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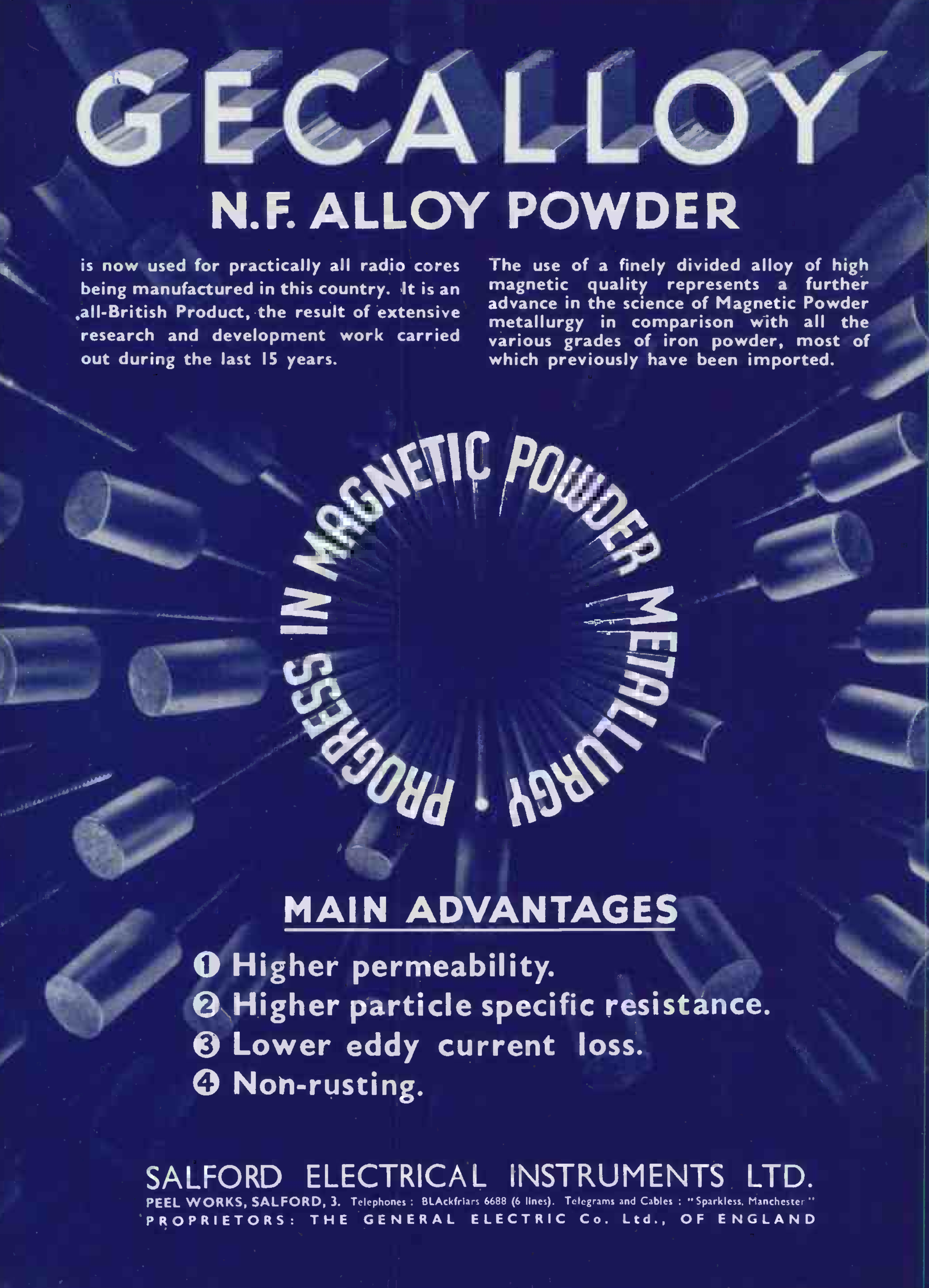
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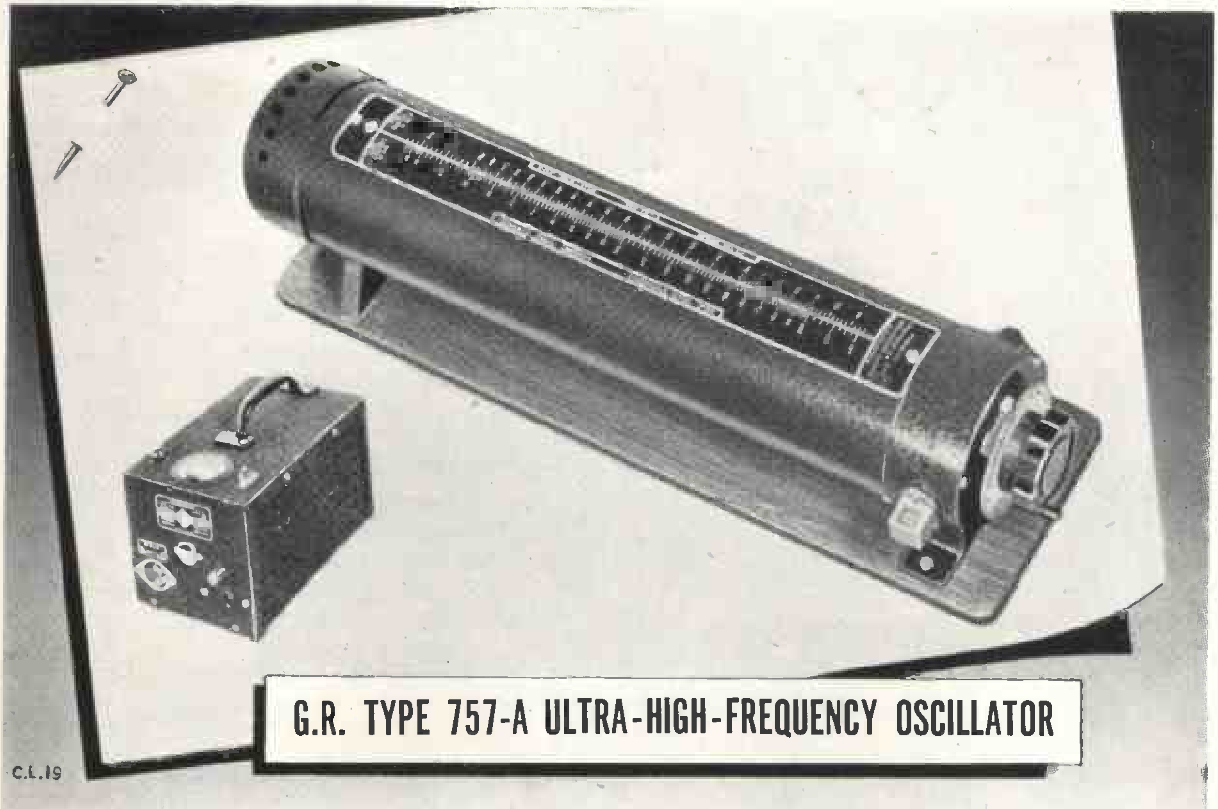

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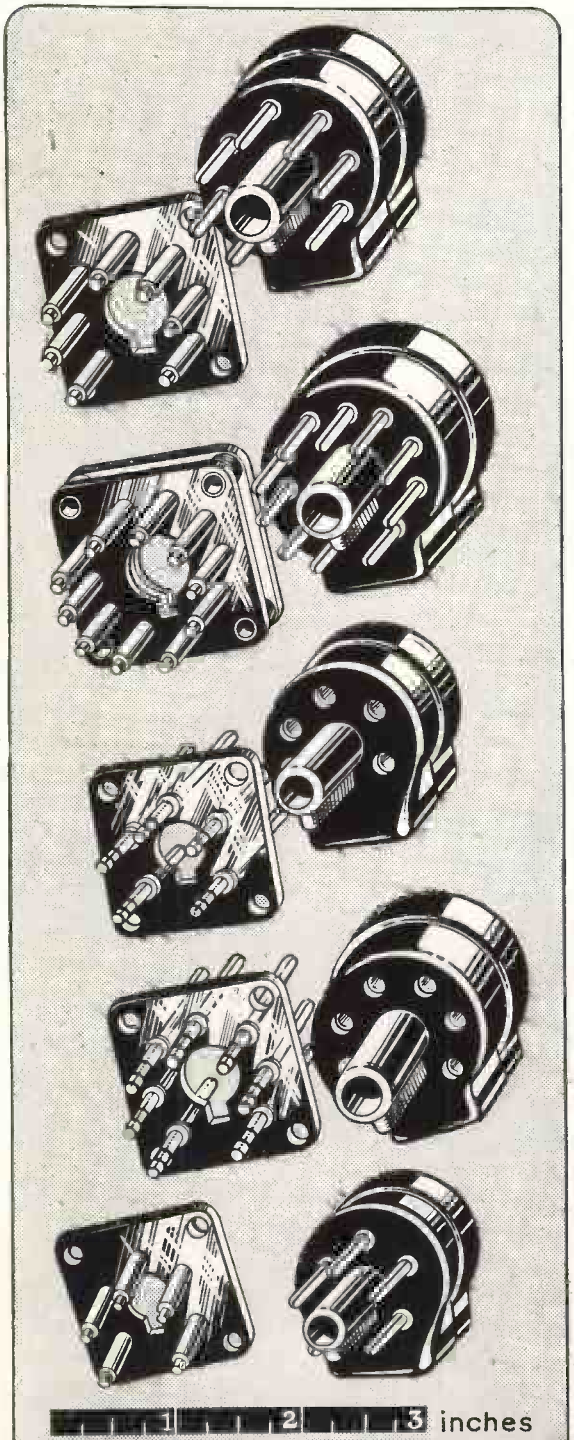
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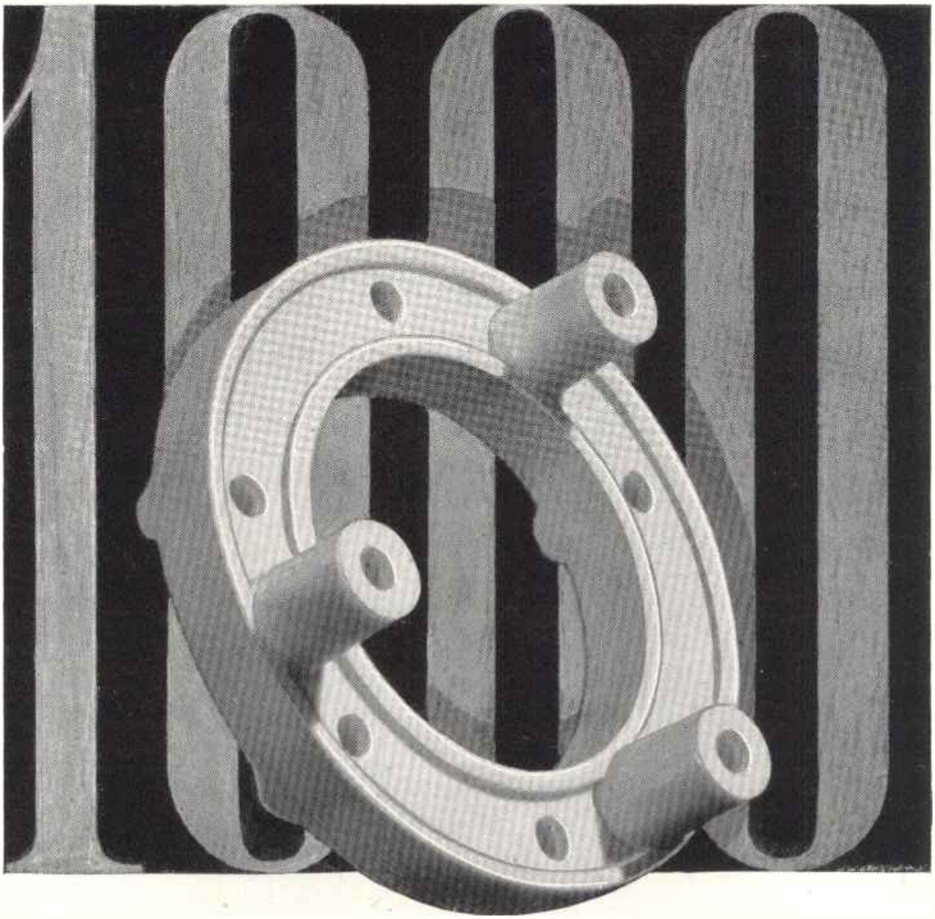
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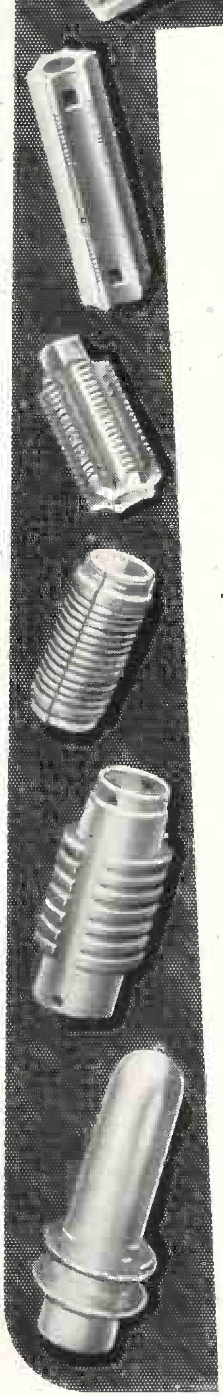

