulding Powders	Rod & Tube	Laminated Sheets	Solid Sheets	Film	Moulding	Machining	Coating	Maker
Light Brown O.														●	Bakelite	●	●						●	●	●	Bakelite Ltd.
White Tl.												●			Beetle	●	●						●	●	●	British Indstl. Plas.
Off White Tp.									●						Bexoid		●	●	●		●	●	●	●		B.X. Plastics
White Tl.														●	Catalin				●		●			●		Catalin Ltd.
Off White Tp.									●						Celastoid			●	●		●	●	●	●		Brit. Celanese
Off White Tp.								●							Celluloid	●			●		●	●	●	●	●	Celluloid Corpn.
Yellowish O.			●												Chlorovene			●	●		●		●	●		F. A. Hughes & Co.
Brownish O.											●		●		Delaron				●	●				●		De la Rue
White Tl.							●								Diakon		●	●	●		●		●	●		I.C.I. Plastics
White Tp.						●									Distrene			●	●		●		●	●		Brit. Resin Prodcts
Yellowish O.														●	Elo	●	●						●	●	●	Birkby's Ltd.
Yellowish O.														●	Epok	●	●						●	●	●	Brit Resin Prodcts
Yellowish O. White Tl.												●		●	Mouldrite	●	●						●	●	●	I.C.I. Plastics
Yellowish O White Tl.														●	Nestorite	●	●						●	●	●	J. Ferguson
Light Brown O.													●		Paxolin				●	●				●		Micanite & Inslatrs.
Dark Brown O.										●					Panilax		●		●	●			●	●		Micanite & Inslatrs.
White Tp.							●								Perspex				●		●		●	●		I.C.I. Plastics
White Tl. Pale Yellow O.												●		●	Rockite	●	●		●				●	●	●	F. A. Hughes & Co.
Yellowish O.											●		●		Tufnol				●	●				●		Ellison Inslators.
White Tl.			●												Welvyc			●	●		●		●	●		I.C.I. Plastics
White O. Tp.								●							Xylonite	●			●		●	●	●	●	●	B. X. Plastics
Wax White O. Tl.				●											Alkathene		●		●		●		●	●		I.C.I. Plastics
Wax White O. Tl.		●													Ethyl Cellulose		●		●		●		●	●		B.X. Plastics
Off White Tl.	●		●												P.V.C.	●	●	●	●		●		●	●	●	B.X. Plastics
Off White Tl.					●										Polybutene		●				●		●	●		I.C.I. Plastics

NOTES ON THE TABLE.

To find the basic composition of any proprietary plastic material, refer to the left-hand columns and read the title at the head of the column marked with the black dot.

The forms in which the material is available are given in the right-hand columns, the last three on this side indicating the methods of manipulation.

Colour. The colours shown on the left are a guide to the basic colours of the material and must not be interpreted too closely. " White " means water-white ; O, opaque ; Tl., translucent and Tp., transparent.

Celluloid, although an American proprietary name, has been included in this table for completeness.

ADDENDA.

MYCALEX. This material, manufactured by the Mycalex Parent Corporation, has a foundation of bonded mica and can be moulded but not machined. It is also available for moulded components. Basic colour : yellowish-brown.

MICANITE. A similar material to Mycalex, manufactured by the Micanite and Insulator Co., Ltd.

ERRATA.

For " Welvyc " in the above table, read : " Welvic." In the case of Diakon and Catalin read Tp. for Tl. under " Colour."

While every care has been taken in the preparation of the above table no responsibility can be taken for the accuracy of the statements therein.

Frequency Modulation

Part I. — General Nature of the System

By K. R. Sturley, Ph.D., A.M.I.E.E.

THE direct transmission and reception of speech or music over long distances, though not impossible, is impracticable and propagation of audio frequencies is usually accomplished by using them to modulate an R.F. wave acting as a carrier, *i.e.,* the audio frequencies are used to control one of the three characteristics, amplitude, frequency or phase, of the carrier. The most common method is by modulation of the carrier amplitude, the rate at which the amplitude is changed being directly proportional to the frequency of the original sound and the magnitude of the amplitude change being directly proportional to the intensity (a low intensity producing a small change of amplitude). This is illustrated in Figs. 1a and b, the unmodulated carrier amplitude in each case is constant at 1 volt. Fig. 1a corresponds to a low intensity sound, the carrier amplitude varying between 0.9 and 1.1 volts, whilst Fig. 1b corres-

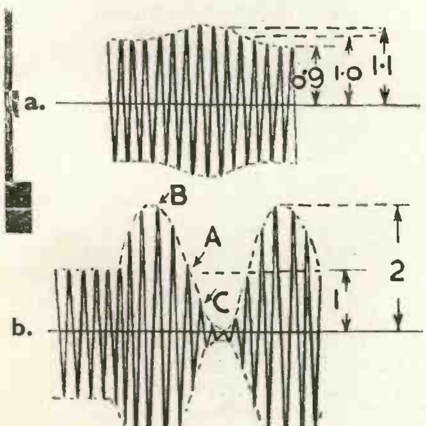


Fig. 1. Amplitude modulated wave.

ponds to a high intensity sound, the carrier being 100 per cent. modulated, its amplitude varying from 0 to 2 volts. In frequency modulation, the carrier amplitude remains constant and its frequency is varied at a rate corresponding to the modulation frequency (1,000 times per second if f mod = 1,000 c.p.s.) and the frequency deviation (rise and fall from the central unmodulated carrier frequency) is controlled by the intensity of the audio frequency. For example, suppose a 1,000 c.p.s. note is being transmitted on a carrier frequency of unmodulated value, 1,000 kc/s, the variation of the carrier frequency takes place at the rate of 1,000 changes per second and the frequency limits may be

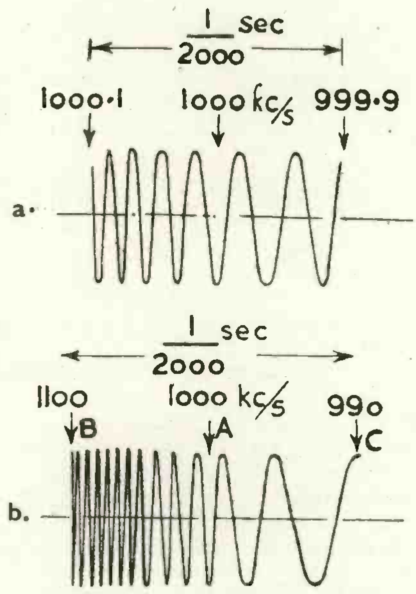


Fig. 2. A half modulation cycle of a frequency modulated wave.

± 100 c.p.s. (the carrier frequency changes between 1,000.1 and 999.9 kc/s) for a low intensity to ± 100,000 c.p.s. for a high intensity note. These two conditions are illustrated in Figs. 2a and b for a half cycle of the modulation frequency. With phase modulation the amplitude of the carrier remains constant and its phase angle with respect to its unmodulated condition is advanced and retarded at the frequency of the audio signal. The magnitude of the phase change is determined by the intensity of the audio frequency. Phase modulation has an effect on the carrier akin to frequency modulation, and whilst the phase of the carrier is varying its frequency is also varying. There is a difference between the two, but this is discussed later.

Until recently neither frequency nor phase modulation has been used to any great extent, largely because more complicated apparatus is required for reception and transmission than for amplitude modulation and they appeared to offer few advantages. Armstrong[5]* has, however, demonstrated that frequency modulation can, under certain conditions, give better fidelity, greatly improved signal-to-noise ratio† and larger broadcast service area than amplitude modulation and it seems probable that frequency modulation may be considerably developed in the future.

* Numbers in text refer to Bibliography, p. 489.

† Credit must be given to H. J. Round, who first envisaged the possibilities of an improved signal-to-noise ratio from a frequency modulated system in a letter to the " Radio Review "(Volume 2, p. 220) in 1921.

The Principles involved in Frequency and Phase Modulated Transmission.[3, 7]

For understanding the operation of any type of modulation a vector diagram is most useful, and amplitude modulation is quite simply illustrated if the modulation envelope is sinusoidal. The amplitude modulated signal is represented mathematically by

$$\hat{E} \sin 2\pi f_0 t \;\; [1 + M \sin (2\pi f_m t)] \quad (1)$$

where $\hat{E}$ is the unmodulated carrier peak value.

f_0 = carrier frequency.

f_m = modulating frequency.

M = the modulation ratio, the maximum value of which is 1. The vector (expression 1) rotates at a speed of fc c.p.s. and varies in amplitude fm times per second. An observer rotating with the carrier vector would see it as stationary with amplitude varying between the limits $\hat{E}$ (1 + M) and $\hat{E}$ (1 − M) as shown in Fig. 3a. Expression (1) can be expanded to

$$E \sin 2\pi f_0 t + \frac{\hat{E}M}{2} \cos 2\pi (f_c - f_m)\, t - \frac{\hat{E}M}{2} \cos 2\pi (f_c + f_m)\, t \quad \ldots \; (2)$$

which consists of a carrier vector $\hat{E}$ rotating at fc c.p.s. and two equal sideband vectors $\frac{\hat{E}M}{2}$ rotating at $(f_c + f_m)$ and $(f_c - f_m)$ c.p.s. about the same point as the carrier vector. Since these two sideband vectors only influence the carrier amplitude it is clear that their resultant must always be in line with the carrier and this is shown in Fig. 3b for successive instants of time corresponding to points A, B and C on Fig. 1b. The upper frequency sideband vector S_u is rotating round the carrier vector in an anti-clockwise direction (the accepted positive direction of frequency) at fm c.p.s., whilst the lower frequency sideband vector S_L rotates in a clockwise direction round the carrier

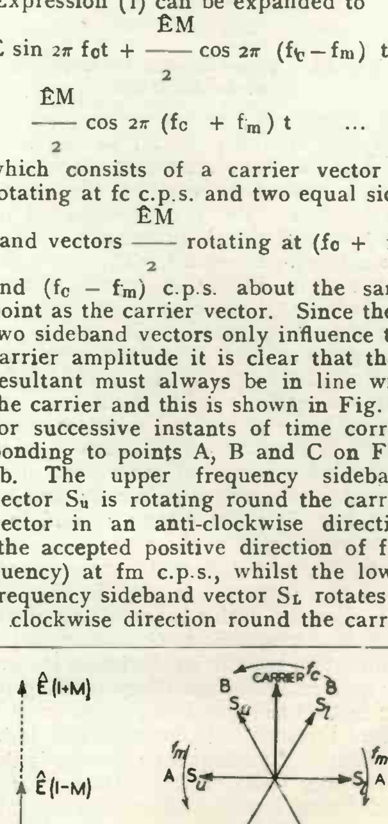


Fig. 3. Vector diagram for amplitude modulated wave.

vector at the same frequency. The carrier vector in Fig. 3b is, for convenience, shown as stationary though actually it moves round in an anticlockwise direction at fc c.p.s.

The problem of representing frequency modulation by a single vector is complicated by the fact that the frequency of the carrier is varying in accordance with the amplitude of the modulating frequency and this means that the carrier vector rotates at varying speeds. Taking the example given above, for a frequency deviation of ± 100,000 c.p.s. the carrier varies from 1,100 kc. to 900 kc., and if we, acting as observers of the carrier vector, were to rotate at a frequency fc c.p.s. (the carrier unmodulated value) in the same direction as the carrier vector, the latter would appear to oscillate backwards and forwards like a metronome, at the frequency of the modulating wave, *i.e.*, 1,000 times per second. This condition is illustrated in Fig. 4a; again, like the metronome, the vector is stationary at the extremes, positions X′ and X″, of its stroke so that the carrier frequency is instantaneously at its unmodulated value f_c (this is point A in Fig. 2b), whilst it is moving at its fastest, backwards or forwards at the centre X of its swing. Movement of the vector in an anti-clockwise direction means that the frequency is greater than f_c and in a clockwise direction the reverse. Hence point X when the vector moves anti-clockwise corresponds to B in Fig. 2b, but when the vector is travelling clockwise X corresponds to C. In frequency modulation the carrier deviation is fixed for a given amplitude of modulating input so that the speed of the vector as it passes through X is constant and independent of the frequency of oscillation backwards and forwards (that of the modulating input). Treating the problem as a mechanical one, the initial velocity at X′ or X″ is zero, and the final velocity v at X is constant so that the distance travelled from X′ to X or X″ is proportional to vx t, but time t is

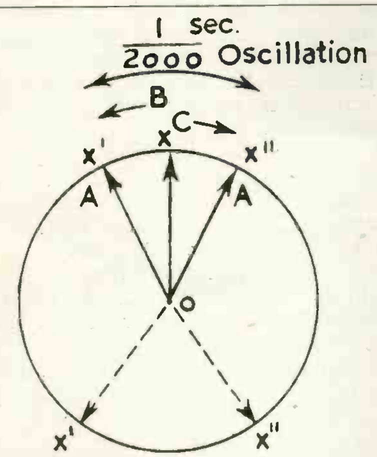


Fig. 4a. Vector diagram for frequency modulated wave.

proportional inversely to the modulating frequency so that

$$X'X = X''X = K\,vt = K_1 t = \frac{K_2}{f_m} \propto \frac{1}{f_m}$$

Hence the angle swept out by the carrier vector is large for low modulating frequencies and small for high modulating frequencies; dotted positions X′ and X″ correspond to a lower modulating frequency than the full line positions. This again is analogous to the metronome which increases its angle of sweep as the frequency decreases. The mathematical expression for a frequency modulated wave is

$$E \sin\left[2\pi f_c t - \frac{M f_c}{f_m} \cos 2\pi f_m t\right] \ldots \quad (3)$$

$$\text{where } M = \frac{\text{f deviation}}{f_c}$$

and the angle swept out by the vector is $\frac{M f_c}{f_m}$ radians or $57.3\,M f_c/f_m$ degrees, which is seen to be inversely proportional to f_m. In the same way that expression 1 for amplitude modulation can be turned into a carrier and sidebands so can expression 3 be treated, but instead of only two sidebands per fundamental modulating frequency it is found that there are a large number[1, 2] spaced from the carrier by frequencies of $\pm f_m$, $\pm 2 f_m$, $\pm 3 f_m$, etc.

The theoretically infinite number of sidebands is for all practical purposes fortunately limited as the amplitudes of the sidebands more distant from the carrier normally decrease very rapidly. It is not only in the number of sidebands that frequency modulation differs from amplitude, but also in their position with respect to the carrier. All odd numbered sideband vectors $\pm$ fm, $\pm 3 f_m$, etc., from the carrier are so placed that their resultant falls on a line at right angles to the carrier[3, 4] vector, and all even numbered sidebands have a resultant in line with the carrier vector. The addition of a carrier and two sideband vectors (spaced $\pm f_m$ from the carrier) having a resultant 90° displaced from the carrier vector is shown in Fig. 4b. These two sideband vectors rotate round the carrier vector point O at f_m c.p.s. and their resultant adds to the carrier to cause the latter to oscillate backwards and forwards along the line AB. In fact it is the same as Fig. 4a apart from the amplitude variation of the vector, and by adding suitable amplitudes of wider spaced sidebands we can neutralise the amplitude variation causing the point of the vector to describe an arc X′ X″ giving only frequency modulation. Another important point to note with regard to frequency modulation sidebands is that the individual amplitudes are not directly proportional to the amplitude of the original modulating frequency as in amplitude modulation, but actually vary widely (sometimes becoming zero) as the angle swept out by the carrier vector changes. When this angle is small (fm high) all sidebands except those nearest to the carrier are so small in amplitude that they can be neglected, but for a large angle of oscillation (f_m low) there are many sidebands of appreciable amplitude. For example, if $f_m = 50$ c.p.s. and its amplitude such as to give a frequency change of carrier of ± 1,000 c.p.s., the angle swept out by the vector moving from X′ to X is $\frac{1{,}000}{50} = 20$ radians or 1,146°, whereas for fm = 5,000 c.p.s. and the same frequency change the angle swept out by the vector is $\frac{1{,}000}{5{,}000} = 0.2$ radians or

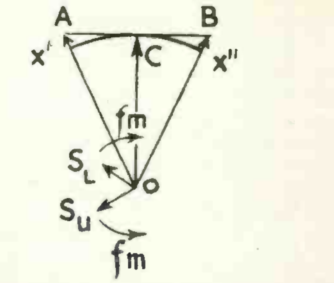


Fig. 4b. Frequency modulation due to 900 kc/sec. shift in sideband vector resultant with respect to the carrier.