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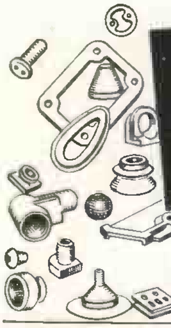

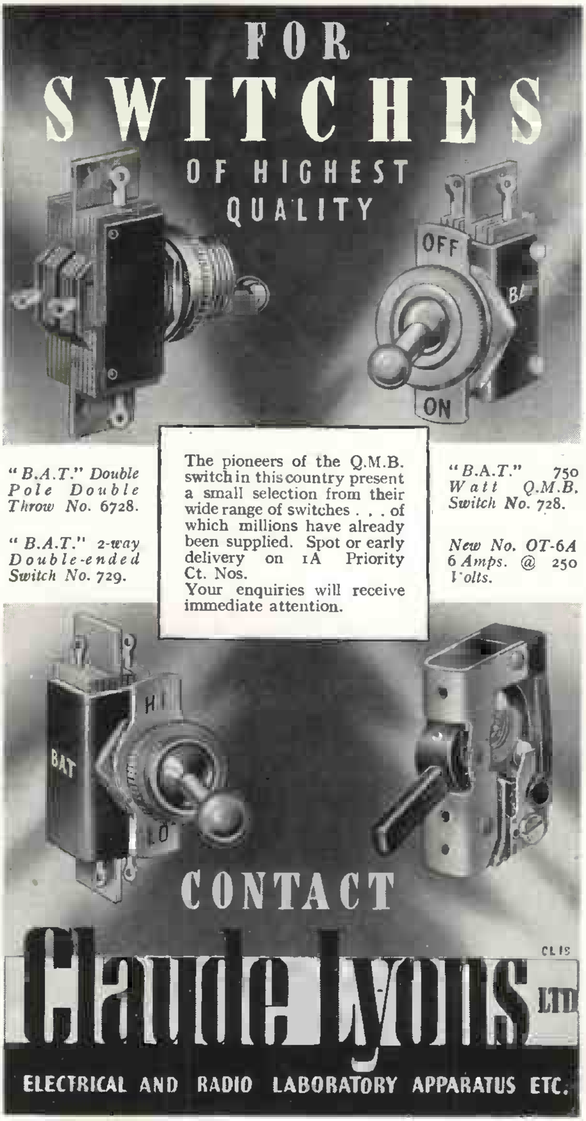

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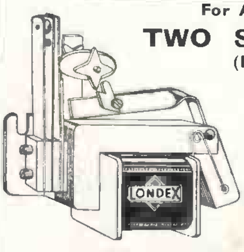

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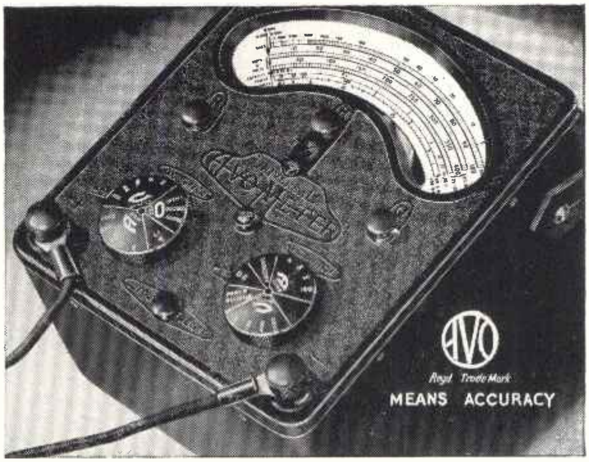
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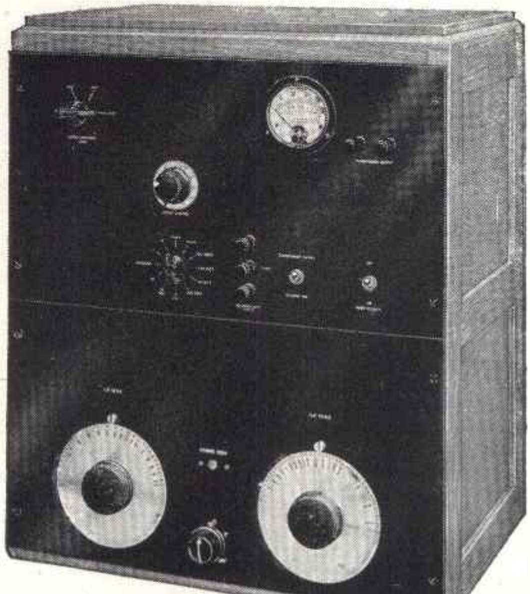


WIRELESS
ENGINEER

Editor HUGH S. POCOCK, M.I.E.E. Technical Editor Prof. G. W. O. HOWE, D.Sc., M.I.E.E.

VOL. XX MARCH, 1943 No. 234

Editorial

Fundamental Electromagnetic Concepts and Their Dimensions

IN the Editorial of our January number, we reviewed briefly the spate of articles on the subject of dimensions that has poured forth during the last year or two into the pages of the *Philosophical Magazine* and the *Proceedings of the Physical Society*. Some of these articles were constructive but others were calculated to make confusion worse confounded, and we therefore consider it opportune to set out clearly what we consider the reasonably indisputable dimensional relations between the various concepts by means of which electromagnetic phenomena are described. In addition to the three almost universally accepted fundamentals, viz., L, M, and T, we shall regard one of the electromagnetic magnitudes as fundamental, and for the present purpose we shall take either a quantity of electricity or an electric current; everyone is agreed that a coulomb is an ampere-second, and how the unit is otherwise defined is immaterial at the moment. We may imagine that, in addition to the standard metre and standard kilogramme, there is at Sèvres also a standard ammeter. Anyone who finds this too great a strain on his imagination may substitute the ampere-balance at Teddington. Unlike the metre and the kilogramme standards, the ampere standard is checked and corrected from time to time to bring it into closer agreement with what it is supposed to be.

We now consider a coil, a solenoid say, or preferably a uniformly wound toroid, through which we pass a current. The effect of this is to produce a magnetic field, or, to be more precise, to produce at each point a magnetic induction B. The prime cause of this magnetic induction is the current in the coil, or the total ampere-turns—the so-called magnetomotive force—but this can be divided by the length of the magnetic path, and the magnetic induction B at any point can be regarded as the effect of this localised magnetising force H of so many ampere-turns per cm at the given point. (We are purposely omitting such numerical coefficients as $4\pi/10$). Only in the case of a toroid can the ampere-turns be simply divided by the length; in other cases they must be distributed over the length of the magnetic path in a way depending on the values of B and μ from point to point. This is strictly analogous to the concept adopted in the application of a load to a specimen in a tensile strength testing machine. The applied mechanical force causes a strain throughout the material, and the strain at any point is regarded as the effect of a localised stress of so many pounds per square inch acting at the point. In the ideal case of uniform strain the stress is calculated simply by dividing the applied force by the area, but in other cases the force must be distributed over the area in a way depending on the values of the strain and Young's modulus from point to point. The magnetising force H and the mechanical stress have also this important characteristic in common, that they cannot be experimentally observed or measured, but must be deduced from their observed results, *i.e.* from the magnetic induction or the strain, or, in the ideal uniform cases, from their integral values, viz., the total applied magnetomotive force or mechanical force and the length or area over which they are distributed. Just as stress = force/area so H = magnetomotive force/length.

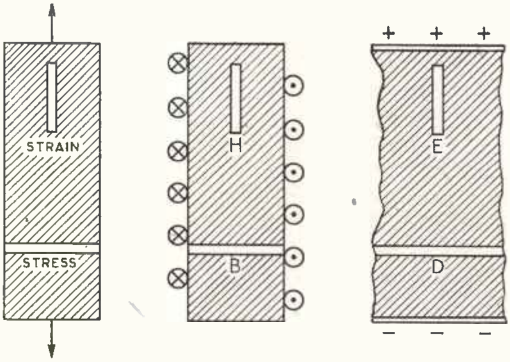
The Unit-pole Myth

The unit-pole concept—one might almost say myth—has led to the idea that H can be measured. The unit north pole is obtained by magnetising a steel needle of such a length that the south pole is so far away that its effect can be neglected, and then assuming that the north polarity is all concentrated at a point. If we overlook these disadvantages and try to determine whether the force on the pole is a measure of H or B, we are immediately faced with the question as to what would happen to the magnetism of the needle if it could be immersed in a medium having a permeability differing from that of space or air. It is meaningless to say that it is assumed to retain unit strength, because unit strength has only been defined in space. If we were to replace the steel needle by a long solenoid of small diameter, we could maintain the current constant when the solenoid was placed in various media. Although we have no liquid or gaseous medium with a permeability differing appreciably from that of space, no one doubts that, if it were possible to carry out such an experiment, the force on the solenoid would be found to be a measure of B and not of H. The force on the solenoid could be made proportional to H by always adjusting the current to be inversely proportional to the permeability of the medium. This indicates that the unit pole must be assumed to have constant magnetic flux when transferred to various media, that is to say, the surface integral of the normal component of B taken over the whole pole must be assumed to remain constant ; but surely all this undermines its qualifications for playing the rôle of a fundamental character.

Although, in imitation of the shape of the magnetised knitting needle, we assumed above that the coil that replaced it was a long solenoid of small diameter, this is not really necessary. It might consist of a single turn.

Like stress, H is real in the sense that it is $\frac{4\pi}{10}$ times the quotient of two real things, viz., ampere-turns and length.

The crevasse and tunnel method usually employed for defining B and H is closely analogous to something that could be done to define strain and stress in the specimen under tensile test. In both cases we wish to determine two things, only one of which can be measured. We make very narrow longitudinal tunnels and very thin transverse crevasses and fill them with some standard material or medium, platinum, say, in the mechanical case, and space—or ether if you prefer it—in the magnetic case. In the mechanical case the observed strain of the standard material in the tunnel is equal to the strain in the material under test, whereas the observed strain in the crevasse may be very different ; it is a measure of the stress in the standard material and therefore of that in the material under test. Similarly in the magnetic case the values of B in tunnel and crevasse can be determined—at least in imagination—by the force on a current-carrying conductor or in some other way. Here it is the observed value of B in the crevasse that is equal to that in the iron, while that in the longitudinal tunnel, which may be very



Mechanical, magnetic and electrical applications of the tunnel and crevasse.

different, is a measure of the magnetising force in the iron. This difference is in keeping with the fact that the total force is obtained by integrating the stress over the transverse area, whereas the magnetomotive force is obtained by integrating the magnetising force over the length.

It is important to note that, although the same thing is measured in both tunnel and crevasse, one of the measurements is used to determine something entirely different in the material under test. It is for this purpose that the tunnel and crevasse are filled with a standard material or medium. This disposes of the argument sometimes advanced that B and H must be of the same nature because they are both measured in the same way. The same might be said of the stress and strain.

The Electric Field

Turning now to the electric field, let us consider a parallel plate condenser. If a given charge—either the unit or some quantity measured in terms of the unit—is placed in the field between the plates, it experiences a force which depends only on the strength $\mathcal{E}$ of the electric field, i.e. the PD divided by the distance, irrespective of the medium between the plates. $\mathcal{E}$ then, and not the displacement D, is the magnitude that can be measured. To obtain D we divide the total quantity Q which constitutes the charge by the area—at least, in the simple case of uniform displacement; in other cases Q must be distributed over the cross-sectional area in a way depending on the values of $\mathcal{E}$ and κ from point to point.

Here again in the case of a solid dielectric one can adopt the idea of a longitudinal tunnel and a transverse crevasse filled with a standard medium, viz. space. In both cases the force on the unit charge is a measure of $\mathcal{E}$ in the space; in the tunnel it is a measure of the value of $\mathcal{E}$ in the solid substance, whereas in the crevasse, the observed value of $\mathcal{E}$ enables us to determine the value of D in the space and therefore also in the solid material. Here again, this is strictly analogous to the mechanical case. Like H, D is real in the sense that it is the quotient of two real things, in this case a quantity of electricity and an area.

The Unit of Current

Let us now return to the question of the unit of current, which we have assumed to be one of our fundamental magnitudes with the same status as the metre, the kilogramme, and the second. If we pass a current round a single turn of r centimetres radius, it will produce in space at the centre an axial magnetic induction, and if we pass the same current through 1 centimetre of wire placed at the centre in the plane of the coil, it will experience a force. We now adjust the current until the force is exactly $2\pi/r$ dynes, and we take this current as the c.g.s. electromagnetic unit of current, a tenth of which is taken as the practical unit—the ampere. It is perhaps simpler to consider a long solenoid of 1 turn per centimetre with 1 cm of wire at right angles to the axis connected in series with the solenoid, and the current adjusted until the force is exactly 4π dynes; this will require the same current as the single-turn coil, viz. 10 amperes. H is by definition the magnetomotive force per cm, *i.e.* $4\pi/10$ times the ampere-turns per cm, which gives $H = 4\pi$. Since the unit of B is so chosen that the force on the centimetre of wire is equal to $IB/10$ dynes, B is also 4π. Thus we see that the units of H and B have been so chosen that the two magnitudes are numerically equal in space.

The experimental determination of the unit of current is, of course, not carried out exactly as we have described, but the principle is the same as that of the ampere-balance at the National Physical Laboratory.

Some one may point out as an objection to the above as a definition of a fundamental magnitude, that it involves a property of space, viz. its permeability. This is true, but as a reply to such an objection one need only draw attention to the fact that the unit of mass depends not only on that of length, but also on a property of water, viz. its density, which is much more fickle than the permeability of space, unless the latter plays unsuspected tricks.

We are now in a position to express the various concepts dimensionally. Since the force on an element of wire of length ds carrying a current I amperes in a magnetic field is equal to $BdsI/10$ dynes, we have $B = \text{force}/IL = M/IT^2, = M/QT$, and since $H = I/L$, we have $\mu = B/H = \text{force}/I^2$

$= ML/I^2T^2 = ML/Q^2$. Since EIT = energy we have $E = ML^2/IT^3 = ML^2/QT^2$.

Since $\mu = ML/Q^2$, Q^2 can be replaced in any dimensional equation by ML/μ; for example, inductance $= \Phi/I = BL^2/I = ML^2/I^2T^2 = ML^2/Q^2$ or $BL^2/I = BL^2/HL = \mu L$.

An International Commission has recommended as the fourth fundamental magnitude, not a current or quantity of electricity, but the permeability of space—or a multiple of it—which, as we have seen, is involved with L, M, and T in our definition of unit current.

Turning to the electrostatic field we have $D = Q/L^2$ and $\mathcal{E} = E/L = ML/QT^2$; hence $\kappa = D/\mathcal{E} = Q^2T^2/ML^3$, or putting $Q^2 = ML/\mu$, $\kappa = \dfrac{T^2}{\mu L^2}$ and $\kappa\mu = T^2/L^2$. Hence $\kappa\mu = 1/(\text{velocity})^2$—a very well-known relationship.

It is perhaps unfortunate that there is no gaseous or liquid medium with a permeability differing very much from that of space, in which we could immerse our unit poles, and in which we could measure the forces exerted on current-carrying wires. In solids the crevasse method is usually impracticable and we are compelled to determine the magnetic induction in another way, viz. by measuring the quantity of electricity that passes round a circuit when the magnetic flux through it is reversed. In a gas or liquid one can do this by rotating the coil, but in a solid one has usually to do it by reversing the magnetisation of the solid. Since $E = \Phi/T = BL^2/T$ and EIT = energy $= ML^2/T^2$ we have $B = M/IT^2$, which is, of course, the same dimensional equation as was obtained above. This method of determining B gives the average value, since it is really the flux Φ that is determined and this is simply divided by the cross-sectional area.

If the various dimensional equations established above are examined it is found that in every case they involve two electromagnetic magnitudes, so that it is impossible to express any electromagnetic magnitude in terms of L, M, and T alone, unless one is prepared to make some arbitrary assumption. By suppressing the permeability of space and putting $\mu = 1$ in the dimensional equations, after having replaced κ, wherever it occurs, by $T^2/\mu L^2$, the so-called electromagnetic system of dimensions is obtained. By suppressing the permittivity of space and putting $\kappa = 1$, after having replaced μ, wherever it occurs, by $T^2/\kappa L^2$, the so-called electrostatic system of dimensions is obtained. Such arbitrary assumptions are bound to lead to differences of opinion and we doubt the utility of the controversies which arise from time to time as the result of such arbitrary assumptions. Perhaps the most interesting assumption was suggested by Fitzgerald in 1889, viz. to assume that μ and κ have the same dimensions, which, since $\mu\kappa = \dfrac{T^2}{L^2}$, must be T/L, *i.e.* the reciprocal of velocity. The dimensions in this so-called consolidated system must, of course, be the geometric mean of those in the electromagnetic and electrostatic systems.

Surprise is sometimes expressed that the velocity of light should enter into calculations that do not involve any optical phenomena, but are concerned with experiments that could be done in the dark. This, however, is not surprising. Electromagnetic waves are propagated through space at a definite velocity which presumably is determined by certain electromagnetic properties of space. Sound is transmitted through air at a velocity depending on two mechanical properties of the medium, viz. its density and its compressibility (the reciprocal of its bulk elasticity) and the velocity is related to these two properties in exactly the same way as the velocity of electromagnetic waves is related to the permeability and permittivity of the medium. Hence in both cases one of the properties can be expressed in terms of the other property together with the velocity. Now there are numerous experiments that can be performed with air or other gases or liquids or solids, which do not involve sound waves, and can be carried out in silence, but which do involve the density or the compressibility. Similarly with electromagnetic experiments, they may not involve light waves but they may involve μ or κ, either of which can be expressed in terms of the other and the velocity of light. Similarly it is not surprising that the velocity of electromagnetic waves enters into the relations between the units in the two systems, one of which is based on an experiment involving the permeability, and the other on an experiment involving the permittivity of the medium.

With regard to the suggestion that B and H should be regarded as having the same dimensions, and their quotient μ therefore as a dimensionless numeric, it should be pointed out that similar arbitrary assumptions could be made about more familiar magnitudes. In the case of the sound wave just considered it would be possible to assume that mass and volume had the same dimensions and that the density ρ was consequently a dimensionless numeric. The assumption that μ is a numeric reduces the number of fundamental magnitudes from four to three by eliminating the electromagnetic one; the further assumption that ρ is a numeric would reduce the number to two, through the elimination of M by means of the equation $M = L^3$, but *cui bono?*

G. W. O. H.

Standards and Standardisation*

By W. H. F. Griffiths, F.Inst.P., M.I.E.E., M.I.R.E.

SUMMARY. The difficulties of "standardising" the grading of electrical standards for the communication industry are dealt with.

An attempt is made to define "accuracy" as applied to standards of self-inductance, capacitance and resistance. The many different values of accuracy which may be associated with these standards are enumerated, examined and related.

The effects of frequency upon the accuracy of standards of self-inductance, capacitance and resistance are then considered, followed by a detailed enumeration of the various factors which influence these effects.

Finally, the accuracies available commercially are given with reference to a series of curves showing the inaccuracies of modern standards.

Introduction

THE Editorial of the August issue of this journal must have been of interest to engineers and research workers in all branches of communication engineering. The need for the clarification of the grading of standards, especially those of capacitance and inductance, has long been felt, and the "Orders of Precision" proposed in the Editorial referred to may form a basis for some kind of standardisation. The proposed scheme, which is based upon the logarithm of the reciprocal of tolerance, is reproduced here for convenience.

Tolerance %	Reciprocal of Tolerance	Logarithm of Reciprocal	Order of Precision
1	1	0	O
0.1	10	1	I
0.01	100	2	II
0.001	1,000	3	III

This grading is probably too coarse for universal use by the manufacturer, for while it is relatively easy to improve the design of a 1 per cent. *standard* † until an accuracy of 0.1 per cent. is reached, it may be only with extreme care, and at great cost, that an accuracy of, say, 0.03 per cent. is attained. Having been at pains to produce this 0.03 per cent. standard, could the manufacturer, in fairness, be asked to classify it as having only a grade I "order of precision"? But to improve the product still further from 0.03 per cent. to 0.01 per cent. might in most cases, and by most manufacturers, be considered uncommercial. One conceivable result of such coarse grading therefore might be the elimination of many extremely useful standards of intermediate accuracy.