11.46°. It should be noted that the carrier vector may make a number of revolutions for low modulating frequencies.

The vector representation of phase modulation is similar to that of frequency modulation with one important difference; the angle swept out by the vector is constant for a given amplitude of all modulating frequencies and is dependent only on the amplitude of the latter. This essentially means that the velocity of the vector at the centre X (Fig. 4a) increases as the speed of oscillation increases, *i.e.*, the rise and fall in carrier frequency (frequency deviation) is directly proportional to the modulating frequency. It is possible to turn phase into frequency modulation by inserting in the modulation frequency amplifier a network having an amplification characteristic inversely proportional to frequency, giving a low frequency a large amplitude and a high frequency a small amplitude, *i.e.*, the phase angle is no longer constant, but increases as the modulation frequency falls. The mathematical expression for phase modulation is

$$E \sin\left[2\pi f_c t + \phi M \sin 2\pi f_m t\right] \ldots \quad (4)$$

and the phase angle swept out is equal to ϕM where ϕ is a constant and M is proportional to the amplitude of f_m, but independent of its frequency. Phase modulation has an infinite number of sidebands spaced $\pm f_m$ $\pm 2 f_m$, etc., from the carrier, but since the phase angle change is constant (unlike fre-

(*Concluded on page* 489)

Review of Progress in Electronics

VIII.—Grid Control of Gaseous Conduction

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

"The development of grid controlled rectifiers for heavy current purposes has been related to the vacuum tube of light duty practice. With the grid-controlled tubes it is possible to solve a large number of problems coming within the sphere of low current engineering and extending also into heavy current practice."—Dr. M. Schenkel, in a lecture on the Principles and Applications of Grid Controlled Rectifiers and Converters, E.T.Z., August 11, 1932.

FOLLOWING the purely theoretical researches on gaseous conduction to which reference was made in the last article of this series, attention was directed to the subject by investigators interested in the possibilities of commercial development. As a result of this work there appeared firstly the mercury vapour rectifier, followed by the gasfilled triode or thyratron, and its larger prototype the grid controlled mercury arc rectifier. These were developments of major importance in the progress of electrical engineering practice, and occupied a period of more than twenty years.

The true sequence of discovery, representing the contributions of individual workers, is difficult to trace owing to the obscuring factor of commercial secrecy, and it is necessary to rely somewhat upon the unsatisfactory evidence provided by patent specifications.

The Course of Development

In 1903, P. H. Thomas[1] patented a means of suppressing or releasing the anode to cathode discharge in a rectifier by means of an auxiliary electrode; the arrangement being strikingly similar to the modern one. The electrode could either be internal, in accordance with modern practice, or in the form of a metal band outside the glass bulb of the discharge apparatus and adjacent to the cathode. Thomas also described a means of obtaining phase displacement with the object of allowing the discharge to pass at definite points of the anode voltage cycle.

A similar electrode arrangement, intended for the suppression of backfiring in mercury arc rectifiers, was described in 1906 in a patent by P. Cooper Hewitt.[2] In this case the auxiliary electrode took the form of a cup or shroud surrounding the anode of the rectifier. The anode could be prevented from acting as a cathode by connecting this auxiliary electrode to a suitable source of potential.

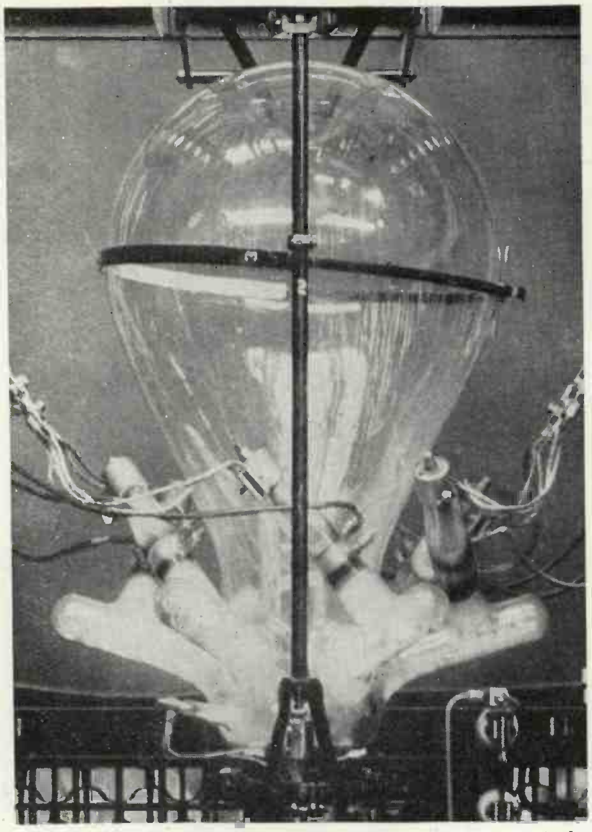


Fig. 2. Glass-bulb mercury arc rectifier with grid control.

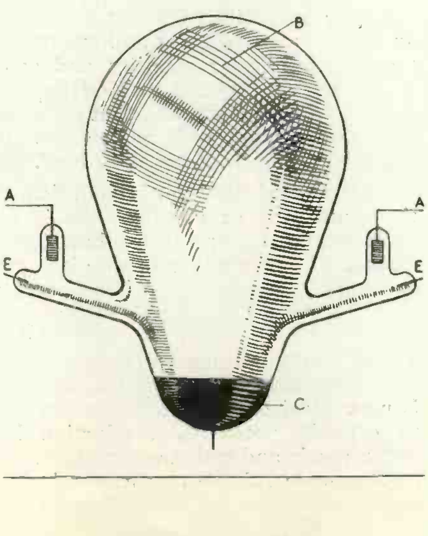
In March 1914, G. W. Pierce[3] applied for a patent covering the applications of a grid-controlled gas discharge device. In this patent there are 26 claims, referring mainly to the detection and amplification of signals in radio work. There is little doubt that Pierce was a pioneer in this particular sphere of development, but his work has been overshadowed to some extent by later developments.

It was shown by I. Langmuir[4] in 1914 that control of a discharge could be obtained by means of a suitably disposed grid in a gasfilled enclosure containing a hot cathode and an anode on the same general lines as an ordinary three-electrode thermionic valve. The gas filling was provided by the inclusion in the evacuated bulb of a small amount of mercury, the vapour of which imparted to the arrangement certain characteristics differing entirely from those of the ordinary valve. The device was called a Thyratron, from the Greek word *thyra* meaning a door, owing to the observed property that when the flow of anode current had been initiated by suitable adjustment the grid potential, no subsequent variation of this potential had any effect on the current flow as long as anode voltage was maintained.

Considerable attention was directed to Langmuir's thyraton, and numerous uses were found for it. F. W. Meyer,[5] for example, applied the principle to high-tension direct current transmission, frequency changing, rectification and amplification of signal currents and conversion from direct to alternating current.

A study of the thyratron was commenced in 1922 by P. Toulon,[6] who improved upon Langmuir's method of control by varying the phase of the grid voltage with respect to that of the anode voltage so as to vary the duration of the conduction period in each positive half-cycle of anode voltage when the device is used as a rectifier. In this way the average value of the anode current could be controlled smoothly between a maximum, with the grid and anode

Fig 1 (below). Typical arrangement of glass bulb mercury arc rectifier.



voltages in phase, and zero with these voltages 180 degrees apart. This form of control is now widely used in practice, and the large number of ways in which phase displacement of the respective voltages may be obtained has imparted to the arrangements a correspondingly large sphere of application.

With regard to the study of gaseous conduction generally, a great deal of work was carried out by Langmuir[7] in a series of researches published in 1923 and 1924. These researches added greatly to knowledge of the exact processes occurring in gaseous conduction, and led to a better understanding of the principles and possibilities of the thyratron.

The Mercury Pool Cathode

The extension of the grid control principle to conventional mercury arc rectifiers, both glass-bulb and ironclad type, having a mercury pool cathode represented a great advance, as it extended to the limits of rectifier capacity the advantages of this form of control.

In the conventional glass bulb rectifier shown schematically in Fig. 1 the cathode C takes the form of a pool of mercury at the bottom of the bulb. The anodes A are of a material such as graphite which is strongly resistant to vaporisation, and are located in tubular extensions to the bulb. Sometimes the anodes are located in the ends of the extensions as at E, in which case the arc drop on load is somewhat less than with the arrangement shown. The number of anodes naturally depends upon the number of phases and the circuit arrangements. The upper part of the bulb takes the form of a large dome, the function of which is to provide cooling surface for condensing the vaporised mercury coming from the cathode under load conditions.

In this type of rectifier the grid may be introduced in a variety of ways. It may be placed so as to cover the internal cross section of the anode extensions or may be arranged in the form of a shroud enclosing the anodes. By using higher grid voltages it is possible to obtain control with an electrode in the form of a metal strip wrapped round the outside of the extension arms. Such an arrangement is clearly seen in Fig. 2, which shows a modern grid-controlled glass bulb rectifier.

An alternative form of rectifier having an ironclad construction is shown in Fig. 3. The ironclad type of rectifier forms an interesting contrast to the glass bulb type, from which it differs in practically every feature except the basic principles of operation. The external water-cooling jacket contains a vacuum chamber in which the main and excitation anodes, control grids and mercury pool cathode are located. The somewhat elaborate auxiliary apparatus required for maintaining the vacuum of the inner container, as well as for vacuum measurement and temperature control, are mounted on the outer steel casing.

There has been some controversy concerning the relative advantages of the alternative types, but the chief point of comparison is that the intensive form of cooling in the ironclad type results in the possibility of dealing with large amounts of power in a small space. In favour of the glass bulb rectifier can be stated that there is a permanent vacuum, maintained without the use of auxiliary pumping plant and apparatus, that cooling water supplies and associated circulating and cooling apparatus are not necessary, and that no losses due to vacuum and cooling pumps occur when the rectifier is off load.

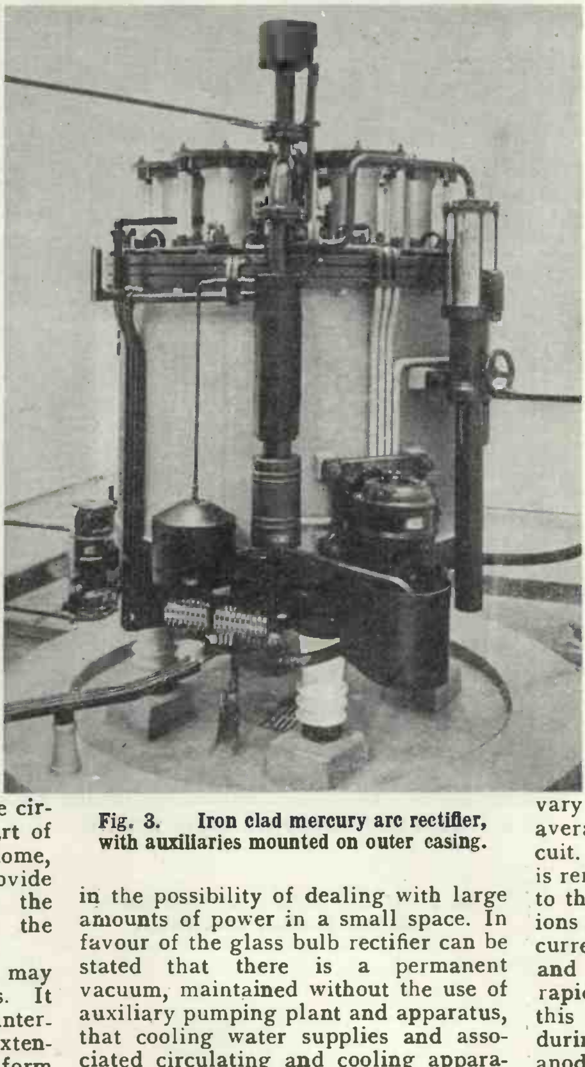


Fig. 3. Iron clad mercury arc rectifier, with auxiliaries mounted on outer casing.

The general theory of operation of the controlling grid is the same in all the types of apparatus we have mentioned. The anode to cathode discharge can pass in normal circumstances only when the anode is positive with respect to the cathode, so that if an alternating anode voltage is used a rectified current flows in the load circuit. If there is no control grid, or if it is connected to cathode potential, conduction between anode and cathode occurs as soon as the anode voltage reaches the breakdown value at the beginning of each positive half-cycle, and continues till the end of the half-cycle. In rectifiers of the thyratron type, containing only one anode, there is half-wave rectification, but by employing two, three or six anodes it is possible to arrange for full-wave, three phase and hexaphase working. The latter is usually employed for industrial power purposes.

The presence of a sufficiently high negative potential on the grid provides an electrostatic barrier to electrons moving from the cathode region under the accelerating influence of the electric field from the anode. For a given instantaneous value of anode voltage a definite negative grid potential, proportional to the anode voltage, suffices to prevent conduction resulting from the access of electrons to the anode region, but if the negative grid potential is reduced, or the positive anode potential increased, the cathode electrons are able to pass through the grid region. In their highly accelerated movement towards the anode they cause ionisation by collision with the gas molecules (either mercury vapour or other gas, according to the type of tube) and cause the immediate establishment of a discharge between anode and cathode. This discharge persists, and results in current flow in the load circuit, until the anode voltage falls to the extinction value, which is at the end of each positive half-cycle when alternating anode voltage is used. By applying the phase-shift method of control and alternating voltage of the same frequency on anode and grid it is possible to vary the striking point and thus also the average rectified current in the load circuit. When anode current flows, the grid is rendered completely ineffective owing to the formation of a sheath of positive ions over its surface, but after the zero current stage the recombination of ions and electrons in the arc space is so rapid that at all normal frequencies this space is completely deionised during the negative half-cycles of anode voltage. It is consequently possible to obtain smooth and instantaneous control of load current by the phase-shift method.

These are the fundamentals of grid control as applied to gaseous conduction, but, of course, there are many other considerations, as well as a wide variety of circuit arrangements developed for special purposes. More detailed considerations are contained in a recent series of articles by the author.[8] Some of the American textbooks on electronics contain detailed information concerning thyratons, notably the recent book by H. J. Reich.

A notable development is represented by the use of rotary distributors for impressing momentary potentials in a definite sequence on the control grids of groups of gasfilled triodes (thyratrons) or individual multiple-anode rectifiers of the larger type so as to obtain a cyclic sequence of conduction in the respective anode circuits. The resulting pulses of anode current are supplied to the primary windings of a transformer, whose secondary accordingly produces alternating voltages. In this way the problem of inversion is solved in a manner which has very considerably increased the usefulness of grid controlled rectifier in electrical engineering practice.

Principal Spheres of Application

Outstanding practical applications include the following:

1. Rectification, with gradual control of output d.c. voltage between zero and maximum when desired.

2. Inversion from d.c. to a.c. by means of rotary distributors. This feature is of great value as a means of utilising the advantages of high-voltage direct current transmission, since it allows of inversion at the receiving end for the supply of existing a.c. apparatus.

3. Transformation of d.c. voltages. This can, for example, be achieved by combination of the inversion and rectification properties mentioned under 1 and 2 above, through the medium of suitable transformers, according to the degree of transformation.

4. Frequency conversion, utilising the properties of the distributor, and permitting the supply of low frequency net-works, *e.g.*, for traction purposes, from an ordinary 50-cycle supply.

5. Long-distance high-voltage d.c. transmission as mentioned under - above, representing a proposition of the greatest importance in the electrical transmission of power in view of the attendant advantages over a.c. transmission, as follows:—

(a) With a given line, maximum permissible voltage for d.c. is 1.4 times that for a.c.

(b) The d.c. system usually requires fewer conductors than the a.c.

(c) The d.c. system is not subject to losses due to eddy currents or dielectric hysteresis as in a.c. systems.

There has been considerable discussion among electrical engineers, notably on the Continent, concerning the future possibilities of high-tension and extra high tension d.c. transmission over long distances.

6. Operation of commutatorless motors, a most important development from the traction view-point, opening up a wide sphere of use for the grid-controlled mercury-arc rectifier in this field. The commutatorless motor has only two collector rings, the torque being obtained by periodic excitation of the field coils in time and space phase, approximating to a translatory field in the airgap. This feature is obtained by distributor control of the anode current.

7. Infinitely gradual control of the speed and torque of ordinary d.c. motors between zero and maximum, utilising the variable-voltage property of the rectifier, without the necessity for contactor control gear and bulky starting and regulating resistors. This also is a development of considerable interest to traction engineers.

8. Elastic coupling of a.c. networks, in which a rectifier is fed from Net. I with or without a transformer, the output d.c. being applied to an invertor as mentioned in 2 above, whose output a.c. feeds Net. II either directly or through a transformer, according to the respective network voltages. The grid-control feature allows of regulation of the amount of power transferred from one network to the other.

The foregoing are merely outstanding applications, and by no means exhaust the sphere of usefulness of the grid-control system, which also has important applications to such widely differing spheres of use as the supply of variable d.c. for electrolytic purposes, for which rectifier units with grid control are at present available up to some 5,000 amperes capacity; control of the current and timing in electric welding, in which the rapidity of grid control renders possible very high speed operation; reverse-energy absorption in regenerative systems; and the supply of high-voltage d.c. for radio transmitting stations requiring anode voltages up to 20 or 30 kV, in which control grids provide efficient and rapid means for the extinction of backfiring.

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4. I. Langmuir, U.S. Patent 1,289,823.
5. F. W. Meyer:

U.S. Patents.	*British Equivalent.*	*Subject.*
1,364,129	162,961	H.T. Transmission (D.C.).
1,369,457	164,924	Control of elec. machines.
1,408,118	165,986	Frequency changing.
1,649,036	168,107	Rectification and Amplification.
1,669,527	165,985	D.C. to A.C. Conversion.

6. P. Toulon, U.S. Patent 1,654,949; also papers written in collaboration with L. Dunoyer in Comptes Rendus, 1924, p. 179; Journ de Phys., 5, 1924, pp. 257, 289.
7. G.E. Review, 26, 1923, p. 731; 27, 1924, pp. 449, 538, 616, 762, 810; see also Science, 58, 1923, p. 290; Phys. Rev., 22, 1923, p. 148.
8. Electronics and Television, Sept., 1940, to March, 1941, inclusive.

Frequency Modulation
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quency modulation) the wider spaced sidebands for low as well as high modulating frequencies can usually be neglected. The resultants of all odd numbered sidebands are 90° out of line with the carrier and those of the even

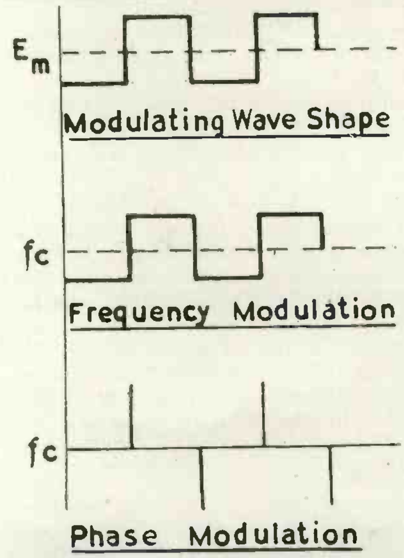

Fig. 5. Illustration of the essential difference between frequency and phase modulation.

numbered ones are in line with the carrier vector. The amplitude of each sideband vector is dependent only on the amplitude of the modulating frequency.

The clearest distinction between frequency and phase modulation has been indicated by Professor Howe.[6] He considers a square-shaped modulating wave as in Fig. 5 so that for frequency modulation the carrier frequency varies above and below its unmodulated value in accordance with the amplitude of the modulation. Phase modulation, however, shows that apart from the sudden instantaneous changes of phase when the carrier frequency becomes + ∞ or − ∞ the latter is constant at its unmodulated value.

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Rhodium Contacts

A New Metal for Use in Radio Apparatus

By E. H. LAISTER

THE use of precious metals in electrical apparatus has long been familiar, particularly for contacts of various kinds, and is very largely due to their outstanding property of stability or permanence. Precious metals are comparatively inert chemically, and are accordingly resistant to deterioration as a result of oxidation, tarnish and corrosion.

The advent of radio-communication has largely extended the applications of these metals, and the rapid advances which have been made during the last 25 years have raised many new problems, a few of which are peculiar to this branch of electrical science. Among these are certain contact difficulties in the solution of which substantial advances have recently been made.

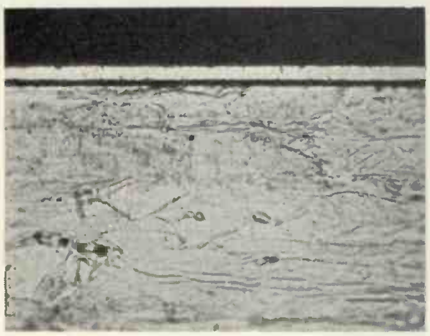

Fig. 1. Photomicrograph of section of rhodium plated contact showing the uniformity of layer. The extreme hardness of the film is indicated by the black " gutter " underneath due to the polishing away of the softer nickel silver.

The design of flexible and easily handled equipment usually involves a very considerable amount of switching, and the currents to be handled are for the most part extremely small.

Many of the switch contacts carry only Radio-frequency or speech-frequency currents of minute proportions with no D.C. potential difference across them to assist in breaking down any oxide or tarnish film that may form during idle periods. Since any changes in the current passing through the closed contacts are more often than not magnified many thousands of times by the following amplifiers, any unstable contact will result in the output being unreliable, possibly marred by crackles and other distressing noises if not failing altogether.

The proneness of many receivers to this type of defect owing to wave-change switch troubles will be as familiar as it is exasperating. Nickel-silver contacts are particularly bad offenders in this respect in the absence of a very strong wiping action, owing to the high resistance of nickel oxide. It may be as well to offer a reminder that many metals which remain comparatively bright in appearance owe this property to the protective effect of a film of oxide, which is generally an excellent insulator. They would, therefore, be quite unsuitable for the contact faces of such a switch.

Various methods have been adopted for dealing with this problem in ordinary switches, and usually the strong wiping action introduced, together with the breaking down effect of the potential difference across the contacts, is sufficient to ensure satisfactory action. Where R.F. currents only are to be carried these conditions do not obtain, especially as capacities must always be kept to a minimum. It is, therefore, standard practice to employ some contact material which is stable in itself, and some form of precious metal is commonly used. Cost plays an important part, and special alloys such as gold-silver and gold-silver-platinum, which are reasonably cheap and efficient, are made for this purpose in large quantities. They are usually fitted in the form of tiny rivets mounted in the contact blades.

Where absolute reliability under adverse conditions is required, however, a comparative newcomer to the family of contact materials is now available, which is finding wide and successful application. This is rhodium, one of the platinum group metals, comparatively unfamiliar until recently, although discovered nearly 140 years ago.

PHYSICAL PROPERTIES OF RHODIUM

Atomic Weight	102.91
Specific Gravity	12.44
Specific Resistance	4.90×10^{-6} ohms per cm. cube
Melting Point	1907°C
Coefficient of Linear expansion	8.5×10^{-6}
Colour	Silvery-white

From the above table it will be seen that rhodium closely resembles platinum in many physical attributes.

It is, however, much rarer, and electro-deposited rhodium costs at the present time about forty-five pounds per ounce troy. Unlike platinum it is very hard—actually file-resistant—and has remarkable wearing properties.

Chemically it is more inert than platinum, being completely unattacked at ordinary temperatures even by boiling Aqua Regia, whilst oxidation in air does not take place below 600°-800° C. The name rhodium is derived from the fact that most of its salts are of a red colour. (Gr. Rhodos = Red.)

Although a difficult metal to work, rhodium can be deposited electrolytically with comparative ease, and extended tests which have been carried out on polished rhodium surfaces have shown that even with heavy pressure and strong wiping action very little wear is produced in the rhodium, although a soft metal underneath may show some depression if the contact face is narrow and pressure great. At the same time contact is satisfactory at extremely light pressures.

Fig. 2. Photomicrograph of semi-cylindrical contact showing the effect of flawed base metal.

Since rhodium is so expensive it is necessary to decide with some care the minimum thickness which can be employed for any given purpose, and while, as with most things, experience is the safest guide, some description of practical deposits and their applications should prove useful.

The maximum thickness at present available commercially is .001 in., and although this is not great, judged by ordinary standards, it is amply sufficient for R.F. contact purposes even under the most drastic conditions. It may be remarked that .001 in. of electrodeposited rhodium costs in the region of 10s. per sq. in., so that greater thicknesses would tend to become unnecessarily expensive, even if they were practicable.

It is possible, however, to limit the deposit to quite small areas, and for anything over about .0001 in., this is usually done. In fact it is quite common practice to plate an area of less than 1/16th sq. in., so that this very expensive metal only appears where it is actually needed.

An electrodeposit of 0.001 in. is therefore specified where conditions are adverse and heavy pressures and much wear are encountered.

0.00025 in. is a good average to employ for less drastic requirements, and is, of course, correspondingly less expensive.

0.0001 in. is sufficient when wear is not great, and is largely used not only for R.F. contacts but for various types of low current relay circuits which may only operate on extremely light pressures, and after long idle periods. Some kinds of automatic alarm and safety devices are good examples.

0.000015 in. is about the thinnest deposit which is used for contact purposes, and is entirely satisfactory for conditions somewhat less exacting from the point of view of reliability over long periods.

Any of these deposits is sufficient to prevent completely the deterioration which takes place so readily in many contact materials in the presence of vulcanised rubber.

It should be made clear that, with the exception of special applications, such as the relays already mentioned, these remarks refer to radio-frequency, speech-frequency and minute currents generally. These thin rhodium deposits are not suitable for contacts at which arcing or sparking are likely to take place frequently, as is the case where comparatively large direct or alternating currents are being broken, particularly in inductive circuits. Perforation is likely to take place quite soon under these circumstances, although large R.F. currents may safely be carried.

Much experimental work has been carried out to discover the treatment most suitable for various conditions, and, while thicknesses of rhodium deposits must have first consideration on account of cost, it is also necessary to give some attention to the metal on which it is to be applied. The best and closest grained deposits of rhodium are obtained on silver which should therefore be used, either as a basis metal, or as a preliminary electro-deposit if the rhodium is to be thin. This is not so important for thicknesses exceeding about 0.0002 in., when there is sufficient " body " in the rhodium to provide full protection of the base, as well as good wearing and contact properties.

Where any electro-deposit is used as an undercoat, a basic material should be chosen which is not likely to suffer from pin-holes and other defects. These will not be covered over and may result in failures at a future date, when they make their presence felt owing to physical or chemical changes taking place just below the surface. Plating solutions, particularly cyanides, are absorbed by any porous metal and tend to set up corrosion there. This state of affairs is obviously undesirable at such a point as the working part of a switch, especially as the latter may be at the other end of the world before trouble develops. It is particularly necessary to beware of some of the poorer types of brass, which have been known to produce most disconcerting results under these conditions. (Fig. 2). Nickel-silver and phosphor-bronze are usually fairly satisfactory in this respect.

A further field where rhodium has proved of great value, while not strictly a contact problem, is closely allied to it. This is the case of ultra-high frequency apparatus, where the need for low losses and short leads has resulted in the parts being built on to one another, so to speak, connecting wiring being practically or entirely eliminated so far as R.F. circuits are concerned. " Skin-effect " at high frequencies becomes very noticeable, and it is undesirable that the bulk of the current should be carried by a high-resistance oxide film on the surface. On account of this effect and in order to obtain the highest efficiency, it is common practice to silver plate the various parts so that the low resistance silver may carry the current with minimum losses. This is quite satisfactory as long as the silver is untarnished, but some deterioration takes place as the tarnish film grows. This is not, however, so great as to reduce the efficiency seriously. What is more serious is the fact that movable " taps," or contacts on the inductances, must be provided, and, when moved, must make instant contact of the lowest possible resistance. The final application of 0.000015 in. of rhodium over 0.001 in.—0.005 in. of silver will produce a durable and reasonably economical finish which will fulfil the foregoing conditions and will protect the whole apparatus from corrosion and consequent deterioration. Where unusually exacting conditions such as sea air or spray or tropical heat and moisture are to be encountered the thickness of the rhodium may well be increased somewhat and the higher figure for the silver should also be used.

The use of the protective powers of rhodium is, of course, extended to all kinds of radio apparatus where an attractive and lasting finish is needed, while its fine white colour and high reflectivity—approaching 80 per cent. total reflexion—may be utilised in making parallax and other mirrors.

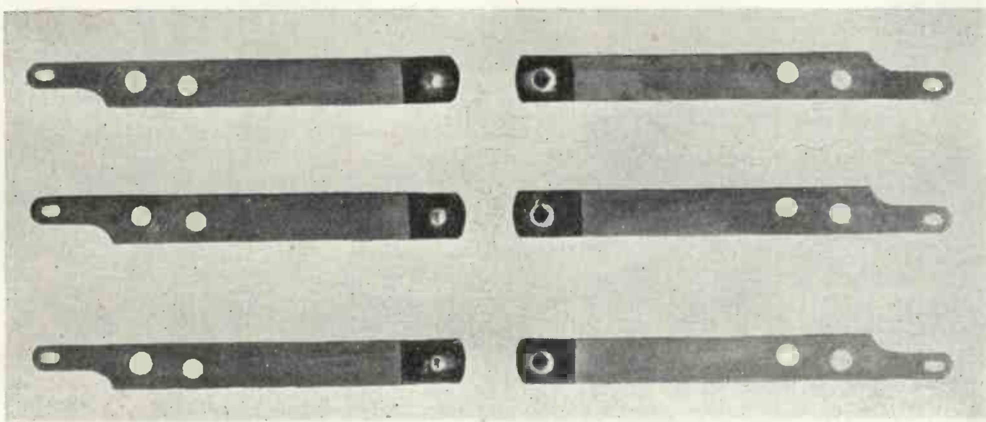

Fig. 3. Contact springs plated with rhodium, showing the restriction of the deposit to the contact area (shown dark in the photograph).

Thanks are due to Messrs. Johnson, Matthey & Co., Ltd., for permission to publish this information and the photographs illustrating it.

The Application of Electronics to Industry

III. Measurement

by John H. Jupe

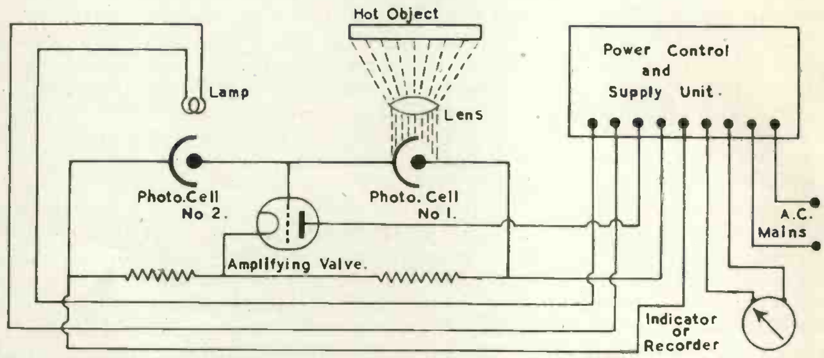

Fig. 2. Photocell Temperature Measuring System. The lamp current also passes through the indicator and varies with the anode current. The resulting light change re-balances what is essentially a "Wheatstone Bridge." This arrangement avoids errors due to cell drift and supply variations.

(Honeywell Brown Ltd.)

THE world of physics and chemistry has been revolutionised during recent years by the introduction and development of electronic devices as measuring instruments. Some were not thought possible ten years ago and yet to-day the cost of the necessary apparatus is comparable with that of older measuring equipment.

Such electronic instruments may conveniently be considered in two groups :

1. Direct reading or separately calibrated scale instruments. (Fig. 1).
2. Comparison or "sample versus standard" instruments. The cost of using instruments in each section, together with considerations of sensitivity and overall accuracy must be dealt with in individual cases and it does not necessarily follow that quantitative measurements require more expensive apparatus than qualitative ones. This is perhaps more true in the electronic field than any other.