The grading is particularly coarse when applied to inductances, condensers and resistances, for these products can hardly be termed standards if their inaccuracies at ordinary frequencies are greater than 0.1 per cent. whereas it is only with great diffi-

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* MS. accepted by the Editor, October, 1942.

† The term standard is applied, somewhat loosely, throughout this article to any instrument with which a calibration is associated and which is used to calibrate other products.

culty that an accuracy of 0.01 per cent. is surpassed even at low frequencies.

Apart from this difficulty of coarseness, however, the author feels that the grading of standards of any electrical quantity should be relative to the best accuracy to which measurements of that quantity are usually possible.

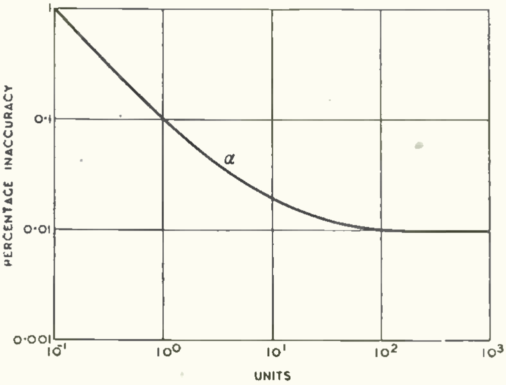

Fig. 1. *The inaccuracy of a typical decade standard. The total value of this standard is* 1,000 *units, four decades giving finest increments of* 0.1 *unit.*

Thus the grading could be

$$\log . \frac{\text{innacuracy}}{\text{lowest inaccuracy possible}}$$

The best standards of *any* quantity, therefore, would always be termed grade 0 (no avoidable error) standards followed by grade 1 standards and finally by those of grade 2. Such a scheme could be made to embrace the standards of quantities of widely different accuracies and could be applied to standards other than those of an essentially electrical character. Assuming the following to be the best accuracies possible in commercial measurements and in the standards by which such measurements are governed:

Frequency (standards)* . .	0.0001%	or 1 part in 10^6
Frequency (resonant circuit wavemeters)	0.01%	or 1 part in 10^4
Resistance† . .	0.01%	or 1 part in 10^4
Inductance . .	0.01%	or 1 part in 10^4
Capacitance . .	0.01%	or 1 part in 10^4
Current‡	0.1%	or 1 part in 10^3
Voltage‡ . .	0.1%	or 1 part in 10^3
Power‡	0.1%	or 1 part in 10^3

the accuracies associated with the various quantities in which the radio engineer is more particularly interested would be as tabulated below.

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* The best accuracy of frequency measurement may be nearer 1 part in 10^7, but such an accuracy cannot perhaps be regarded strictly as commercial.

† Direct current resistances of fixed value of the oil immersed sub-standard type, such as are to be found in the laboratories of standardising institutions and instrument makers, may, perhaps, be considered to be accurate to 1 or 2 parts in 10^5. The use of these standards is not strictly commercial however and is too limited to permit their inclusion in a universal classification.

‡ Measurements of voltage, current and power may be effected to a better accuracy by means of a standard cadmium cell and accurate potentiometer. It is thought, however, that such measurements, and those in which a Kelvin ampere balance is employed, are, owing to their limited application, outside the scope of this proposed classification, especially as there are no actual "standards" of corresponding accuracy.

Quantity	Inaccuracy (per cent.)		
	Grade 0	Grade 1	Grade 2
Frequency (standards) . .	0.0001 (1 pt. in 10^6)	0.001 (1 pt. in 10^5)	0.01 (1 pt. in 10^4)
Frequency (resonant circuit wavemeters)	0.01 (1 pt. in 10^4)	0.1 (1 pt. in 10^3)	1
Resistance	0.01 ,,	0.1 ,,	1
Inductance	0.01 ,,	0.1 ,,	1
Capacitance	0.01 ,,	0.1 ,,	1
Current	0.1 (1 pt. in 10^3)	1§	?
Voltage	0.1 ,,	1§	?
Power	0.1 ,,	1	?

§ It will be seen that these inaccuracies agree with the British Standards Institution specification for first grade accuracy. The same specification, however, determines second grade accuracy as 2 per cent., thus tending to show that the above classification is too coarse for commercial meters.

The inaccuracy used for grading in this manner should be that of adjustment to nominal value plus a reasonable allowance for change of value with age and with varying ambient atmospheric conditions. If such accuracy is obtained only after calibration corrections are applied to the reading or nominal value of the standard the suffix *C* should be added, thus :—Grade 1 *C*. Much thought would have to be given to such a scheme before it could be adopted. It is by no means complete because the best accuracy associated with any of the above quantities will vary with the order of value* and with frequency† ; it will be complicated by the range‡ in the case of an adjustable standard, and it is too coarse for all standards except those of frequency.

Before such a scheme of grading can be discussed usefully, or, once agreed upon, employed intelligently, the communication engineer may need to be educated in the orders of accuracy to be expected of standards under varying conditions. This may apply more particularly to some radio engineers who, on account of specialisation, are divorced almost entirely from the low frequencies at which most standards have their basic and best accuracy.

Accuracy—A Variable

Before discussing the accuracies of particular standards an attempt should be made to define " accuracy " as applied to standards of inductance, capacitance and resistance. These standards are important because the electrical quantities which they govern represent the properties of circuits. It is possible to set up *and preserve* standards of resistance, inductance and capacitance and to reproduce them industrially with greater facility than is possible in the case of current or voltage. The ratio of the volt to the ampere is determined by the value of the ohm which may therefore be reproduced accurately by employing the effects of voltages and currents of somewhat less accurately known values. It follows that this is true also of the henry and microfarad. Frequency standards alone are capable of a still higher order of accuracy since they may be standardised entirely in terms of time and are not dependent upon electrical quantities. For this reason frequency standards cannot be grouped with electrical standards when discussing accuracy and are therefore considered to be outside the scope of the present article. In passing, however, it should be remembered that the most accurate measurements of small electrical quantities may sometimes be effected by means of their influence upon frequency.

The closeness of adjustment to a nominal value is often—far too often—accepted as " the accuracy " of a standard. Even this simple gauge of quality, erroneous though it often is, cannot be constant throughout the range of a standard of widely adjustable value. The accuracy of adjustment to nominal value of a standard of four decades usually varies somewhat as shown in Fig. 1. In this case, however, it is usually accepted that for accurate work the decades of lower denominations should not be used alone, but should be used rather for the finer subdivision of the major decades. Thus the accuracy of the standard is generally rendered more concise at the expense of range. For this reason, whenever possible, in bridge measurements, the highest decade of a standard should be arranged to be included in the circuit by an appropriate adjustment of the ratio of arm impedances.

There are, however, other factors which make it difficult to assess concisely the accuracy of a standard. Ignoring, for a moment, the effects of frequency, there are the following four distinct values of accuracy, or rather inaccuracy* which may be associated with the *true* value of a standard.

α — the inaccuracy of adjustment to *nominal* value at a frequency f_0 sufficiently low to avoid the effects of frequency upon that value.†

α_0 — the inaccuracy of statement of *actual* value at this low frequency. This is not

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* See Figs. 5, 6, 12, 18 and 21.
† See Figs. 7, 13, 19 and 25.
‡ See Figs. 5, 12, 18 and 22.

* It is confusing sometimes to speak of 0.01 per cent. being a *greater* accuracy than 0.1 per cent. It is better to use the terms *superior* and *inferior*. Much confusion, however, is avoided by speaking of inaccuracy when the more quantitative terms *greater* and *less* may be used with complete safety.

† Standards are sometimes adjusted to be accurate at a particular frequency, but except for special applications this is not good practice.

governed by the standard itself* but by the accuracy of the measurement by which it is standardised. The accuracy of measurement is, in turn, governed by the accuracy of the knowledge of the ultimate standard against which the comparison is made and by the sensitivity of the method of comparison. The latter, however, is not usually of importance in these days of high gain amplifiers for bridge balance detection and powerful oscillators of sinusoidally pure waveform.

α'_0 — the probable change in the actual low frequency value with age. This is usually termed the long period permanence and is governed by the design of the standard generally—particularly in the choice of materials—and in the quality of craftsmanship employed in its construction. This inaccuracy factor depends to some extent upon the time which has elapsed since the most recent determination of actual value—it may be eliminated altogether by standardisation immediately prior to use. The nature of the treatment (mechanical, electrical and atmospheric) to which the standard has been subjected since its most recent calibration will sometimes influence this factor.

α''_0 — the short period instability of *actual* low frequency value. This embraces temperature and humidity coefficients and, like α'_0, is governed by design and perfection of construction[1] [2]. The choice of materials plays an important part in the stability of a standard.

It would seem that α, α_0 and α'_0 must all be combined in some way to form a concise figure of overall inaccuracy. It is obvious, however, that α and α_0 are alternatives and only one of these need be added to α'_0 depending upon whether the latter accuracy sufficiently approaches α_0 to render the application of calibration corrections of use. The safe value of inaccuracy is always $\alpha + \alpha'_0$ in the absence of more exact knowledge.

The short period instability α''_0 may be neglected in assessing the inaccuracy of a standard provided that ambient atmospheric conditions are sufficiently close to those prevailing during the most recent calibration. The value of α'_0 should always be pitched high enough to embrace, for instance, the change of value caused by a temperature variation of a few degrees C. That this has been done by the manufacturer should not be taken for granted however and it is well to satisfy oneself on this point before deciding not to add α''_0 to α'_0.

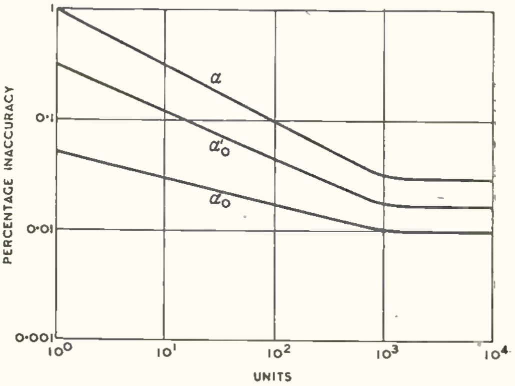

Fig. 2. *The three components of the overall inaccuracy of a typical standard of good design.*

It should be remembered that even though α is high, α_0 is doubtful and α'_0 is unknown, it is possible to make use of a standard of good short-period stability for special determinations of the behaviour of a product under varying conditions throughout a brief period of time. Examples of such use of a standard of unknown precise value but of small short period instability are the measurement of temperature and humidity coefficients and the effects of varying current and voltage.

The curves of Fig. 2 show the relations between α, α_0 and α'_0 which may well exist in a typical standard. It is seen that the inaccuracy of adjustment to nominal value almost embraces the possible inaccuracies due to errors of standardisation and changes of value with age. But it is only the direct reading inaccuracy of the standard which is

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* This is not *strictly* true. The terminal arrangements of the standard and its electric or magnetic field if it is unshielded may affect the accuracy to which it may be standardised.

[1] For the effects of humidity and temperature upon Standard Inductances see " Recent Improvements in Air-Cored Inductances " by the present author, *Wireless Engineer*, Jan. and Feb., 1942.

[2] For the effect of temperature upon Standard Condensers see " The Temperature Compensation of Condensers," by the present author, *Wireless Engineer*, March and April, 1942.

governed by α or more accurately by $\alpha + \alpha'_0$. If calibration corrections are applied the inaccuracy is reduced to $\alpha_0 + \alpha'_0$.