In the space available it is only possible to mention a few of the many examples, but they at least give some indication of the scope of the electron as an industrial and laboratory measuring tool.

Fig. 1. Typical electronic precision measuring instruments—valve voltmeters by the Salford Electrical Co.

Temperature measurement by this method is an easy province for the photocell and it has the great advantage of not requiring contact with the hot body as temperature is actually measured in terms of colour. The scope of such apparatus is given in the table on the next page. Fig. 2 shows a typical circuit arrangement.

High accuracy is becoming increasingly important in steel manufacture where customers' requirements call for special grain size and tensile strength, particularly when the open hearth process is used.

By extending the measurement of temperature from the products to the furnaces themselves considerable saving may be made in refractory brick linings. For example, in a case of non-regulated furnaces, repairs to the linings were necessary after 300 batches of steel had been made, but with electronic temperature control this was increased to 450-500.

For mechanical measurements the electron tube has been adapted with complete success in the motor car industry and self-contained units are available for measuring, sorting, and grading parts such as roller bearings, the calipering being done to an accuracy of 0.0001 in. (Figs. 3 and 4). The actual electronic methods are either to use the interruption of a light beam by gauge arms or to measure the variation in an oscillating valve circuit. In the latter method the grid circuit condenser is built in such a manner that one of the plates is displaced by the material under measurement, causing a frequency change. Such a method enables deflections of 0.000001 in. to be noted and in a particular commercial thickness gauge of this type 0.125 in. plus 0.0000005 causes sufficient change to cause full scale deflection of an ordinary indicating instrument.

Mechanical forces can be measured by piezo-electric or capacitance oscillograph methods, the latter being perhaps the better known of the two in its application to the problems connected with the internal combustion engine, where various pressures and movements and their relationships may be observed on cathode-ray tube screens. The piezo-electric method has been developed to a large extent in Germany and has been applied to gun pressures, and motor vibrations as well as small displacements. It is applicable to forces as low as 0.02 of a pound and to displacements down to 0.0003 in.

Of particular interest to the electrical engineer is the stroboscopic method of testing integrating meters. Here, light from an incandescent lamp is broken into pulsations by means of meter element with a notched disk. These light pulsations are picked up by a photocell and after amplification, are passed on to a neon tube used to illuminate the meter under test. Thus, to calibrate this meter it is only necessary to adjust its speed until the disk appears to stand still.

Another very large field of electronic measurement is that of colour by means of photocells, and in most cases the accuracy is higher than that obtainable with the human eye. For instance, in chemical analyses use is often made of methyl orange as an indicator of the end-point of reactions and here it is generally possible to obtain 10 times the usual degree of visual precision by substituting for the eye of the chemist, a photocell, a single stage of amplification and a milliammeter. This is due to the fact that the human eye is more sensitive to changes of quality than quantity of light, whereas with cells rather the reverse is the case. So, in the example (methyl orange) the eye seeks for a change in hue to detect the end-point and is not very efficient. A filter, however, chosen to transmit a narrow band of the spectrum in the region of interest will produce a rapid change in the quantity of light passed and this is a change to which photocells can be made very sensitive, with the result that the overall accuracy is increased.

Lastly, attention should be drawn to the photocell as a counting device for very high speed work. Its general use in this respect is well known, but it is not so well known that an interrupted light beam can count faster than any mechanical device. Furthermore, by using another electron tube, the thyratron, in conjunction with an amplifier, it is possible to count in excess of 1,200 units per second.*

A table of electronic measuring devices not included in the above is given in the adjacent column.

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Quantity Measured.	*Name of Device.*	*Electronic Principle.*
Sound.	Sound level meter.	Microphone and amplifier.
	Sound analyser.	,, ,, ,,
Humidity.	Humiditometer.	Humidified articles cause capacitative change in resonant circuit.
*p*H Concentration (hydrogen ions).	*p*H Meter.	Measurement of high resistance between electrodes, using thermionic valves.
Time.	Electronic clock.	Piezo-electric oscillator.
	Electric timer.	Measurement of charge on condenser.
		Gas discharge tube with condenser and resistance.
Light Intensity.	"Lightometer."	Photocell and meter.
Velocity.	Speed indicator.	Electric timer operated at intervals (by photocells).
Waveform.	Oscilloscope.	Cathode-ray tube.
Voltage.	Valve voltmeter.	Valve with moving coil indicating instrument.
Resistance (electric).	Wheatstone Bridge (electronic).	Thermionic valve in one or two arms of the bridge for very high resistance measurements.
Depth of ocean.	Echo sounder.	Magneto-striction oscillator.
Earth's Magnetic Field.	Electron compass.	Development of cathode-ray tube.
Solutions of mathematical equations.	Electronic calculator.	Special transformers and thermionic amplifiers.

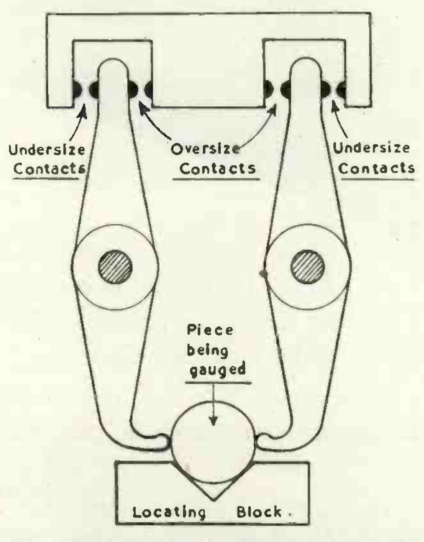


Fig. 3. Self Centring Gauge fitted with contacts. Usually made up as multiple units connected to "Thyratron" grid circuits for gauging to accuracy of 0.0001 inch. Contacts only carry a few microamperes grid current and there is no wear due to sparking.
(*Electronic Control Corp.*)

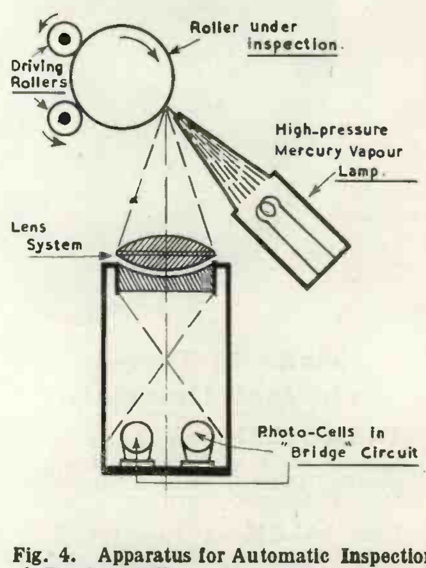
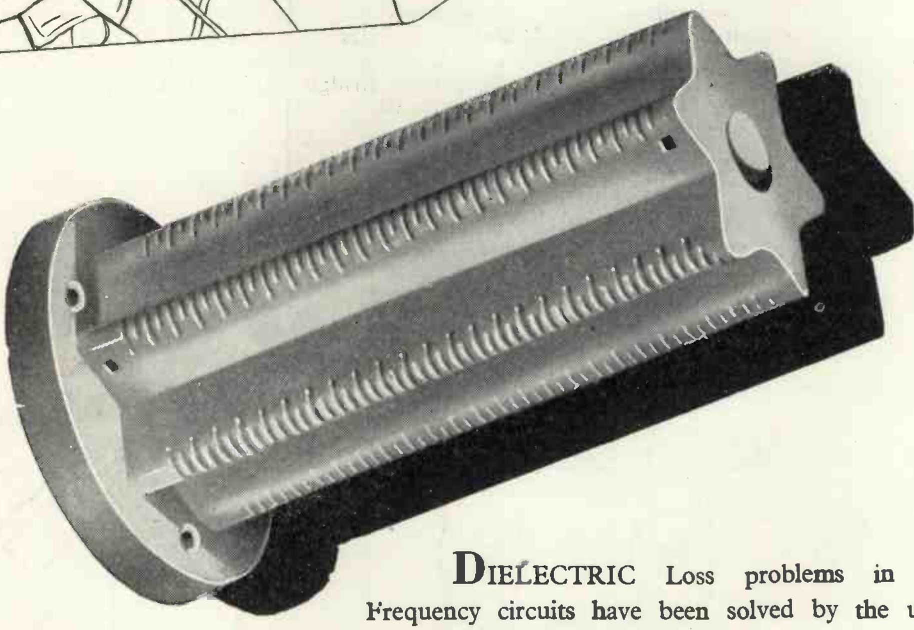


Fig. 4. Apparatus for Automatic Inspection of Bearing Rollers. The equipment, in its full form, contains 57 photocells and the rollers are slowly rotated whilst their surfaces are being scanned. Large optical magnification is used and the slightest crack causes a shadow to be cast on one row of cells. Solenoid operated triggers remove the defective rollers.
(*Electronic Control Corp.*)

Photocell Pyrometers.

Range.	*Valve Amplification.*	*Voltage Regulation.*	*Special Optical System and Light Filter.*	*Accuracy.*
980° F. to 3,300° F.	Yes. Multi-stage.	Yes. Full.	Yes.	±5° F.
1,100° F. to 2,000° F.	Yes. Two stages sufficient.	Yes. Partial.	Yes.	±10° F.
1,300° F. to 2,000° F.	Yes. Single stage only required.	None required.	None required.	Very low but suitable for some purposes.

"Everything O.K. Sir!"



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Electronic Engineering

DATA SHEETS XV, XVI & XVII

The Inductance of Single Layer Solenoids—(Contd.)

IN last month's Data Sheets Nagaoka's Formula for the calculation of multiturn single layer coils was discussed, this formula is, however, inapplicable to single turn coils.

Inductance of Single Turn Coil at H.F.

At high frequencies the current flows only in a thin skin near the surface of the wire and we can thus apply the low frequency formula of a coil made of very thin tubing to the case of a solid wire at H.F.

Formulæ for single turn inductances of thin tubing have been derived by both Maxwell and Grover; the one given below is due to Grover.

$$L_0 = 0.006283D\left[\left(1 + \frac{d^2}{4D^2}\right)\log_e \frac{8D}{d} - 2\right] \mu H \quad (8)$$

and as in the majority of cases d/D is very small the approximation:

$$L_0 \approx 0.00628.D\left[\log_e \frac{8D}{d} - 2\right] \mu H \quad (9)$$

will be sufficiently accurate. Equation (9) has been plotted on Data Sheet No. 17 for a range of "D" (coil diameter between wire centres) from 2.5 cms. to 30 cms. and "d" from 0.01 cm. to 1.0 cm. A S.W.G. wire scale has been provided in addition.

Formula (9) and Data Sheet No. 17 may also be used for the case of a single turn coil wound with a thin tape, with the tape lying parallel to the axis of the coil. To make the calculation we replace "d" in (9) by 0.223w, where "w" is the width of the tape in cms.

Inductance of thin Coil $D \gg l$.

Raleigh and Niven have given the following formula for the inductance of a single layer coil when the length of the coil is much smaller than its radius, *i.e.* $l \ll D$.

$$L_0 = 0.006283\,DN^2\left[\log_e \frac{4D}{l} - \frac{1}{2} + \frac{l^2}{8D^2}\left(\log_e \frac{4D}{l} + \frac{1}{4}\right)\right] \mu H \quad (10)$$

When $L < \frac{1}{4}D$:

$$L_0 = 0.00628\,DN^2\left[\log_e \frac{4D}{l} - \frac{1}{2}\right] \mu H \quad (11)$$

to the order of 1 per cent. accuracy. In (10) and (11), however, "l" is the length of the coil from the outside of the first turn to the outside of the last turn.

Approximations.

The majority of inductance coils used in radio receivers have their inductances finally adjusted at R.F. against a standard coil by physically displacing one or more turns by a small amount. The inductance of the standard itself is also adjusted experimentally to provide the required performance (for reasons see first paragraph of last month's Data Sheet). Under these conditions it is a waste of labour to calculate inductances to too high a degree of accuracy or use complicated formulæ which only provide a very high degree of accuracy at low frequencies. Once the principle of limited accuracy is accepted it is possible to produce charts or derive empirical formulæ which will greatly reduce the labour of calculation.

Data Sheet No. 16 is an example of the method of reducing the labour required by solving Nagaoka's Formula (equation (1)) in the form of a series of curves. As one inch equals 2.54 cms. the half centimetre steps are approximately equal to 0.2 inches. For any other number of "turns per cm." the inductance read off the Data Sheet

is multiplied by the factor $P = \left(\frac{N_1}{10}\right)^2$

where N_1 is the number of turns per cm. actually used. The value of the factor P for a range of $N_1/10$ from 0.26 to 6.3 is given by the straight line on the Data Sheet 16.

Example 1.

To calculate the inductance of a coil with a diameter of 6 cms. wound with 45 turns of No. 24 S.W.G. wire in a length of 3 cms. From Data Sheet No. 16 we find that the inductance with 10 turns per cm. is $L_s = 56\ \mu H$. Now $P = 15^2/10^2 = 2.25$ so that $L_s = 126\ \mu H$. Checking the order of $\frac{\Delta L}{L_s}$ from Data Sheet No. 14 we have $D/l = 2$, $p = 1/15$ cms. $d = 0.0457$ cm. and $S = 0.685$ which gives $x < 1$. The low frequency inductance L_0 would (apart from reading accuracy) therefore be well within 1 per cent. of the calculated current sheet inductance (L_s).

H. A. Wheeler (*Proc. I.R.E.,* October, 1928, March, 1929) has given a simple empirical formula for the calculation of the current sheet inductance L_s. Using inch units for D and l he gives

$$L_s = \frac{DN^2}{18 + 40\,l/D} \mu H \quad (12)$$

accurate to 1 per cent. for $D/l < 2.5$.

Using centimetre units,

$$L_s \approx \frac{DN^2}{46 + 102\,l/D} \mu H \quad (13)$$

For very short coils the above expressions are not accurate and the following may be employed:

With inch units

$$L_s = \frac{DN^2}{18 - D/5l + 40\,l/D} \mu H \quad (14)$$

accurate to 2% for D/l from 0 to 20.

Using centimetre units.

$$L_s \approx \frac{DN^2}{46 - D/2l + 102\,l/D} \mu H \quad (15)$$

Design of S.W. Inductances.

D. Pollack (*R.C.A. Review,* October, 1937) uses equation (14) with the 46 in the denominator replaced by 45 to calculate inductance and states that it provides results within 2 % of those given by equation (10) for D/l values between 1 and 4. Equation (10) is stated to give results within better than 3% of their true values.

Pollack's work on coil losses between 4 and 25 Mc/s shows that the optimum value of $S = d/p = dN/l \doteqdot 0.7$. Also, the maximum possible coil diameter and length should be employed. However, if a coil shield is used, the coil diameter should be made half the shield diameter and the ends of the coil should not come within one diameter of the ends of the shield. Data Sheet No. 15 has been prepared for the case of $S = 0.7$ and $D/l = 2$, and Pollack's equation then becomes.

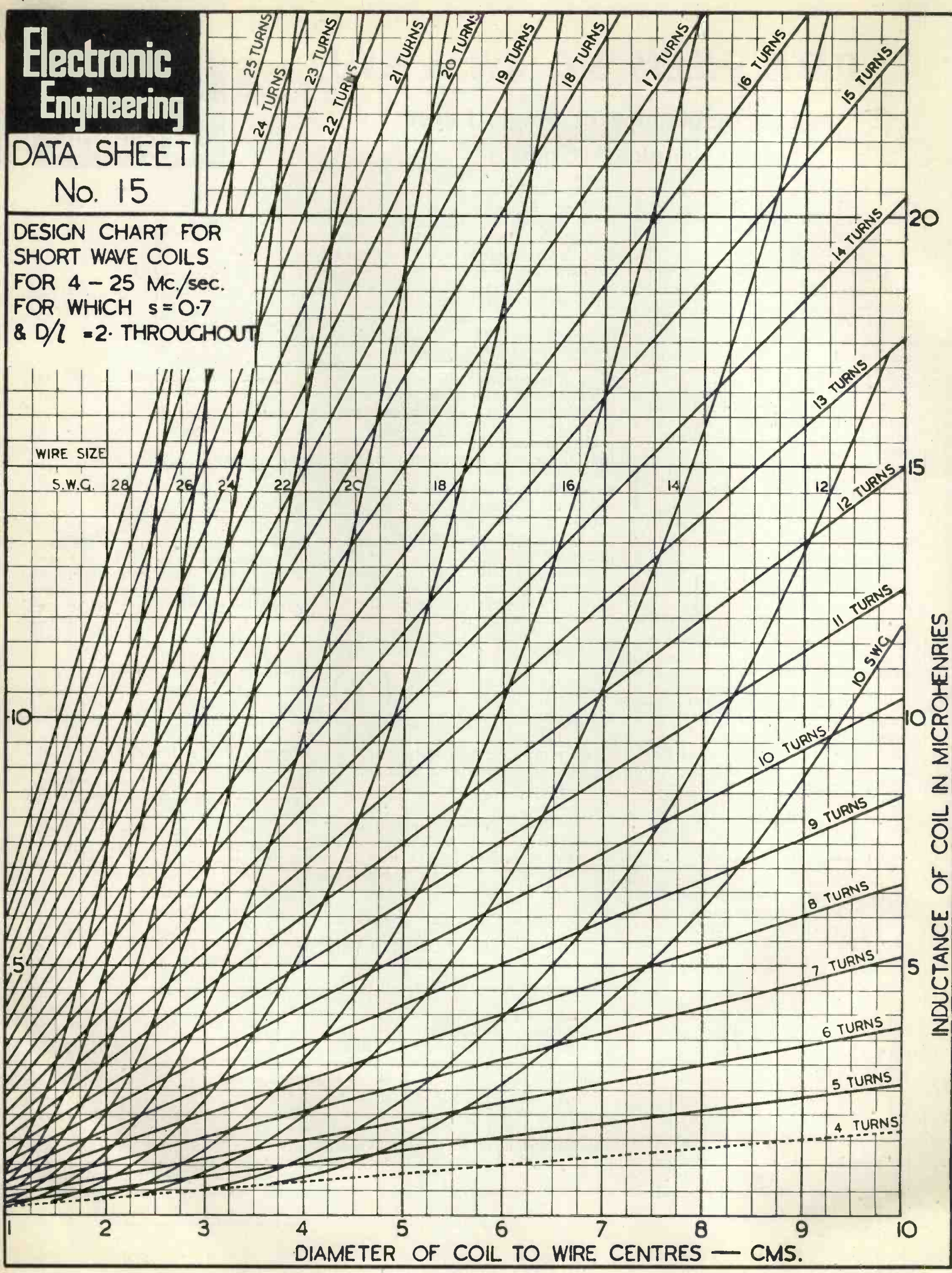
$$L_s = \frac{DN^2}{96} \mu H \quad (16)$$

It is interesting to note that if we put $D/l = 2$ in. Nagaoka's formula (2) we obtain $L_s = D\,N^2/96.5\ \mu H$.

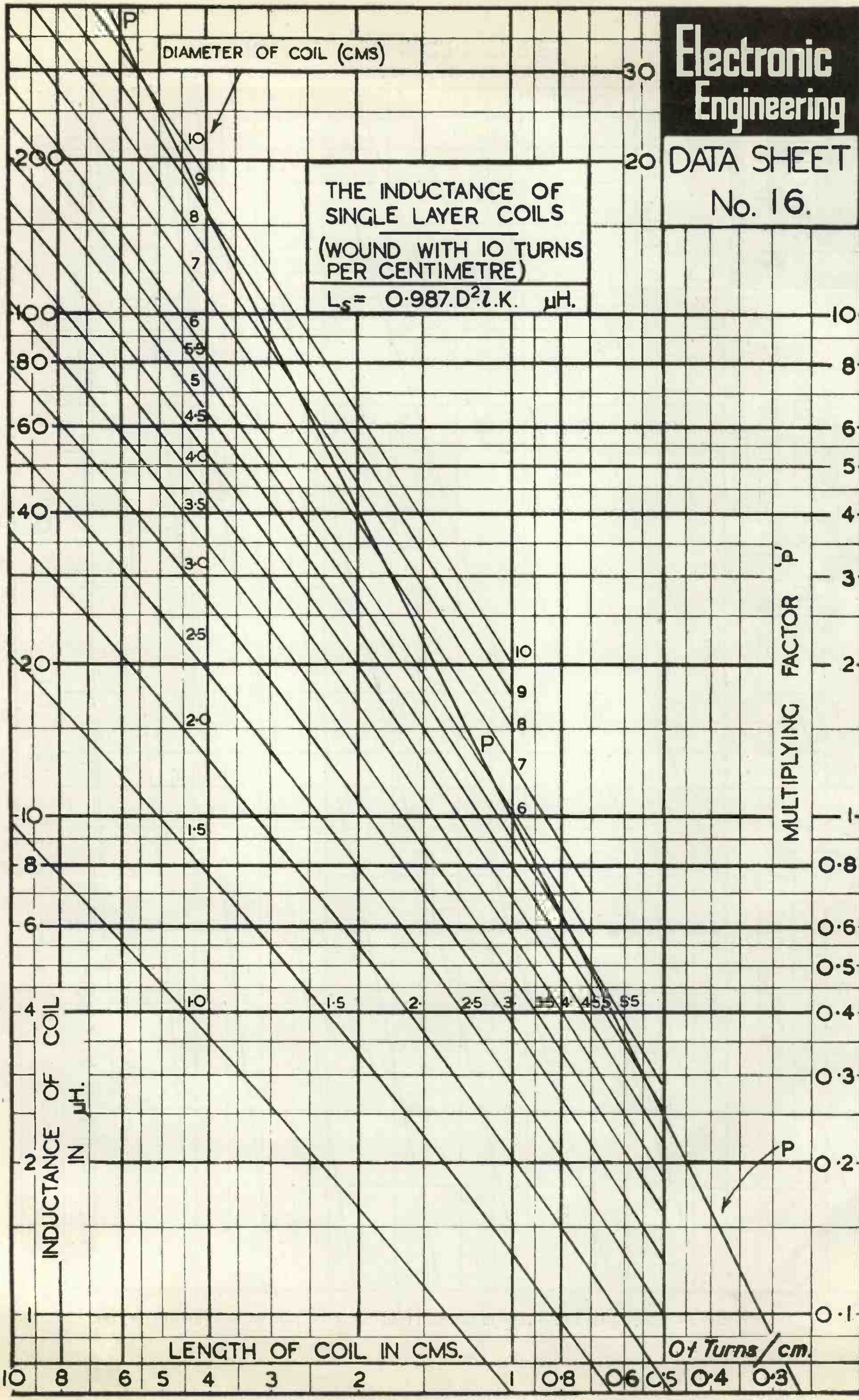
The straight lines on Data Sheet 15 are a plot of (16), while the curved ones are the locus lines of the different wire gauge numbers which satisfy the relation $S = 0.7$.

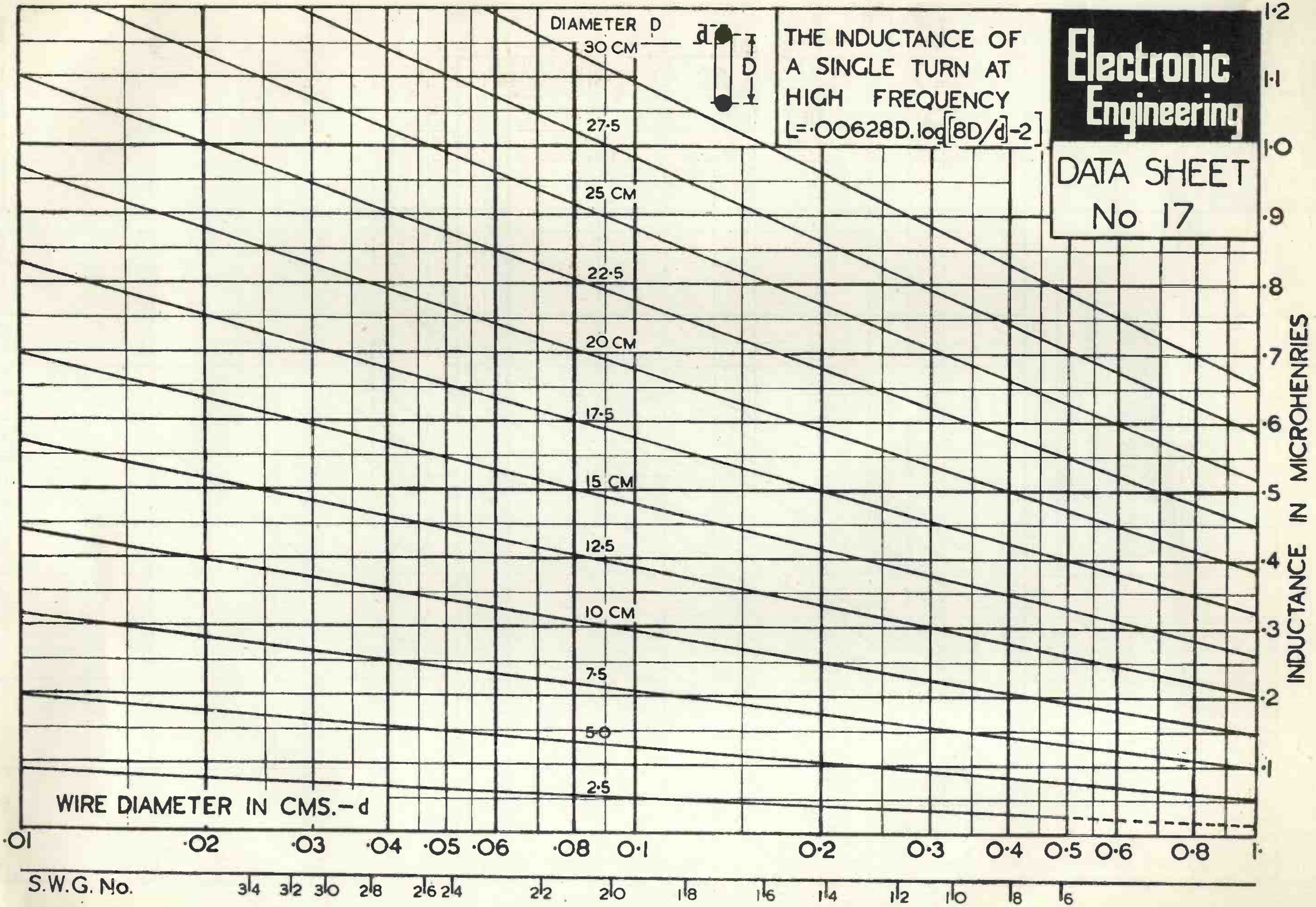
Example 2.

To design a short wave coil of $6\frac{1}{2}\ \mu H$ inductance to be wound on a two inch diameter former. With 2 in. = 5.08 cm. we find that 11 turns of No. 16 wire will give the right order of inductance. The actual diameter of the coil then becomes 5.08 + 0.16 = 5.24 cm. The inductance of the coil would have to be finally adjusted to the required value by moving the last turn.



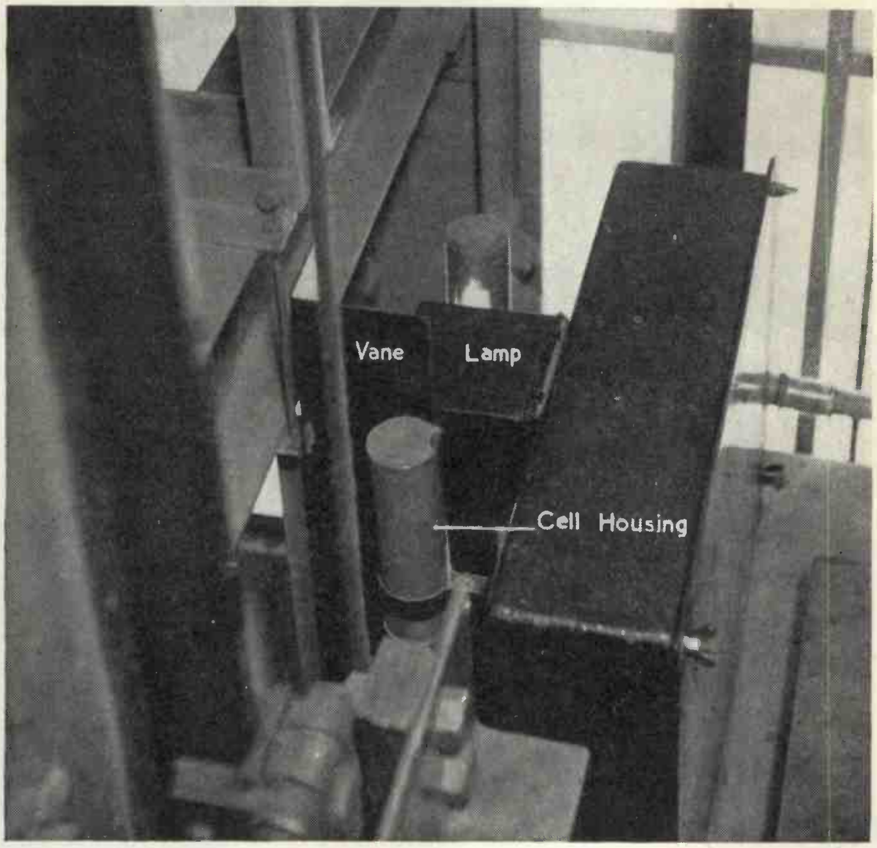
Electronic Engineering
DATA SHEET
No. 15
DESIGN CHART FOR
SHORT WAVE COILS
FOR 4 – 25 Mc./sec.
FOR WHICH s = 0·7
& D/l = 2· THROUGHOUT
WIRE SIZE
S.W.G. 28 26 24 22 20 18 16 14 12
10 SWG
25 TURNS
24 TURNS
23 TURNS
22 TURNS
21 TURNS
20 TURNS
19 TURNS
18 TURNS
17 TURNS
16 TURNS
15 TURNS
14 TURNS
13 TURNS
12 TURNS
11 TURNS
10 TURNS
9 TURNS
8 TURNS
7 TURNS
6 TURNS
5 TURNS
4 TURNS
20
15
10
5
1 2 3 4 5 6 7 8 9 10
DIAMETER OF COIL TO WIRE CENTRES — CMS.
INDUCTANCE OF COIL IN MICROHENRIES


Electronic Engineering
DATA SHEET
No. 16.
THE INDUCTANCE OF SINGLE LAYER COILS
(WOUND WITH 10 TURNS PER CENTIMETRE)
$L_s = 0.987.D^2.l.K.$ µH.
DIAMETER OF COIL (CMS)
P
INDUCTANCE OF COIL IN µH.
MULTIPLYING FACTOR 'P'
LENGTH OF COIL IN CMS.
Of Turns/cm.



Correction :—In Data Sheet 14 the value of X should read 0.0157 x K (D/l) to conform with the text.

Lift Control by Photocells



THE photographs show an interesting application of photocell control to the operation of a passenger lift, fitted by Messrs. A. & P. Steven, of Glasgow. Two lifts in a common well are fitted with this photocell control which considerably simplifies the working and does not require any skill on the part of the operator.