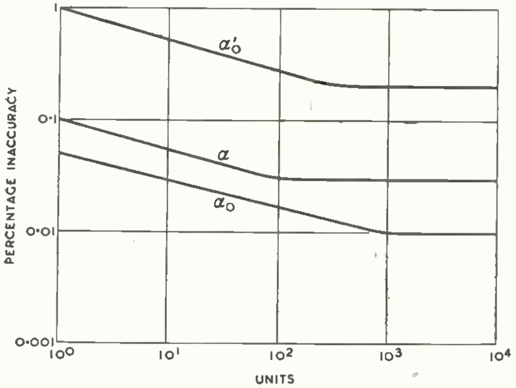

Fig. 3. *The three components of the overall inaccuracy of a poor standard.*

It should be the aim of the designer to make possible the improvement of α until it approaches α_0. The user would thereby be enabled to dispense with the cumbersome application of corrections and the standard could then be said to be truly direct reading.

In a poorly designed standard or one in which the quality of materials or craftsmanship employed is poor enough to vitiate the design principles the curves of Fig. 3 sometimes represent the relation between the various components of overall inaccuracy. In this case both the inaccuracy of adjustment and that of standardisation flatter the standard and the overall accuracy depends wholly upon the correct estimation of the degree of permanence.

The Effects of Frequency

When the effects of frequency upon the value of a standard are appreciable the possibility of a further deterioration of accuracy must be considered. Further components of inaccuracy of value then exist.

α_n — the change of value from low frequency, f_0, to a given higher frequency, f_n. This may be eliminated more or less completely by applying a known frequency correction, $+\alpha_n$, to the nominal or calibrated low-frequency value. Such correction is not always known, however, and hardly ever known to the same accuracy as the low-frequency corrections, and therefore α_n is rarely eliminated completely. The accuracy to which frequency corrections are known diminishes with ascending frequency owing to the impossibility of effecting measurements of effective values at high frequency with the same accuracy as at low frequency.

α'_n — the inaccuracy of the knowledge of the frequency correction $+\alpha_n$ at a given frequency f_n.

α''_n — the probable change in the frequency correction with age at a given frequency f_n.

α'''_n — the short period instability of the frequency correction at a given frequency f_n.

Just as at low frequency it is not always necessary to add all the components of inaccuracy, so at high frequency the total inaccuracy need not necessarily be regarded as $\alpha_n + \alpha''_n$. The inaccuracy of direct reading at a frequency f_n is, of course,

$$\alpha + \alpha'_0 + \alpha_n + \alpha''_n$$

At a particular frequency, of course, some of these components may cancel partially by virtue of the *possibility* of their algebraic signs being opposite; rarely has one any knowledge of this however and, therefore, it cannot be taken into account when assessing the probable overall inaccuracy. When using a standard in such a case one obtains an accuracy of measurement superior to that estimated. The amount of this superiority is rarely recognised except in the alignment of a number of results in the close vicinity of the frequency and value at which the cancellation of errors occurs.

If sufficient data is available for the application of low-frequency and high-frequency corrections the residual inaccuracy may be limited to

$$\alpha_0 + \alpha'_0 + \alpha'_n$$

It is tedious to apply the double correction, however, and at high frequencies it is invariably the practice with good standards to accept the nominal (adjustment) value as correct in which case the resultant inaccuracy becomes

$\alpha + \alpha'_0 + \alpha_n$ if high frequency corrections are not applied or

$\alpha + \alpha'_0 + \alpha'_n$ if such corrections are known and applied.

It is hardly ever necessary to take into account the ageing component of inaccuracy α''_n and much less so α'''_n.

Factors Governing Inaccuracy and Stability at High Frequencies

In a standard condenser the frequency correction depends principally upon its residual self-inductance since the permittivity of air is constant with changing frequency and that of mica very nearly so. This being so, the correction is sensibly proportional to the self-inductance of the condenser and this is in turn governed solely by the geometry of its structure and its internal connections. The residual self-inductance of a condenser standard is therefore constant enough to make both α''_n and α'''_n negligible and the frequency correction is $+\omega^2 C l_r$ (where l_r is the residual self-inductance) the error, α_n, being of positive sign*.

In a standard of self-inductance, on the other hand, the predominant factor in the frequency correction is the distributed capacitance of the coil. The stability of the frequency correction therefore depends partly upon the geometrical stability of the air component of that distributed capacitance but principally upon the stability of the component which is due to the electric field through the solid dielectric materials forming the coil structure and terminal support. This latter component may, through poor design, be variable owing to the variation of permittivity of the solid insulating material with age, temperature and humidity. Assuming that α''_n and α'''_n are reduced to negligible proportions by good design, however, the frequency correction may be computed from $+\omega^2 L c_s$ (where c_s is the distributed capacitance of the coil) the error, α_n, again being positive.

It is not always safe however to associate one definite value of distributed capacitance with any particular standard of self-inductance—a value which may be used in computing the correction factor at all frequencies. This may be good enough for the lower frequencies where the correction factor is small but for the higher frequencies it is safer to determine, from measurements throughout a band of frequencies, the value of effective distributed capacitance which should be used for the computation of the frequency correction within that band.

At high radio frequencies eddy current effects may appreciably affect the frequency correction $+\omega^2 L c_s$. The change of self-inductance due to eddy currents is negative, thus necessitating a correction of opposite algebraic sign to that due to distributed capacitance. The eddy current effect in coils of few turns of heavy wire may, at high frequencies, become so large as to change the sign of the frequency correction factor. In this frequency region, of course, accurate computation of a correction factor is not possible and only measurement of effective value will suffice.

The temperature coefficient of the geometry of a standard self-inductance is included in the short period instability α''_0 at low frequency; but the temperature coefficient of permittivity of the solid insulating material of the coil former may modify the low-frequency value of temperature coefficient and this modification is embraced in the short period instability α''_n of the frequency error.

The effective value of a standard resistance increases with frequency due to "skin-effect" and obviously this increase will be constant at any given frequency. The effective resistance also diminishes with frequency due to the distributed capacitance of the standard. The covering materials and their impregnants are such that changes in their permittivities may occur and so it is just possible that in standards of high resistance, where the effect of distributed capacitance predominates, a change of frequency correction may be experienced.

In standard resistances of low value the "skin-effect" predominates and the frequency correction factor will be constant. In standards of intermediate value both effects are usually small and of the same order of magnitude and so, since they are of

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[*] This means that the actual effective value at f_n is greater than that at f_0. The frequency error at frequency f_n is often regarded as negative, however, as the nominal or read value (or value calibrated at f_0) associated with the standard is lower than the actual effective value and the results of measurements made by comparison with that standard at frequency f_n will have negative errors. Thus the frequency correction must be positive whether applied to the nominal value of the standard itself or to the results of measurements in which that value is used.

opposite algebraic sign and are both proportional to the square of the frequency, the resultant frequency correction will remain small up to quite high frequencies and is likely to remain constant at any given frequency.

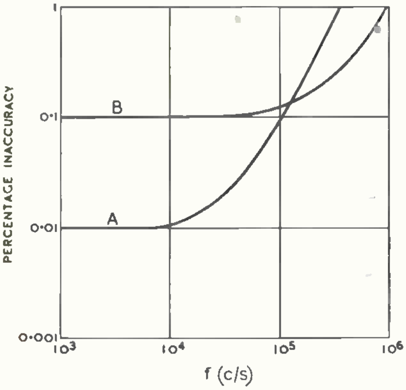

Fig. 4. *The inaccuracies of* effective *values of two electrical standards A and B.*

Frequency Characteristics of First and Second Order Standards

Returning to the difficulty of associating one concise figure of inaccuracy with a standard, it will be seen that the curves of Fig. 4 show how important the frequency error may be in determining the direct reading accuracy. Two standards *A* and *B* have α values of 0.01 per cent. and 0.1 per cent. respectively. As often is the case, however, the standard of lower accuracy has the better frequency characteristic and so, although *A* is ten times more accurate than *B* at 10 kc/s, its superiority vanishes completely at just over 100 kc/s while at about 400 kc/s the accuracy of *A* falls to one-fifth that of *B*.

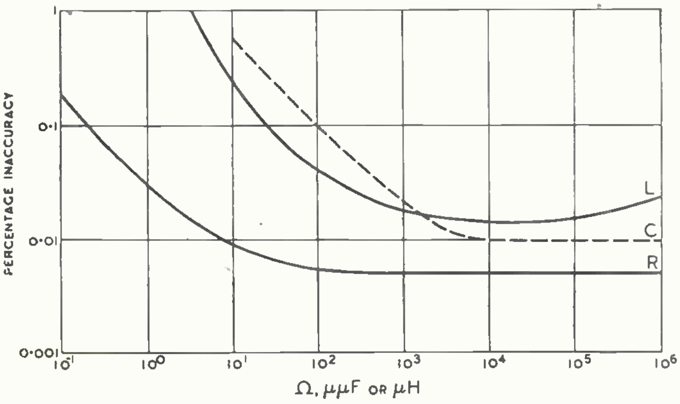

Fig. 5. *The inaccuracies* of direct reading *of the finest standards of decade or fixed-value type resistances, condensers of mica or air dielectric and air-cored inductances.*

Although these curves are purely hypothetical they represent a condition of things which is met with quite often in practice. Standards from which the best accuracy and stability are expected at low frequencies are usually constructed on massive lines and mass nearly always introduces large frequency characteristics for obvious reasons. On the other hand, if a standard is constructed for a lower accuracy it is usually of more compact and frail design—a feature which is of great help in limiting the effects of frequency. Thus a self-inductance standard of lesser accuracy would generally have a smaller diameter of mean turn and a lower value of distributed capacitance on this account. A standard condenser of lesser accuracy would have smaller volume and therefore a smaller value of residual self-inductance. Finally, a standard resistance of lesser accuracy would have a shorter length of a finer gauge of wire and both distributed capacitance and eddy-current effects would be reduced in consequence. All these dimensional reductions, although dictated primarily by cost, help to reduce the frequency errors and it is therefore quite *possible* for the less-expensive standards to have the better frequency characteristics. It is far from the truth, however, to say that the frequency error is *invariably* small in inexpensive standards or in those of small dimensions. Rather should it be said that it is always possible to reduce such errors by the careful design of *any* standard, but that this is more easily effected in the case of standards of small dimensions.

In concluding these general notes on the frequency behaviour of standards, it will be helpful to the reader to emphasise that a standard in which both components α''_0 and α'''_n of short period instability are small and the frequency error α_n is small also, may be used with success to determine the frequency errors of other products. This is true even of a standard in which high values of α, α_0 and α'_0 indicate poor low-frequency accuracy.

Accuracies Available

It is hoped that the foregoing has helped the reader to appreciate more fully the nature of the inaccuracies of commercial standards of capacitance, self-inductance and resistance and the conditions which will affect such inaccuracies. This being so, it is now the author's intention to give the accuracies, usually the best accuracies, which can be expected of these standards. This information, which should prove invaluable to many who are more familiar with the use of standards rather than with their design, will be given in the form of a series of curves. The curves are mostly self-explanatory in nature and very few notes are necessary to elaborate the information they convey.