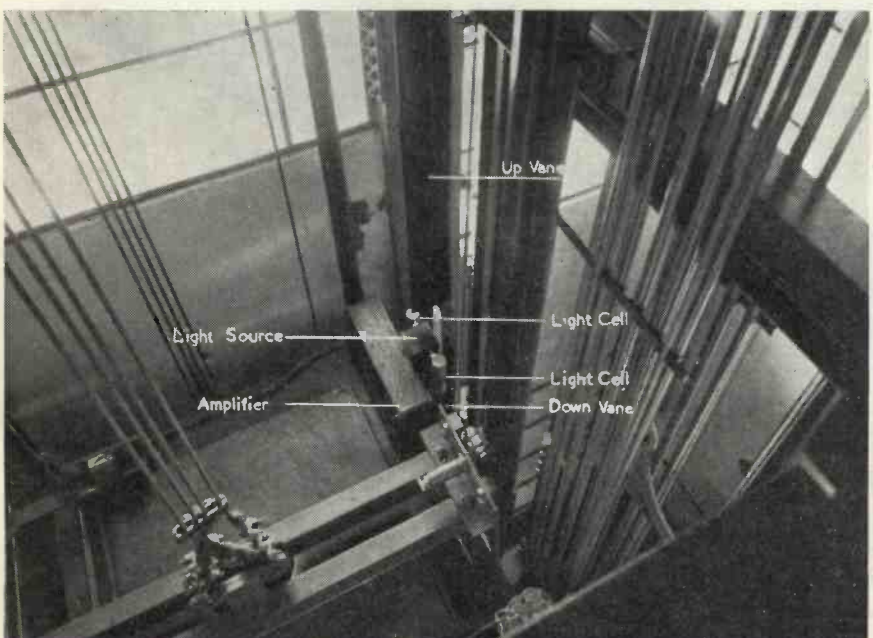
A general view of the installation is shown in the lower illustration which has been taken looking down on the top of the car. On the car is mounted a pair of light cells in screened covers, a light source and amplifier box, which includes relays to work the main contactors of the lift motor.

Mounted down the side of the lift shaft are two sets of screening vanes, one for the "up" travel and one for the down. As seen from the detailed photograph on the right, these are so positioned that they intercept the light ray from the lamp to the photocell unit. The length of each vane is that of the distance between each floor, a gap occurring at a position corresponding to the position of the lamp when the lift is stationary at the floor level.

When the lift is travelling in either direction one of the vanes is interposed between the lamp and the corresponding photocell. The other cell receives light during the movement of the lift, and in the stationary position both are illuminated.

The action is as follows :—

In operating the lift the passenger moves the car switch to either the up or down position and holds in on until the lift passes the floor immediately above or below that at which it Is desired to stop. The car switch is then released, but the cell which is illuminated at the time takes over the control through its relay and prevents the main contactor opening. The motor is, however, slowed down preparatory to stopping at the next floor.



On arriving at the floor level, the gap between the vanes allows light to fall on the other photocell which was previously obscured. The relay connected to this cell then trips the main running contactor and switches off the lift motor.

In re-starting the lift the manual control again takes charge until released, when the same cycle of operation is repeated.

One of the great advantages of the installation is that no special skill is required to bring the lift to rest exactly at floor level. The light-operated control levels the lift to approximately $\frac{1}{2}''$ of the floor level each time and this control is entirely independent of the operator. Further, there is no need for the installation of special switches in the motor room or well to cause the lift to slow down. The usual limit safety switches are, of course, provided in the event of over-running. It is possible that these might be photocell operated if desired.

The equipment has also been fitted to ten lifts in London wharves, the installation being carried out by Messrs. Steven in collaboration with the Radiovisor Parent Co., Ltd., London, N.W 1, and we are indebted to these firms for the photographs and particulars given.

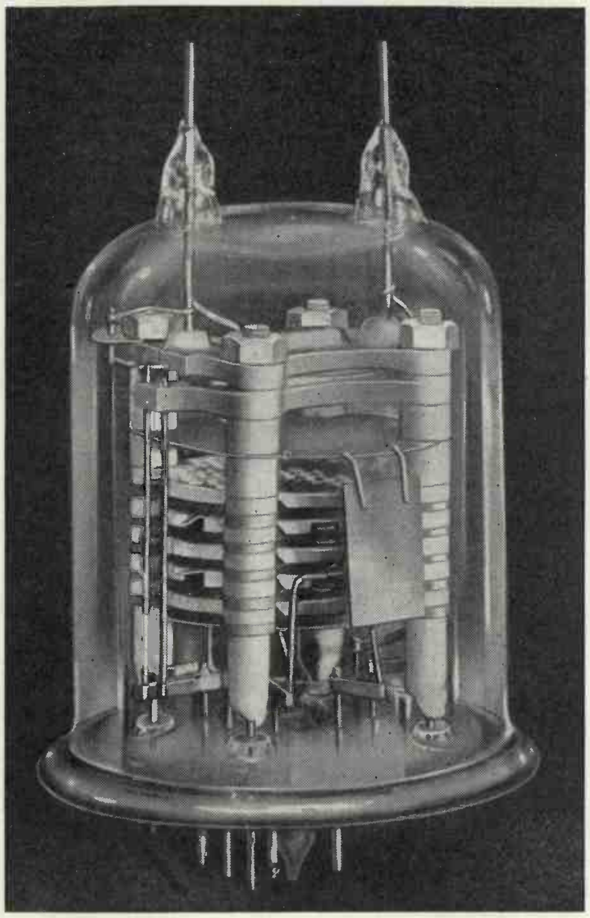
A Note on the Stability of Electron Multipliers

by F. J. G. van den Bosch, D.Sc., I.E.M.
(Messrs. Vacuum Science Products)

At the Annual General Meeting of the Television Society, held on October 4th, at the I.E.E., Dr. van den Bosch read a paper on "Recent Developments in Electron Multipliers, with special reference to the Augetron." The paper in full is being published shortly in a special number of the Society's Journal, and the following extract is reproduced by arrangement. Readers wishing to obtain copies of the full paper should apply to the Editor of the Journal, Mr. W. G. Mitchell, "Lynton," Newbury, Berks.

WHEN examining the properties of any particular electron tube, it is, of course, necessary that the stability of the tube should be sufficient to permit a repetition of results, but a clear distinction should be made between three different kinds of varying results. Any phenomena of instability observed may be due either to unsatisfactory testing equipment or method of testing, or, secondly, through some fault in the assembly of processing of the tube, or finally to some fundamental instability of the electric effects upon which the entire functioning of the tube is dependent.

In order to study secondary emission problems the simplest case is probably that of the photo-electric multiplier in which all the surfaces are of similar chemical composition, and where there is little likelihood of poisoning effects. It will then be found that with moderate illumination (and hence a conservative value of maximum current handled) the characteristics of the multiplier will be exceptionally stable. It is reasonable to assume that under such circumstances any instability observed must be due to some subsidiary poisoning effects complicating the main issue. Actually, the stability attained in a photo-multiplier is very remarkable since in the case of a six-stage multiplier, where the overall gain is the sixth power of the individual average stage gain, a 10 per cent. change in secondary emission ratio would produce nearly a twofold change, and a 10 per cent. change occurring in overall multiplication, which incidentally is easily detectable as a serious instability, only needs about 1.6 per cent. change in average.



The new "Augetron" electron multiplier. A photo-electric type is also available.

Instability is far more likely to be encountered in electron-multipliers where the primary cathode consists of a thermionic cathode, as is the case in the thermionic multiplier. It is unusual in radio valve work to demand very great stability, since in the normal circuits employed a considerable variation in stage gain of a valve amplifier can be tolerated before its effects are detectable by ear. Variations of the order of 5 or even 10 per cent. drift in anode current are not a serious drawback, but in the case of the multiplier with its high slope and high sensitivity the optimum working point on the grid characteristic is of major importance. What we have in mind here is the variation in contact potential caused during running as a result of slow evaporation of metallic barium from the thermionic cathode and its subsequent deposition upon the wires of the nearby grid. A change of as much as 1 volt is possible as a result of this effect and since the optimum working grid potential is critical to within 1/10 of a volt it is obvious that trouble might be anticipated here. However, we have so far not had any difficulty in this direction, as the design of both cathode and grid has been directed to minimise this inconvenience. It is one advantage that the Augetron has over other types of secondary emission tubes so far developed in that its "gun" design has been particularly directed to overcome the inherent disadvantage of using ordinary thermionic cathodes.

It is difficult to say what other changes in conditions at the "gun" assembly end can cause variations at the output end as regards multiplication and mutual conductance. It should be very difficult for small variations in the total emission of a thermionic cathode to have any influence upon these factors, since provided the thermionic cathode is reasonably efficient, its limitation will be completely caused by space charge, and hardly at all by temperature. A more probable cause of trouble is the evolution of gas, mainly oxygen, from the thermionic cathode or from metal parts. A small liberation of gas is likely to have disastrous effects upon the sensitised secondary emitter surfaces. The gas will be ionised and the positive ions will bombard the thermionic cathode resulting in cathode deterioration and subsequent further gas evolution. When the gas pressure is extremely small it usually ionises between the secondary cathodes and generally starts between the last secondary cathode and the collector. Their bombardment will obviously result in serious damage to the sensitised layer. These small gas evolutions sometimes disappear, being "cleaned-up" by the cesium of secondary cathodes acting as a getter; this will be, of course, at the expense of the sensitivity of the secondary emitter. It is probable that there is always a slow evolution of gas from any oxide cathode, and from this point of view, especially in secondary emission tubes, it is advisable to keep the area of the cathode and the emitting surface down to a minimum in order to avoid this as much as possible. Another effect to be considered is the gradual damage to the first secondary emitter by the slow evaporation of barium metal from the thermionic cathode on to this emitter. This effect is the main reason why secondary emission valves may be unreliable during life and why in some con-

(Continued on page 517)

An Inexpensive Sensitive Relay

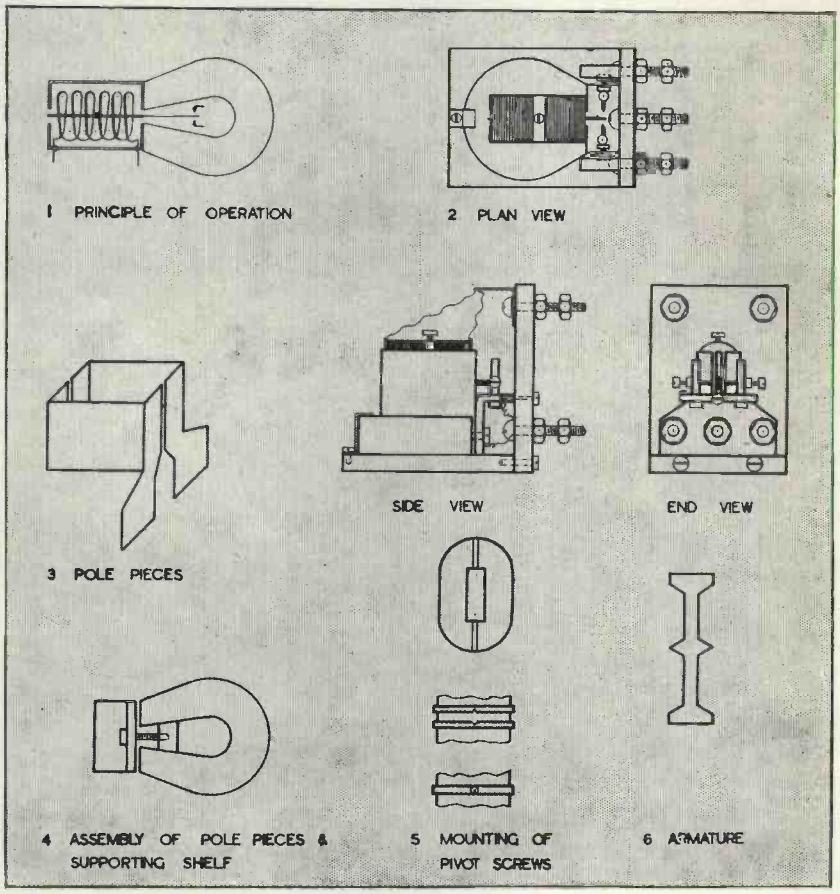
By J. S. Worthington

THIS relay was originally evolved for use in remote-control apparatus for the radio control of models, chiefly aircraft and boats. Its light weight and compactness make it ideal for such uses, and its extreme sensitivity enables the auxiliary apparatus to be kept to a minimum.

The contacts can easily be adjusted to close on .5mA. or less, the best setting being that which caused the contacts to close when the current rose to .5mA. and to open again when it dropped below .3mA. At this setting a power of 100 milliwatts is required to operate it.

When driving the relay through a rectifier by an audio signal, as from a receiver, it should be shunted by a condenser of .1 μF or more, as the armature is so light and sensitive that it endeavours to respond to the audio frequency and speech can in fact be read from it. With a capacity shunt the action becomes clean and rapid and code signals up to 70 w.p.m. have been recorded without difficulty.

The unit, complete with aluminium cover and terminal panel, measures 2 in. by 1.2 in. by 1.4 in. high overall and weighs only $3\frac{1}{2}$ oz. By omitting the mounting base and taking the connexions directly to the coil and the contacts the weight can be reduced to 2 oz. and the size to $1\frac{1}{2}$ in. by 9 in. by 1 in. high without in any way impairing its efficiency.



The movement consists of a light balanced armature suspended inside the energizing coils. The relay is polarized, both ends of the armature being in strong magnetic fields, as shown in Fig. 1. This design permits very sensitive action, and the fact that the armature is balanced avoids the use of return springs.

The construction is made clear by the drawings of Fig. 2, but several points require a little explanation. The pole pieces are made from 1-32 in. soft iron sheet shaped as shown in Fig. 3. The flanges which are pressed against the poles of the magnet should make good contact and are held in place by the piece of Perspex which is bent to an angle section and forms the supporting shelf for the contact screws. The Perspex may be bent easily if it is immersed in boiling water for a few minutes until it softens. This shelf is held tightly in place by a 9-B.A. brass bolt which passes through it and screws into a tapped hole in a wedge-shaped piece of the same material which is jammed between the converging legs of the magnet as shown in Fig. 4. This makes a very rigid assembly. The two coils (taken from headphones) are clamped in place by the extended pole pieces, at the ends of which opposite magnetic poles appear by induction. The coil bobbins can be removed from their original cores quite easily and must be arranged so that the direction of their windings is continuous. Before finally assembling the coils V-shaped notches should be filed on the cheeks which will be in the middle of the completed assembly. The coils should then be clamped in a vice with the two notches in alignment and a 9-B.A. tap run through between them. Care is necessary to avoid damaging the windings, as the cheeks are fairly thin, but it is not a difficult operation when care is used (see Fig. 5). 9-B.A. brass bolts with the tips countersunk form the supports for the armature which is mounted inside the coils. The armature itself is made from 1-32-in. soft iron sheet, and is shaped as shown in Fig. 6. The cut-away shape of it is to keep it as light as possible to reduce the power required to move it to a minimum. The ends of it should project from the coils just sufficiently to be in the fields of the pole-pieces. To the end nearest the shelf is soldered a light piece of brass carrying the moving contact. In the relay shown, a contact is carried on one side only, the other side merely bearing on a back-stop, but there is no reason why contacts should not be fitted on both sides if a change-over action is desired. It is important that the armature should not extend beyond the magnetic field and that all bolts, etc., which do not form part of the magnetic circuit should be of non-magnetic material, e.g., brass. The fixed contact screw and back-stop are 9-B.A. brass bolts with lock nuts, mounted in brass pillars made from $\frac{1}{8}$-in. brass wire, which are in turn mounted on the " shelf." The assembly so far described forms a complete relay, connexion to the moving contact being made via the bottom pivot of the armature. It is realized that this is not a desirable practice as a rule, but the damping introduced by any pigtail connexions destroyed to some extent the sensitivity of the action, and in view of the fact that only small currents at low pressures are normally controlled this method was adopted and so far in practice no trouble has been encountered.

To facilitate handling the relay a base of Perspex was fitted, together with a terminal panel carrying both primary and secondary circuit connexions. A thin aluminium cover completes the construction.

BOOK REVIEWS

Plastics in Industry

"Plastes" 234 pp. 32 plates. Chapman and Hall, 12s. 6d. net.

The pseudonym "Plastes" conceals the identity of two (or possibly more) engineers who are obviously thoroughly familiar with the plastics industry and enjoy writing about it.

Commencing with the usual description of the different types of plastic materials, which, however, is very full and accompanied by tables of their properties, the book proceeds to deal with the technique of moulding and fabrication and then to the applications of plastics to the various industries—chemical, electrical, aircraft, motors and to domestic uses in building and furniture manufacture.

The information contained in the chapter on electrical engineering applications is particularly useful as it embodies data which could only be obtained by reference to numerous special articles which have appeared at intervals in the electrical press.