The curves of Fig. 5 convey useful basic information of a general nature. They give the best accuracy which can be expected from air and mica condensers, air cored (open field) self-inductances and resistance standards. The inaccuracy read from these curves is that, α, of adjustment to nominal value, but it may be stated that it is now possible in the finest standards to guarantee that inaccuracies due to both standardisation* and long period ageing are embraced in this figure. The curves relate to low or telephonic frequencies and, in the case of the resistance standards, to direct current, and it will be shown in later curves to what upper limit of frequency they apply. There must necessarily be a certain amount of approximation in condensing such a quantity of information into three simple curves and this applies particularly to the overlapping of air and mica standards in the region of capacitance where either may be employed. The curves, which are intended to apply equally to standards of fixed value* and to the individual values of any decade of an adjustable standard, show the range of values throughout which standards are available commercially.

Adjustment inaccuracies of resistance, inductance and capacitance standards may be affected after the present war by the possible adoption of the "absolute" system of electrical units instead of those at present in use which are termed "international units." Such a change of units would affect commercial standards of the finest quality only, because it amounts to only about 5 parts in 10^4.

The change would be made only by international agreement and would mean that present standards of resistance and inductance would have to be *reduced* in value by 5 parts in 10^4, and those of capacitance *increased* in value by 5 parts in 10^4, if their accuracies to nominal values were to remain unimpaired. The value of the ampere (and coulomb) would also be changed—increased by 1 part in 10^4 and it follows therefore that the volt would be reduced by 4 parts in 10^4 and the watt by 3 parts in 10^4.

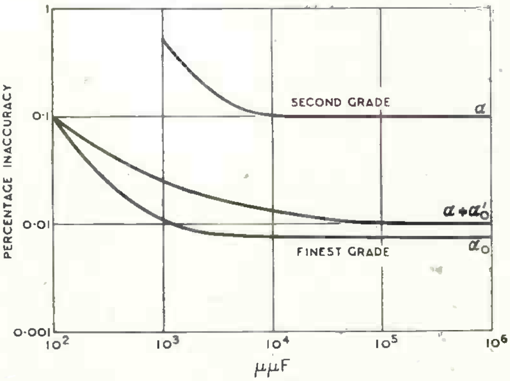

Fig. 6. *Showing the inaccuracies of mica condenser standards of decade and fixed value types.*

Commercial Capacitance Standards — Mica Dielectric

The inaccuracies of mica condensers of fixed value or of the decade type are shown

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* The determination of the actual value of a *commercial* standard by means of an *ultimate* standard of superior accuracy.

* With the exception of the direct current fixed value resistances of the oil immersed sub-standard type which are to be found in the laboratories of standardising institutions and instrument makers and which are of somewhat lower inaccuracy than that shown by the curve *R*.

by the curves of Fig. 6. It should be noted that in recent years the adjustment inaccuracy α and the long period permanence of value α'_0 of the finest standards have been improved until they approach the least calibration inaccuracy α_0 of the National Physical Laboratory for this type of standard. Such condensers may now be included within the category of precision instruments just as resistance standards had been for a number of years previously. It should be noted that α is the direct reading inaccuracy without applying calibration corrections. Such corrections would be very small indeed and in any case could only be applied usefully for a short period after calibration because α'_0 is only of the same order as α.

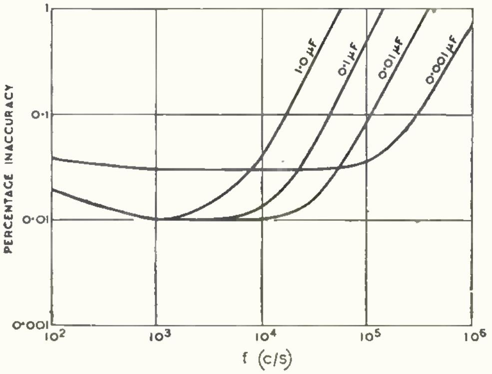

Fig. 7. *The inaccuracy of effective capacitance of the finest mica condenser standards of the multi-decade type. Single decade standards and those of fixed value, especially those of low capacitance, are much less affected by frequency. (See text.)*

The augmentation of inaccuracy of these finest standards by frequency error is given in Fig. 7. The inaccuracies are in this case, by the most careful design and craftsmanship, sensibly reduced to $\alpha + \alpha_n$.

The curves apply only to the various capacitance values of a multi-decade standard in which the residual self-inductance is necessarily appreciable. In single decade standards or those of fixed value the residual inductance will be usually much lower especially at the lower capacitances. Thus the frequency error of a fixed value mica standard of, say, 0.001 μF may be only one-fifth or even one-tenth of that shown in the curves.

The curves of Fig. 7 have been plotted by superposing the positive frequency error $\alpha_n = +\omega^2 Cl_r$ upon the adjustment accuracy α. They are, therefore, plotted, without reference to algebraic sign, to indicate the maximum error which would be experienced if all possible inaccuracies happened to be of the same sign. Such curves must not be confused with those of Fig. 8 which show the pure frequency characteristics of capacitance of the same condensers. These latter curves show the errors (of either algebraic sign) introduced by a change of frequency from 1,000 c/s.—the frequency at which adjustment and chief calibration are usually effected in the case of standards of capacitance intended for the communication industry. They are formed by adding, algebraically, the negative characteristic due to dielectric absorption in the composite dielectric (mica and paraffin wax) to the positive characteristics of the individual standards due to their residual inductances. The effect of dielectric absorption diminishes rapidly with frequency, while that due to inductance increases rapidly. It is seen, therefore, that the error curves of Fig. 7 may be modified slightly by the negative characteristic, but only in the vicinity of 50—100 kc/s where the inaccuracies of standards

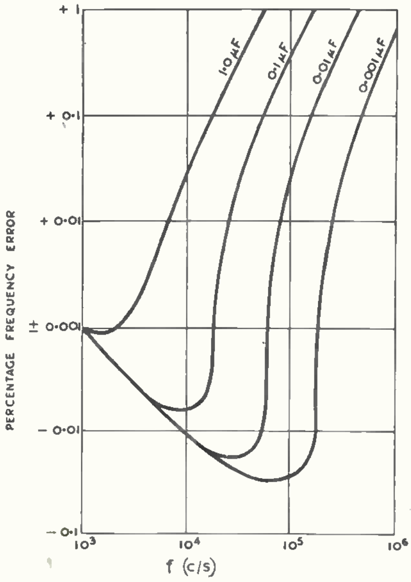

Fig. 8. *The frequency characteristics of the finest mica condenser standards of the multi-decade type.*

of the order 0.01 μF may be somewhat less than those shown by the curves owing to the cancellation of the two frequency errors which are of the same order at this frequency. On the other hand, condensers of the order 0.001 μF *may* have inaccuracies higher than those shown in the vicinity of 50–100 kc/s because there is no appreciable positive error to produce such cancellation at these frequencies.

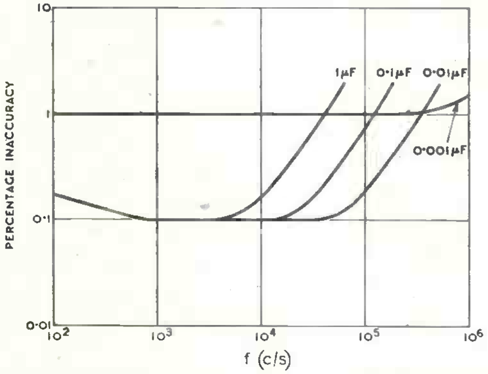

Fig. 9. *The inaccuracy of effective capacitance of second-grade mica condenser standards of the multi-decade type. For fixed value standards see note in caption of Fig. 7.*

The positive frequency characteristics of condensers of capacitances greater than 0.01 μF are unaffected by the negative characteristics and those of condensers less than 0.01 μF are unaffected when the positive frequency errors become considerable.

This complication has been mentioned to show that it is unwise to rely upon the predetermination of frequency errors of condensers of lower than 0.01 μF capacitance in the neighbourhood of 100 kc/s from the knowledge of residual inductance alone.

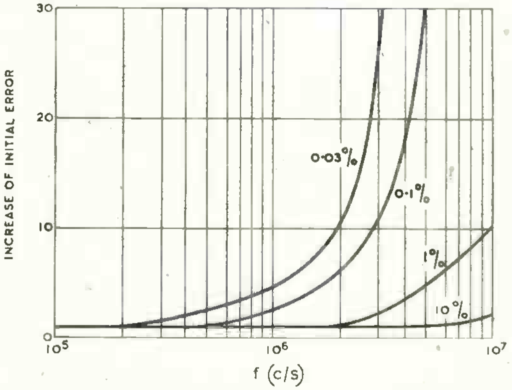

Fig. 10. *Showing the augmentation of inaccuracy of* 0.001 *μF condensers of various accuracies due to residual self-inductance.*

The curves of Fig. 8, like those of Fig. 7, are applicable only to the very finest mica standards and negative characteristics many times as steep as that shown may be experienced in standards of quite good quality.

The augmentation of inaccuracy of second-grade standards by frequency errors is shown in Fig. 9 and is seen to be of somewhat less importance owing to the higher initial inaccuracy. The relative unimportance of frequency error on the nominal values of standards of poor accuracy is shown by the curves of Fig. 10.

For the sake of completeness the power factor curves of Fig. 11 have been included in order to show the best possible power factor which can be expected of the finest decade standard mica condensers. It should be appreciated that these power factors are extremely low and are obtained only by the utmost care in design and craftsmanship. At high frequencies a peculiar discontinuity will be noted at 0.1 μF; this is due to a sudden increase of series resistance caused by the fact that the lower values of the higher decade have fewer condenser units in parallel than have the higher values of the lower decade.

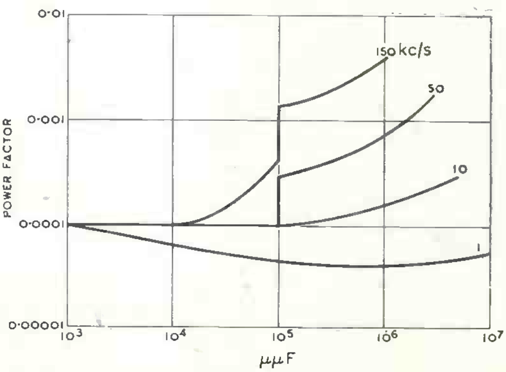

Fig. 11. *The power factors of the finest decade condenser standards available. Standards of fixed value will be much less affected by frequency.*

A standard mica condenser should be used only at reasonably low voltages. Excessively high voltages produce changes in both permittivity and power factor of mica.* Moreover, it is just possible that the application of excessive voltages may produce a permanent change in capacitance value a together with an increase in the short period instability.

For these reasons the voltages applied to an ordinary standard should, if possible, be limited to, say, 300 and should never exceed 500 unless the standard can be subsequently examined and, if necessary, recalibrated.

Standards are available which are designed for use at higher voltages.

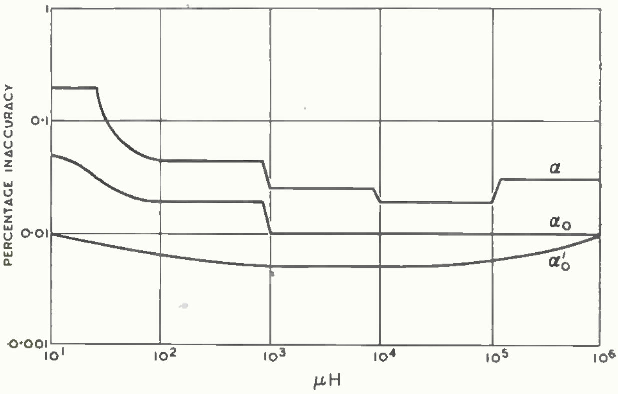

Fig. 12. *The inaccuracy of* true *inductance of the finest Sullivan-Griffiths air-cored temperature compensated standards of self-inductance.*

Self-inductance Standards (Air Cored)

In Fig. 12 are given curves of the various components of inaccuracy of the finest air-cored self-inductance standards of the author's temperature compensated design. Except in the case of standards of the very lowest values it is seen that the inaccuracy of adjustment to nominal value has been reduced to about twice the inaccuracy α_0 of calibration by the National Physical Laboratory. It is seen also that the possible inaccuracy α'_0 due to long period (years) ageing is always, except in standards of the very highest value, low enough compared with α to be almost negligible in assessing the overall inaccuracy which may be regarded therefore as α or $\alpha_0 + \alpha'_0$ depending upon whether a calibration correction is made.

The manner in which the main frequency errors, α_n, due to distributed capacitance, augment the adjustment errors α of these standards is shown in the curves of Fig. 13. The inaccuracies plotted here are merely those given by $\alpha + \alpha_n$ because α''_n has been rendered negligible by design. It should be noted that some improvement of accuracy is possible at the lower frequencies by applying low frequency calibration corrections especially in the case of the 10 μH standard

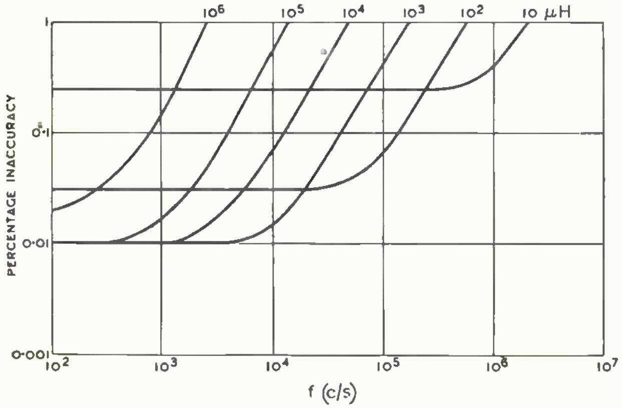

Fig. 13. *The inaccuracies of* effective *inductance of the finest Sullivan-Griffiths temperature compensated standards of self-inductance if the effects of their self-capacitances are included but the magnitude of such effects is either unknown or neglected. The curves apply more particularly to fixed value standards—decade standards have somewhat inferior frequency characteristics at the lower values of each decade. The inaccuracies may be much reduced either by a knowledge of the distributed capacitance or by actual standardisation at given high frequencies.* (*See Fig.* 14.)

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* If the mica dielectric is stressed up to 3,000 or 4,000 volts per mil capacitance changes up to three or four parts in 10,000 may occur at low frequencies and the power factor may be increased some three or four times.

in which α is considerably inferior to α_0 and α'_0.

As has already been pointed out this main frequency error, which is of positive algebraic sign, may be eliminated largely by the application of a frequency correction $+\ \omega^2 L c_s$ if the value of c_s is known accurately. Having effected this correction, however, two other factors of inaccuracy may become important—that, of negative sign, due to eddy current effects and that due to the imperfection of the determination of the effective value of the standard at a given frequency.

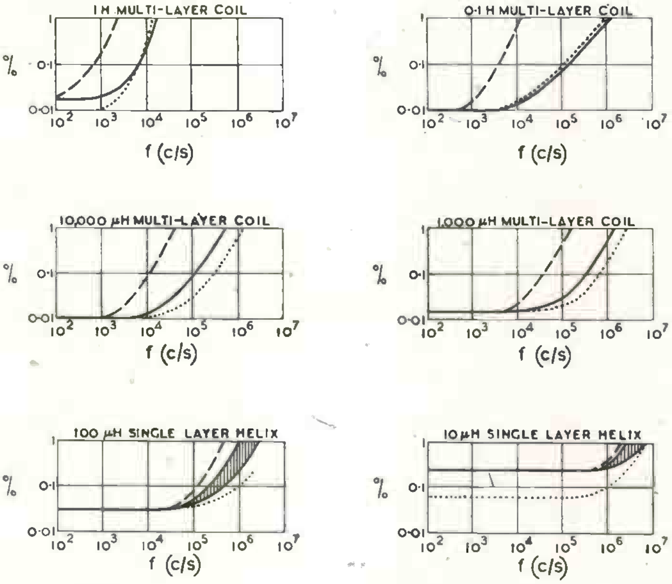

Fig. 14. *Showing the least possible inaccuracies of the finest air-cored inductance standards—the ultimate inaccuracies of the determination of their effective values at various frequencies as shown by the dotted line curves. Shown also is the augmentation of adjustment inaccuracy by the effects of distributed capacitance (broken line) and eddy-currents (full line). It should be noted that in some applications the effects of distributed capacitance are eliminated and the eddy-current effect then becomes the sole source of inaccuracy augmentation. By precise measurement at any given frequency or band of frequencies even the eddy-current inaccuracy may be reduced to that of the determination of value (dotted line) in cases where the latter is appreciably less than the former; it being remembered, however, that the inaccuracy* α'_0 *(Fig. 12) must be added if an appreciable period of time has elapsed since the determination of value. It should be noted also that the algebraic signs of the effects of distributed capacitance and eddy-currents are opposite, although no attempt has been made here to discriminate between positive and negative errors.*

Some idea of the relative importance of these frequency errors may be gleaned from the curves of Fig. 14.

Where the eddy current error is appreciable it will be seen that it can be eliminated largely by the most accurate measurement

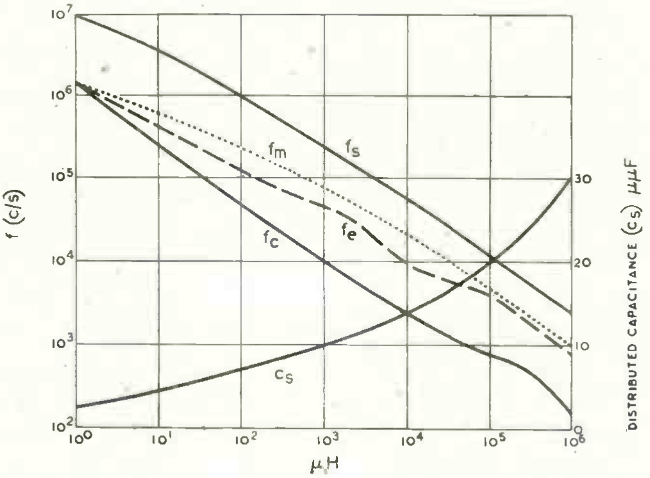

Fig. 15. *Upper limits of frequency for 0.01% standards of self-inductance.*

f_c = *frequency above which the effects of distributed capacitance* c_s *become appreciable.*

f_e = *frequency above which the effects of eddy-currents become appreciable.*

f_m = *frequency above which errors of measurement become appreciable.*

f_s = *frequency above which the short-period stability may be affected by ambient conditions.*

at a given frequency or band of frequencies. It is interesting to observe that accurate measurement fails to determine with certainty the extent of the eddy current error in the coils of 0.1 and 1 henry.

On the other hand, it will be observed that the eddy current component of frequency error becomes very important in coils of 10 and 100 μH. The shaded portion between he two curves of eddy current error is intended to show how the extent of this error may be varied by the use of different types of conductor for the winding of these coils. Coils which are wound with strip conductors in order to obtain a high magnification factor at high radio frequencies have large eddy current errors which approach the upper full line curves whereas, at the sacrifice of magnification, standards may be wound with thin stranded conductors in order to reduce the eddy current errors towards the lower full line curves.

The curves of Fig. 15 indicate the manner in which definite frequency limits should be associated with these standards. The heavy full line curve f_c gives the frequency above which the effects of distributed capacitance become appreciable—at frequencies lower than f_c the *effective* self-inductance is sensibly equal to the *true* self-inductance. The broken line curve, f_e, shows the frequency above which the eddy current effect becomes appreciable and the dotted curve, f_m, the frequency above which errors of the measurement of the standard become appreciable. It should be remembered that these curves and those of Fig. 14 are applicable only to standards of the finest quality obtainable commercially—those of the 0.01 per cent. grade.

The curve f_s (Fig. 15) shows the frequency which may not be exceeded if, under conditions of excessive or greatly varying temperature and humidity, the short period instability α_n''' of the frequency correction is not to exceed that, α_0'', of the true self-inductance value. This frequency may however be exceeded in the case of coils used as standards on a bridge in which double balance is provided for the elimination of the residual capacitance of coils so that their *true* self-inductances only are measured. Higher frequencies may also be employed if the standards are mounted in sealed shielding cases prior to calibration or when unsealed coils are used under reasonably good ambient conditions.

The *effective* distributed capacitances which govern the heights of the frequency curves of Fig. 15 are also given in the same figure. It must be understood, however, that the heights of all the curves of this figure are governed also by the geometrical perfection of the coils since these curves are based upon the maintenance of accuracy and stability of *effective* self-inductance of the same order as is associated with the *true* self-inductance. The curves would therefore be raised for coils of lesser quality and curves f_c and f_s would be lowered for coils of greater distributed capacitance.

For further detailed information upon the qualities of these temperature compensated standards the reader is referred to a recent article published elsewhere[3].

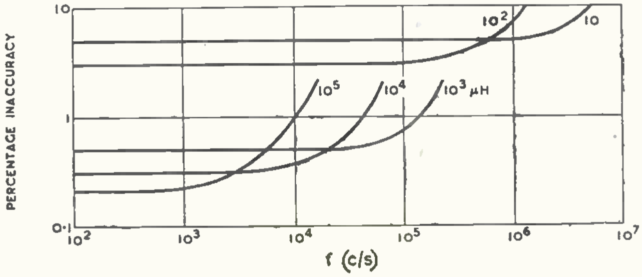

Fig. 16. *The inaccuracies of* effective *values of second-grade standards of self-inductance; if the effects of their self-capacitances are unknown or neglected.*

The curves of Fig. 16 show the relatively smaller augmentation of adjustment inaccuracy by frequency errors in the case of second grade standards. It is important to note, however, that these inaccuracy curves are of $\alpha + \alpha_n$. Quite different curves would be obtained by plotting $\alpha_0 + \alpha_n$ because, as

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[3] "Recent Improvements in Air-Cored Inductances" by the present author. *Wireless Engineer*, January and February, 1942.

Fig. 17 will show, the adjustment inaccuracy for commercial reasons, is much greater than the possible inaccuracy due to ageing. In this case, therefore, the overall inaccuracy of true self-inductance may be taken as $\alpha_0 + \alpha'_0$ if one cares to apply low frequency calibration corrections to the nominal values.