A plate which is of particular interest to radio engineers is that on page 228 which shows the development of the moulded radio cabinet in the designs made by Messrs. E. K. Cole. An interesting comment on the suitability of colours for radio cabinets is made on some coloured radio sets which were produced in 1938. "Some of these were moulded in stone-coloured urea material which unfortunately gave the cabinet a heavy and massive appearance intensified by the tall shape. One had the impression that the cabinets were carved out of solid marble and that if placed on a bookcase would crush it with their weight."

The book is written in a very readable style and can be recommended to engineers for its general interest apart from the valuable data which it contains. The half-tone plates are excellently reproduced and could only have been improved by rendering in colour.

Dictionary of Radio and Television Terms

R. Stranger, 252 pp. with line drawings in text. Geo. Newnes, Ltd., 6s.

This book is particularly opportune in view of the number of recruits to the radio branch of the Services, and should enable them to understand many obscure references in technical literature.

Although its title mentions only radio and television, the book actually covers a wider field including physics and chemistry where their terms have a direct bearing on the subject.

It also includes brief biographies of eminent men in physics and radio engineering and useful tables at the back on radio symbols mathematical constants and sun-spot numbers.

Mr. Stranger writes in an easy colloquial style, which makes the definitions easier to read than those in the average dictionary which are rendered from standard definitions or in the wording of patent specifications. This colloquial style, however, at times leads to ambiguity, as for example, in the definition of "Cell. Photo-Electric": "A glass bulb carrying two electrodes which varies the current flowing through it. . . ." Again: "There are two kinds of photo-electric cells—one with a vacuum bulb and the other gas-filled."

In the next edition, which no doubt will be speedily called for, Mr. Stranger might do more justice to the Iconoscope than to dismiss it in two lines and might include Dr. Zworykin's name among the distinguished physicists, but these are minor points in a book intended for the British market.

Electric Discharge Lamps

Francis and Jenkins. Published by the General Electric Co., Ltd.

The scope of this book is perhaps best indicated by a brief survey of five parts into which it is divided.

Part I, as its title "General" suggests, is devoted to a broad discussion on the production of light, followed by the historical development of discharges, the mechanism of the discharge, the radiation spectrum, and sections on fluorescence and practical discharge lamps.

Part II is entitled "Osira High Pressure Mercury Vapour Discharge Lamps." After a short general description this part develops into an exhaustive treatise on the various types of Osira H.P.M.V. lamps now available, and takes one through the many stages of development and design.

In view of the comparatively recent development of Osram fluorescent tubes and of their evergrowing popularity for lighting industrial and commercial establishments, Part V will probably be the most widely studied chapter of the book. Since the introduction of the Osram tube nearly eighteen months ago, much has been written and said about this descendant of the H.P.M.V. lamp. There is also much of interest to engineers that has not previously been published.

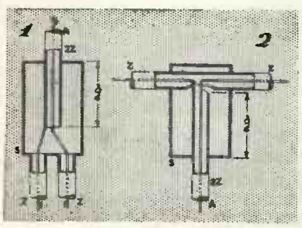
Though necessarily of a highly technical nature, the authors have succeeded in presenting their subject in a very readable and lucid form and it is made still more interesting by the judicious but liberal use of diagrams, illustrations and data tables.

To the professional lighting engineer, this book should be of great value; and it is of particular interest to electronic engineers studying gas discharge phenomena.

Impedance-matching in Concentric Lines

THE R.C.A. Laboratories have recently suggested methods for matching concentric transmission lines whose surge impedances bear to one another certain ratios, which include ratios which are the squares of the natural numbers. These methods use matching sections that employ only concentric lines, and have the interesting feature that the matching is obtained without the use of standing waves. The general principles underlying these methods are illustrated in the figures shown.

Fig. 1 illustrates a method of transforming from a single transmission line A of impedance 2Z to a pair of like transmission lines of impedance Z, but working in balanced relationship. The line A is arranged to project to the extent of a quarter wavelength into the enclosed space S and the outer conductor of the line A is connected to the inner conductor of one of the balanced lines, while the inner conductor is connected to the inner conductor of the other of the balanced lines. As the line a projects a quarter wavelength into the space S, this space presents an infinite impedance to the line and all the current flowing in it must necessarily flow in the balanced conductors. Since the balanced lines are effectively connected in series across the line A, their surge impedances must necessarily be each equal to half that of the line. Fig. 2 shows a very slight modification of the device of Fig. 1, the balanced lines

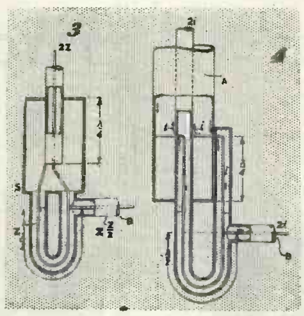


forming with the line A, a mechanical T-structure.

Fig. 3 shows a development of the device of Fig. 1 so as to obtain an impedance transformation in the ratio 4 : 1. Here the balanced lines are joined together with a half wavelength difference in length, their junction point being connected to the line B, which is of such impedance as to match the pair of balanced lines. This matching involves that the impedance of B should be half that of each of the lines. Thus, the impedance transformation in the ratio 4 : 1 is achieved.

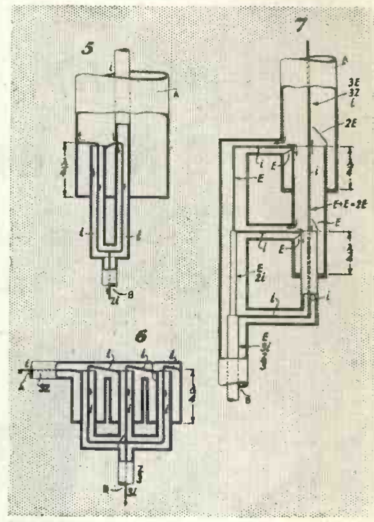
The device of Fig. 4 may be described as a modification of that of Fig. 3 to give an impedance ratio between lines A and B of unity, the two lines differing only in their physical dimensions. The balanced lines are connected to the line B in the same manner as before, but their inner conductors are connected, one to the inner conductor and one to the outer conductor of A in the somewhat different manner shown. If the current 2i flowing in at the conductor B is considered, this current splits into two currents i, each flowing in the balanced lines. With the longer of the balanced lines the current flowing on the inner conductor becomes a current i flowing in the outer conductor of A, while the current flowing in the outer conductor becomes a current i flowing on the inner conductor of A. Further equal currents i are contributed by the shorter of the balanced lines and currents of magnitude 2i are thereby set up in the inner and outer conductors of A.

Fig. 5 shows a device for achieving a 4 : 1 impedance ratio between lines of differing physical dimensions. Line B is branched into a pair of lines, the outer conductor of one of which becomes the inner conductor of line A.



The other of the branch lines projects into the space between the conductors of line A to the extent of a quarter wavelength and its inner conductor is connected to the outer conductor of A; its outer conductor is connected to the inner conductor of the first branch line. A current 2i flowing in at B divides equally into currents i flowing in the two branch lines; the current flowing in the outer conductor of the first branch line becomes the current on the inner conductor of the line A; the current on the inner conductor of the other branch line becomes the current in the outer conductor of the line A. The connexion between the outer and inner conductors of the branch lines can be achieved without setting up reflections, since at the connexion point the sum of the two travelling-wave currents incident upon this point is zero. It will thus be seen that the current 2i flowing in B becomes a current i in the line A. At the same time the voltage between the conductors of A is twice that of the voltage between the conductors of B in view of the connecting together of inner and outer conductors. The impedance transformation is thus in the ratio 4 : 1.

The method of connecting inner and outer conductors of branch lines to give a voltage transformation can be extended to give greater transformation



ratios, and the method is applied in Fig. 6 to obtain a transformation ratio 9 : 1. This demands that the conductor B should be divided into three branch lines. A current 3i flowing in B at a certain voltage thus becomes a current i flowing out at A at three times the voltage.

Another method for giving an impedance transformation in the ratio 9 : 1 is shown in Fig. 7. The line B carrying a current 3i is branched at a first branching point so that a current i travels down a first branching line and a current 2i travels down the continuation of B. This continuation is then branched again so that a further current i travels down a second branching line, and the remaining current, also of magnitude i travels down the further continuation of B which may be regarded as a third branching line. The branching lines are then joined together in the fashion shown in the figure, so that first and second branching lines meet in a first junction point, the paths between first branch point and first junction point being equal, while the second and third branching lines meet in a second junction point, the paths between second branching point and second junction point also being equal. The inner conductor of the first branching line becomes the inner conductor of the line a and supplies the current i in the inner conductor of the line A. The outer conductor of the third branching line is connected to the outer conductor of the line a and supplies the current i flowing in the outer conductor of A. At the first junction point, since the paths between branch and junction points are of equal length, the current in the outer conductor of the first branching line transforms into the current of the inner conductor of the second branch line. As with the device of Fig. 6, method can be extended by increasing the number of branching points to any desired number.

NOTES FROM THE INDUSTRY

Radio Component Manufacturers' Federation

At the luncheon of the R.C.M.F. on October 22, Mr. R. A. Watson Watt, C.B., F.R.S., the guest of honour, made one of his characteristically witty speeches. Dealing with post-war problems of radio, he suggested that even people who think that music is primarily based on the saxophone should be entitled to a 15 kc./s band width.

He would like to see our high-brow programmes kept as low as possible—even underground—in the interests of quality, and he visualised a national line distribution network for Regional programmes.

Other remarks which evoked laughter from the large audience were: "It wasn't for nothing that a Scotsman invented the Ionosphere—or rather it *was* for nothing," and "The measure of a healthy industry is the extent to which it has widened its specifications and narrowed its tolerances."

The chairman was Sir Percy Greenaway, Bart., a former Lord Mayor of London.

Bogus "Royal Radio Institution"

At Salford on September 24, R. W. N. Spencer, who described himself as Secretary and Proprietor of the Royal Institution of Radio Engineers was sentenced to twelve months' imprisonment for false pretences.

In passing sentence the Stipendiary said that he had no hesitation in describing the "Royal Radio Institution" as a ramp. It was alleged that Spencer had purchased the concern from a man named Gorman, who had originated the business because he could see that there was money in it.

There were no examinations and no application for membership had ever been refused. A 17-year-old typist acted as "registrar."

A large share of the credit for exposing this ramp must be given to the British Institution of Radio Engineers, which is a perfectly *bona-fide* organisation which has recently amalgamated with the Institute of Wireless Technology.

The president of the Brit. I.R.E. is Sir Arrol Moir, and the Secretary, Mr. G. D. Clifford informs us that they have never been remotely connected with the bogus concern referred to above. The registered address of the Brit. I.R.E. is Duke Street House, W.1.

New Adhesive for Bakelite

Messrs. Aero Research, Ltd., of Hinxton Road, Duxford, have sent particulars of their newly-developed adhesive "Ardux," which is capable of welding Bakelite mouldings and laminated sheet material with a strength greater than that of the original substance.

Two varieties are available: I for close-fitting joints and II where gap joints are required. It is not necessary to roughen the surface of the material and the surfaces to be joined are clamped together under uniform pressure and baked in an oven at 160° C. to set the jointing material. Flat sheets can be jointed by clamping them on a flat steam-heated table.

Further particulars can be obtained from Dr. N. A. de Bruyne at the address above.

Non-interfering Vibrators

One of the chief sources of radiated interference from vibrators at low frequencies is the rising and collapsing field on the battery leads which carry a pulse of several amperes at each vibrator contact operation. This current variation acting against the inevitable fraction-of-an-ohm resistance of the battery and leads can produce a field of several millivolts per metre.

In the new vibrator packs designed by Masteradio, Limited, for use with communication receivers the form of filtering is one which the vibrator derives each pulse of current from a large capacity fed from the battery through a balanced filter system. This ensures the battery leads carry D.C. only and moreover, since the quantity contained in the condenser is limited a certain amount of rounding-off occurs in the vibrator transformer primary current waveform. Other arrangements are available in which adjustment can be made to completely cancel out a known amount of ripple, in, say, a subsidiary supply to a microphone or valve filament.

A further modification of the waveform of the vibrator transformer current is obtainable by matching the time constant of a combination of condensers and resistances connected across the contacts of the vibrator, so that the time constant bears a relation to the time interval during which the contacts are moving within sparking distance. This has enabled a considerable reduction to be made in the R.F. contained in the waveform, apart from the amount inherent in the square waveform. By attention to the transition of the contacts over this critical period of their cycle, it is possible to increase the current rating without danger of sparking, or overheating, up to the normal rating of the contacts as for D.C.

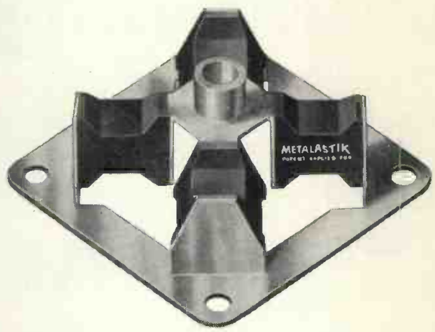
The details of these points have been covered in Patent Applications Nos, 3970/41 and 3971/41.

The Vibratorpacks are supplied as a self contained unit, in a cadmium plated steel case provided with terminals for input and output, measure 8¾ in. by 4¾ in. by 5¾ in. high, weighing 8½ lb. approx., and are built for use under tropical conditions.

For special requirements units can be designed to operate from up to 40 volts and give outputs of up to 60 watts.

Anti-Vibration Mountings

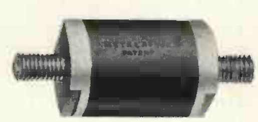
The difficulties in protecting high gain amplifiers from microphony due to floor vibrations are well known and have given rise to some Heath Robinson designs in rubber suspensions and spring mountings. The anti-vibration rubber mountings designed by Metalastik, Ltd., of Leicester, will be of particular interest to engineers who have amplifier installations in the neighbourhood of vibrating machinery. The photograph shows two types of mounting, one a rubber-metal



cross for holding instruments and the other a rubber rod with metal inserts which should be very suitable for chassis suspension.

One of the objections to rubber metal mountings of the conventional type is the tendency of the rubber to part company with the metal, but the special process used in the preparation of Metalastik mountings produces a metal-to-rubber "weld" which is proof against the severest torsional and shear stresses. In the ordinary tensile test the rubber still adheres to the metal after the breaking stress has been applied.

The end pieces for chassis mounting shown in the photograph below are supplied in five sizes from ⅜ in. dia. to ⅞ in. dia., the smallest having an overall length of 3/16 in. excluding threads.



The "Cross type" instrument mountings on which the chassis shown in the photograph is suspended, are a new development. They represent a great improvement on former types, having a greater load carrying capacity obtained by an increase in the inner bonding surface, and permitting absolute control of the movements in various directions. Dimensioned drawings can be obtained from the manufacturers at Evington Valley Road, Leicester.

Fire Extinguishing Powder

It is not often appreciated that there is a real fire risk in the processing of inflammable alloys such as magnesium, particularly when they give rise to fine filings and powder. While it is not possible to ignite these alloys in bulk, special fire precautions have to be taken in the treatment of swarf and grinding dust from machines.

Messrs. National Fire Protection Co., of Richmond, Surrey, have produced a fire-extinguishing powder which is particularly suitable for use with inflammable metals, not forgetting incendiary bombs. The " D.X." Powder is claimed to extinguish all fires in incendiary metals in their early stages. On application it melts into a viscous liquid which coats the unburnt metal and excludes oxygen. On cooling it again solidifies and enables the unburnt metal to be recovered for scrap.

If ignited by excessive heat from molten metal it burns with a light easily extinguishable flame. A very important feature of the powder is that it is non-abrasive and can therefore be liberally applied to machines without risk of damaging bearings, etc.

D.X. Powder (Pat. No. 518,717) is supplied in 56 lb. drums and should be kept by the machine ready for shovelling on to the fire. It is, of course, only one of the many fire-extinguishing products supplied by this firm, and manufacturers should apply for a series of instructive booklets on industrial and A.R.P. fire protection.

Beryllium Copper

THE unique properties offered by beryllium-copper have been familiar to designers for a number of years. The combination in this alloy of exceptionally high tensile and fatigue strengths, high hardness, electrical conductivity and resistance to wear and corrosion have established its great usefulness where such properties are demanded for heavy duty springs, current carrying parts of electrical equipment, instrument diaphragms and a variety of other components of precision equipment.

It is now announced by Mallory Metallurgical Products, Limited (an associate company of Johnson, Matthey & Co., Limited), of 78 Hatton Garden, London, E.C.1, that they are manufacturing an improved ternary alloy of this type, developed from the original beryllium-copper by the addition of a small percentage of cobalt, this resulting in improved and more uniform physical properties. This alloy, known as Mallory 73 Beryllium-Copper, is available as strip, wire and tube in the soft state for forming into springs, switch blades, contact clips, diaphragms, bellows and similar parts. After forming, a short precipitation hardening process develops maximum physical properties—a tensile strength up to 85 tons per square inch, a proportional limit of 50 tons per square inch and a hardness of 360 to 400 Brinell.

Leland Instruments

IN a full-page advertisement in our contemporary *The Wireless Engineer*, Messrs. Leland Instruments have published a letter to them from the Clough-Brengle Co., which reads as follows :—

" Gentlemen :

This will acknowledge your several communications relative to some unfounded doubt that we were appointing other distribution in the British Isles in competition to your interests. Let this letter assure yourselves or any authorised witness of it that your company continues as the sole authorised distributor of our products in the British Isles and that any representations to the contrary are unauthorised by this company.

As you must be aware, there has at no time been filed with you any communication signed by this company nor any officer thertof or any person or corporation having power of attorney for this company or its officers discontinuing or threatening to discontinue the trade relationship which has been existing for some time past. Further, there is no action contemplated by this company or its officers which would be prejudicial to the existing relationship."

(Signed) Kendall Clough, President.

This notification will remove any doubts which radio engineers may have had regarding the continuance of the service which Leland Instruments are giving in American equipment.

PATENTS RECORD

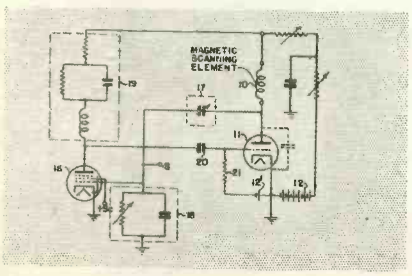
The information and illustrations on this page are given with the permission of the Controller of H.M. Stationery Office. Complete copies of the Specifications can be obtained from the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1s. each.

TELEVISION

Periodic Wave Generator

Current rises through the winding 10 and the internal resistance of the tube 11. This current rise produces a change of voltage across the tube 11 and the resultant drop in its anode potential is applied by way of the impedances 17 and 18 to the control grid of the tube 16. The tube 16 is thus cut off during this portion of the cycle of operation, which corresponds to the trace period of the generated periodic current wave through the inductance element 10.

After a certain period, the rate of rise of current through the winding 10 begins to decrease, due to anode saturation of the tube 11 or to curvature of its mutual-conductance characteristic, so that anode potential of tube 11, applied to the control grid of tube 16, increases positively. The latter tube begins to pass current, and the resultant drop in its anode potential is applied by way of condenser 20 and resistor 21 to the control grid of tube 11, serving still further to reduce the rate of rise of the current through this tube and actually to initiate a reduction of the current. Since this action is highly regenerative, the anode current of the tube 11 is rapidly reduced to a low value. The period of this rapid drop in anode current of the tube 11 through the inductance element 10 corresponds to the retrace period of the generated current wave. The grid of the tube 11 remains negative, maintaining the conductivity of this tube at a low value, only during the short retrace period after which the grid returns to its normal bias as determined by battery 12^1 so that the current again begins to rise through the inductance element 10 and tube 11 and the cycle begins anew.



—*Haseltine Corporation* (*Assignees of J. C. Wilson*). *Patent No.* 538,064.

Reception

An aerial system which substantially eliminates all of the vertically polarised wave components of a received and transmitted wave.

—*Standard Telephones and Cables, Ltd.* (*Assignees of A. Alford*). *Patent No.* 538,036.

RADIO AND COMMUNICATIONS

Diversity Reception

To provide means for automatically switching a receiver from an aerial in which the signal strength has fallen to a predetermined minimum to a second aerial receiving the same signal, but in which the signal can be of greater amplitude. An embodiment includes an arrangement responsive to the a.v.c. voltage for actuating either a mechanical relay or a pair of thermionic relays of different characteristics in a form of inverter circuit at the same location or at a different location for switching the receiver from one aerial to another.

—*Marconi's Wireless Telegraph Co., Ltd.* (*Assignees of H. O. Peterson*). *Patent* No. 537,937.

Transmission

A carrier wave communication system provided with means for maintaining the communication currents at or below a specified transmission level. A sending device is provided at one end for sending signalling currents at a definite level above that of the transmission currents, and a receiving device is provided at the other end responding to signalling currents, but not to communication currents.

—*Standard Telephones and Cables, Ltd., and B. B. Jacobsen. Patent No.* 537,966.

Improvements in Micro-wave Devices

A micro-wave device including a component for carrying high frequency oscillating current and a reflector associated with it spaced at such a distance, that the normal variation in frequency modulation or accompanying amplitude modulation, will not include the resonant frequency of the circuit corresponding to the reflected energy. The whole arrangement is such that the currents induced shall not pass through a critical phase change.

—*Marconi's Wireless Telegraph Co., Ltd.* (*Assignees of R. A. Braden*). *Patent No.* 538,040.

Thermal Converter Arrangement

A thermal converter arrangement for producing a d.c. voltage proportional to the product of two current inputs, comprising a set of thermocouples in bridge arrangement, a pair of input circuits conductively connected to the thermocouples and conjugate to each other, and a d.c. output circuit connected to them at points conjugate to the connexions of the inputs.

—*Weston Electric Instrument Corporation. Patent No.* 537,938.

ABSTRACTS OF ELECTRONIC LITERATURE

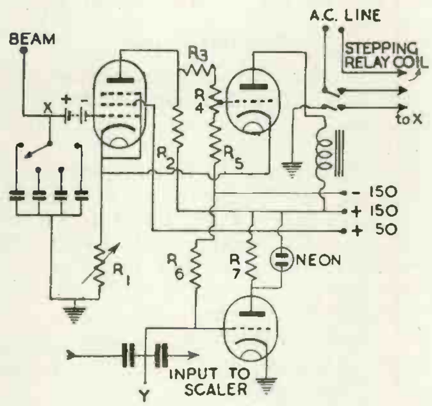
Circuits

A Valve Current Integrator

(G. J. Perlow)

In experiments in nuclear physics, the useful data are the numbers of disintegrations observed for a given number of particles striking a target. If the primary particles are charged, it is convenient to have a current integrator which will stop the counting after a given charge has been collected at the target.

In the apparatus described, the target current charges a condenser to a voltage sufficient to trip a trigger circuit which in turn operates an ordinary relay to discharge the condenser. A stepping relay is also employed. In the type used pulses through a coil cause a contact armature to advance successively over contacts arranged in a circle.



Component Values.

R1 200 ohms.	R4 20,000 ohms. pot.
R2 0.1 meg.	R5 0.5 meg.
R3 0.5 meg.	R6 & R7 1 meg. relay res.—2,500 ohms.

Valves: 6J7G and 6F8G.

The beam coming from the left is collected on any one of four condensers of different sizes and raises the grid potential of the pentode. The 45 volt bias battery insures that this valve is initially non-conducting. When the grid-cathode difference of potential reaches a point shortly above cut-off, the grid of the triode to the right, directly coupled and normally conducting, starts dropping rapidly, which decreases the current through the common cathode resistor R1 and diminishes the pentode bias further. The process is cumulative and very rapid. The result is that the triode is very nearly cut-off and the relay in its anode circuit is de-energised, thereby closing two pairs of contacts. One pair energises a stepping relay, moving its armature one step. The other pair shorts the charging condenser at the point X and drops the pentode grid voltage.

This is sufficient to restore the circuit to its initial state and the triode relay re-energises, permitting the stepping relay to recover and the beam to be collected again. When the stepping relay has made the proper number of steps, as determined by the switching system to its right, half of the armature shorts the beam at X, while the other half, by earthing Y, by-passes to earth the signals being counted. At the same time the grid of the lower triode is brought to the potential of its cathode and the neon lamp in its anode circuit turns on, indicating the end of the counting period. The circuit is re-set by keying the stepping relay once. This is best done by keying the pentode anode to ground.

—*Rev. Sci. Inst.*, Vol. 12, No. 8, August, 1941, page 412.

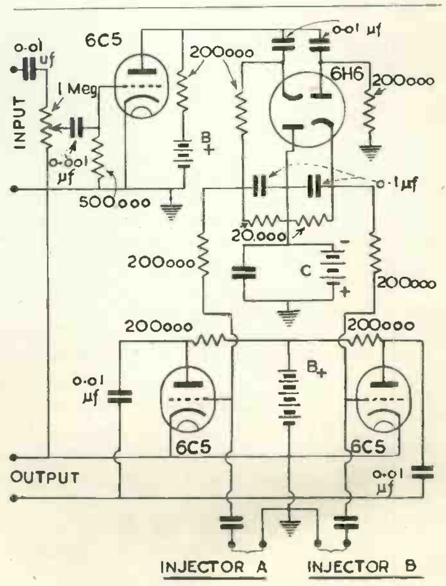
Half-cycle Electronic Switch

(E. Moen)

The first valve of the circuit, a 6C5, is a repeater-amplifier which may be a single valve oscillator. The amplified waves then enter a 6H6 "clipper" valve, in which positive crests enter one channel and negative crests the other channel. A battery and by-pass condenser are inserted to bias grids of the following 6C5's to or beyond cut-off until the appropriate voltage from each wave-crest is delivered by the 6H6. Then during the half-cycle in which the grid of one of the last two 6C5's is made sufficiently positive for the tube to be conducting, any signal voltage injected at A or B will be superimposed upon the input voltage.

The final resultant voltage can then be scanned on a cathode-ray tube if the scanning wave is made linear and synchronised with the original input.

—*Electronics*, Vol. 14, No. 8, August, 1941, page 54.



ABSTRACTS (*contd.*)

Industry

Mains Voltage Stabilisers
(Denco)

The author gives brief details of suggestions which have appeared in various foreign technical journals regarding electricity at stabilised mains voltage. In one form of stabiliser a mains voltage change of 5 per cent. is claimed to cause an output voltage change of 0.05 per cent. with a maximum operating time of 0.2 seconds and negligible harmonic distortion.

—*Electrician*, August 22, 1941, page 106.*

Metal Coating of Plastics

It is claimed that in the process of coating plastics with zinc, aluminium, copper, or tin, the metal particles join with the synthetic resin particles, and therefore strengthen the surface of the moulded article. The process can also be applied to cast resin and to laminated and cellulose products. Results are given of tests carried out to compare the electro-magnetic screening properties of the metal film with tinfoil of the same dimensions.

—*Br. Plastics and M.P.*, September 1941, page 106.*

G.E.C. Heavy Alloy
(Price, Williams and Garrard)

In this article, the authors describe the preparation properties and industrial uses of an alloy which is stated to be fifty per cent. heavier than lead and to have the tensile strength of a good quality steel. It consists essentially of tungsten, and is made by a powder metallurgical process. Its high density makes it suitable for screening purposes, such as for radium containers, while its good resistance to arcing makes it suitable material for circuit breaker contacts.

—*G.E.C. Journal*, August, 1941, page 223.*

Theory

Frequency Response of Parallel Resonant Circuit
(M. B. Reed)

This paper gives in a readily usable form the results of a complete mathematical study of the current versus frequency response of the wave trap.

—*Electronics*, Vol. 14, No. 8, August, 1941, page 43.

Some Analyses of Wave Shape used in Harmonic Processes
(F. R. Stansel)

Analyses by Fourier's series have been made of waves consisting of sinusoidal, rectangular and trapezoidal pulses and also waves of the type found in multi-vibrator circuits. The method of increasing harmonic content by modulating a wave with a submultiple is treated mathematically.

—*Bell System Tech. Jour.*, Vol. 20, No. 3, July, 1941, page 331.

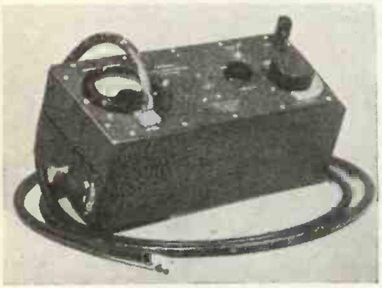
*Supplied by the courtesy of Metropolitan-Vickers Elec. Co., Ltd., Trafford Park, Manchester.

A New Portable Wavemeter

H. Tinsley & Co's. Model 4825

THIS instrument was developed to meet the demand for a portable wavemeter which would have a high degree of sensitivity and discrimination, for frequencies ranging from 160 megacycles to 260 megacycles.

Its advantage over the absorption type wavemeters, generally in use for the same frequency band as portable instruments, is greatly superior sensitivity and greater accuracy. The instrument was developed by Pye, Limited, Radio Works, Cambridge, and H. Tinsley & Company, Limited, London, S.E.25, which latter are taking up quantity production.



Specification

Frequency range on single continuously variable dial:

160 to 220 Mc./sec. or, alternatively, 210 to 260 Mc./sec. (the instrument can cover either one or the other frequency range, but not both).

Performance.

A voltae of 3mV. at the end of the artificial line attached to the wavemeter will produce a deflection of not less than 20 per cent. full scale on the indicating instrument (that is, 20 per cent. full scale for resonance). Selectivity is such that ½ Mc./sec. can be discriminated. Accuracy is of the order of ¼ per cent.

Supply:

Either a 6 volt battery or 230 volt, 50 cycle mains, according to whether vibrator unit or mains eliminator unit is supplied. (The wavemeter can, of course, be supplied with both units, in which case one of them is supplied as a separate item).

Overall dimensions: 12 in. by 5½ in. by 5½ in. Weight: Approximately 12 lb.

The instrument is supplied in a teak case which contains a compartment for the calibrated artificial line, which plugs into the wavemeter and serves as aerial.

The price or any further particulars can be obtained on application to H. Tinsley & Co., Ltd., Werndee Hall, S.E.25.

The Stability of Electron Multipliers (*Contd.*)

structions of single stage secondary emitters the secondary emitter is sometimes shielded, where the thermionic cathode employed is of normal dimensions rated to give an electron current of 10 or more milliamperes. In the case of the Augetron multi-stage electron-multiplier, however, the initial current is less than 10 microamperes and hence with a small thermionic cathode the amount of barium to settle is small. This in any event has to pass through the opening of the accelerator plate, which has been reduced to a minimum, so that this and only the first secondary emitter will be affected by this phenomena. If, however, such poisoning actually took place this would result in a gradual decrease in the secondary emission ratio of the first secondary emitter and would not affect the remaining secondary emitters a definite advantage of the multi-stage secondary emission tubes. We have not so far observed this phenomena in Augetron tubes during life tests.

Apparent instability may be caused by unsuitable test equipment. Voltage supply should be perfectly stable so as not to affect voltage distribution resulting in variations in secondary emission. When testing an Augetron with thermionic cathode for pure static tests care should be taken to protect the multiplier against self-oscillation by shunting both grid and cathode with a condenser of .001 mfd. In doing so, using as short leads as possible, it should be remembered that the Augetron is a high-gain and very sensitive tube, and therefore oscillates very easily.

When instability is observed it is as well to run the tube in darkness and observe for either a gaseous glow, which has been mentioned already, or for fluorescent effects. These fluorescent effects may be caused by the building up of electric charges upon insulators in the vicinity of the electron stream, which may result in some irregularity of behaviour. The actual nature of the charges on insulators is very complex and the actual potential at any point will depend on the instantaneous value of secondary emission of that portion of the surface. It is possible for an insulator to attain by virtue of secondary emission a positive potential, and these potentials are obviously irregular and subject to very sudden changes. In the Augetron steps to obviate this possibility have been taken with success.

When examining secondary emission tubes for instability it will be found that there is in most cases a minimum condition for which the tube will remain stable, and it must be these conditions which will lead to the cause of the instability. In the case of the Augetron all possible constructional or processing causes for instability having been obviated it will be generally in the circuit arrangement or the apparatus in which the Augetron is used which will cause instability.

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