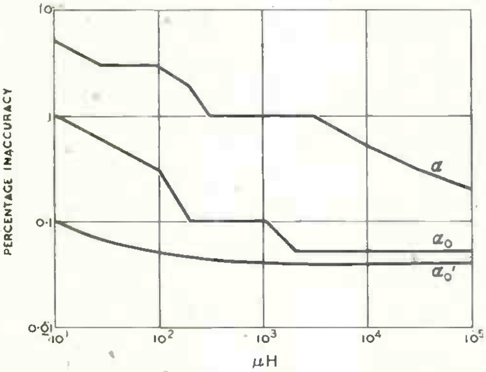

Fig. 17. *The inaccuracies of* true *values of second-grade standards of self-inductance.*

The inaccuracies given in the above curves are those of self-inductance standards of fixed value. Tapped self-inductances and decade standards are available and are very little inferior to fixed standards in accuracy of true self-inductance. If a coil is tapped to a small proportion of its full value, the distributed capacitance of that tapped portion will be considerably greater than that of the full coil. It is to be expected therefore that the augmentation of true self-inductance errors by frequency errors will be somewhat greater in the lowest tappings of a fixed standard and in the lower self-inductances of each decade of an adjustable standard ; the full coils and higher values of each decade will, however, have frequency errors of the same order as those given for standards of fixed value.

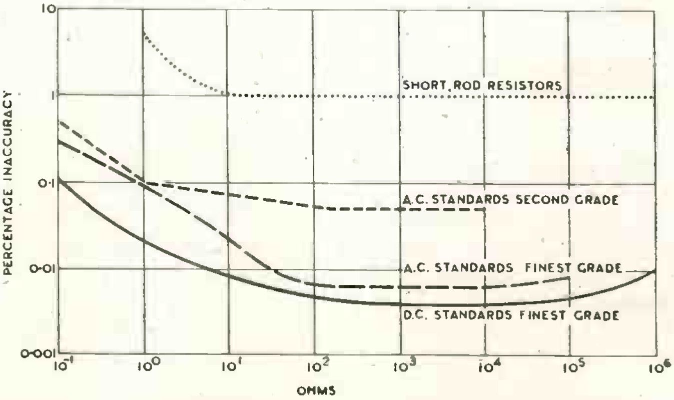

Fig. 18. *The inaccuracy of direct reading of decade resistance standards (and interchangeable inserted rod resistors).*

Owing to the space devoted already to this section the effective resistance of self-inductance standards and the manner in which it varies with frequency will not be discussed here.

Resistance Standards

Standards of self-inductance and capacitance are usually designed to be most accurate throughout a particular range of frequency and to have as low a phase angle of impurity as is practicable throughout such range. The design of resistance standards is, however, influenced by frequency considerations to a much greater extent than are those of self-inductance and capacitance. For this reason commercial decade resistance standards are available in three distinct types—the direct current type, the best accuracy alternating current type and a lower accuracy alternating current type of much smaller dimensions. The latter is sometimes known as the high-frequency type because for these frequencies it is as accurate as the more accurate type and is more easily incorporated in radio-frequency circuits, but it should be remembered that the dimensional limitation tends also to limit the current-carrying capacity of the standard. As previously explained it is easier to limit the gauge and length of wire in a resistance of poor accuracy and the relatively good high frequency behaviour is thus obtained cheaply. At telephonic or " carrier " frequencies the superior accuracy of the better type is available.

The curves of Fig. 18 show the adjustment inaccuracies, α, of the three types. It should be noted, however, that in the case of the poorer A.C. decade type the inaccuracy, α'_0, due to ageing is much less than that, α, due to adjustment and so if one is prepared to apply corrections the inaccuracy of this type of standard may nearly always be reduced. At very high frequencies all wire wound resistances are inaccurate and known changes in circuit resistance can be effected only by the insertion of short rod type resistors of fixed value. Such resistors can rarely be considered to be of less inaccuracy than that shown in Fig. 18 at the frequencies at which they are most useful. Resistance standards of fixed value generally have inaccuracies somewhat less than those shown by the curves of Fig. 18. Especially does this apply to sub-standard resistance units of the oil immersed type used in the standardisation of direct-current resistances.

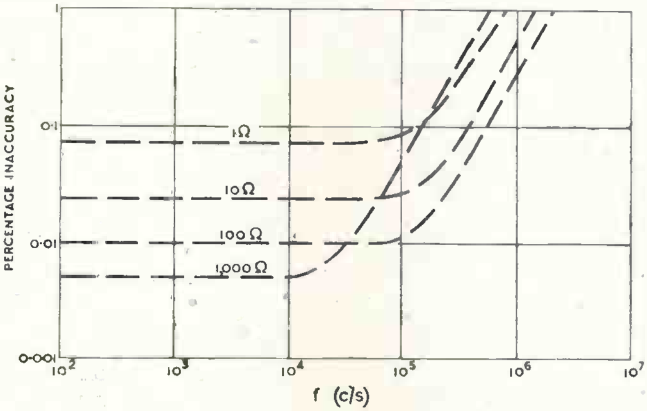

Fig. 19. *The effect of frequency upon the direct reading accuracy of the finest decade resistance standards (alternating current type).*

The effective value of a standard resistance at high frequency may be different from its low frequency value due to the causes already given. In the curves of Figs. 19 and 20 are given the effects of frequency upon the inaccuracy of the two types of alternating current standards. From these curves it will be seen that the lower inaccuracy of the finest standard is available up to frequencies of the order 100 kc/s while the lower grade of standard usually cannot be improved upon for the frequency band of 100 to 1,000 kc/s. Above 1 Mc/s short rod resistors are superior to wire wound standards as is well shown in Fig. 20.

For some uses it is important to remember that owing to the effect of residual self-inductance* the impedance errors of these standards at the highest frequencies may exceed the errors in effective resistance. This is especially the case with resistance units of high and low values; intermediate values of, say, 10 to 300 ohms are invariably the best for both errors of effective resistance and reactance. The residual inductance of the "box"† also (as distinct from that of the resistance units) may cause very large reactance errors on low values of resistance. If the decade resistance is being used at high frequency in a resonance method of test, however, the effects of this large box reactance are separated from those of effec-

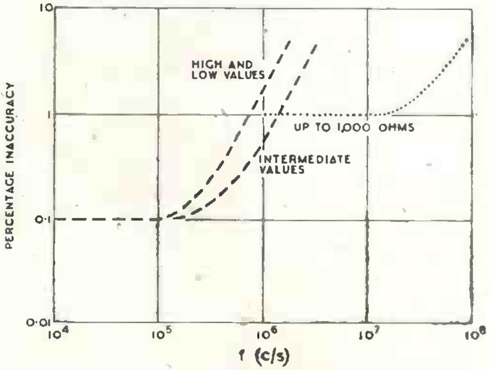

Fig. 20. *The effect of frequency upon the direct reading accuracy of decade resistance standards of the high-frequency type (and of short rod resistors). For key see Fig. 18.)*

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* The "phase quality" of a resistance standard is conveniently expressed as residual self-inductance whether the residual reactance is positive or negative. Thus the algebraic sign of residual self-inductance may be positive or negative.

† The "box" values of a decade standard are those of the electrical values at the terminals of that standard when all decades are set to zero. The incremental values of each decade are adjusted and calibrated independently of such box values which are usually compensated in use.

tive resistance. At low frequencies such reactance errors are reduced to reasonable proportions in any case.

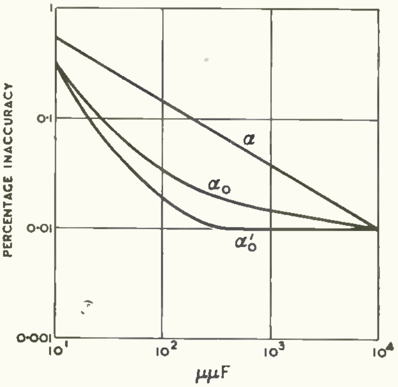

Fig. 21. *The inaccuracies of the finest fixed air condenser standards.*

Air Dielectric Capacitance Standards

For capacitance values lower than, say, 2,000 or 3,000 μμF standards of air dielectric are more reliable than those of mica dielectric. There is no sharply defined line of demarcation between the two types however. Mica standards may be used with success down to 200 μμF or so and air standards are often of great value up to 10,000 μμF.

In the curves of Fig. 21 are given the inaccuracies of fixed value air standards of the best quality. It is seen that in these standards the inaccuracy α'_0 due to long period ageing is always less than that, α_0, of a National Physical Laboratory statement of value. This is a sure indication of the quality of an air condenser—the long period permanence. Because α'_0 is less than α_0, a calibration correction may be applied ; in which case the overall inaccuracy is reduced from $\alpha + \alpha'_0$ to $\alpha_0 + \alpha'_0$. A word of warning should be given here, however, on the accuracy of calibration of a low capacitance standard of fixed value. The calibration accuracy in such cases will depend almost entirely upon the stray capacitances (between connecting leads and terminals and in some cases to nearby earthy bodies) which exist at the time of calibration of the standare and which cannot be reproduced with certainty when it is itself used subsequently to calibrate other condensers. In the case of the standards to which the curves of Fig. 21 apply, a terminal linking system is provided therefore, to eliminate these uncertainties which would otherwise render impossible the accuracies of calibration represented by the curve α_0.

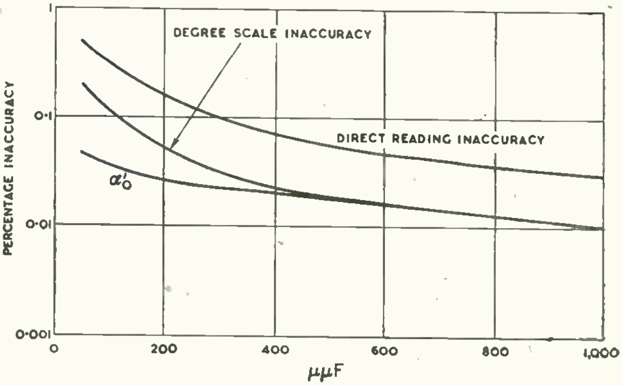

Fig. 22. *The inaccuracies of a typical silica mounted variable air condenser standard of the finest quality (linear law of capacitance).*

The inaccuracies of a typical variable air condenser standard of the finest quality are given in Fig. 22. It is seen that the degree scale reading inaccuracy is practically coincident with the quality of the condenser, as judged by the long period permanence (α'_0), for values greater than 300 μμF, but falls off rapidly as the minimum capacitance is reached. This is characteristic of all variable condensers in which a linear law connects capacitance and scale reading angle. The limitation of accuracy by scale reading is minimised by the adoption of a logarithmic law of capacitance[4] as is shown by the curves of Fig. 23. These curves, which are for variable condensers of the good laboratory type, show how a single condenser having a logarithmic capacitance law may have a greater range than three linear capacitance-law condensers without loss of scale accuracy. Especially should it be noted that the range

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[4] " Wide Range Variable Condensers for Special Laws," by the present author. *Wireless Engineer*, Vol. XI, No. 131, pp. 415–418.

of a logarithmic variable condenser may be extended to embrace exceedingly low values of capacitance.

It is useless, however, to extend the range of a variable condenser to very low values unless a "slope" calibration[5] is resorted to. A slope calibration from an arbitrary "zero" has the effect of eliminating the capacitance uncertainties due to the ageing of the solid insulating material in the electric field of the condenser which would otherwise be present in all but the finest silica insulated standards. The curves of Fig. 24 show the improvement of accuracy of two typical variable condenser standards, one logarithmic and one linear, by the adoption of slope calibration.

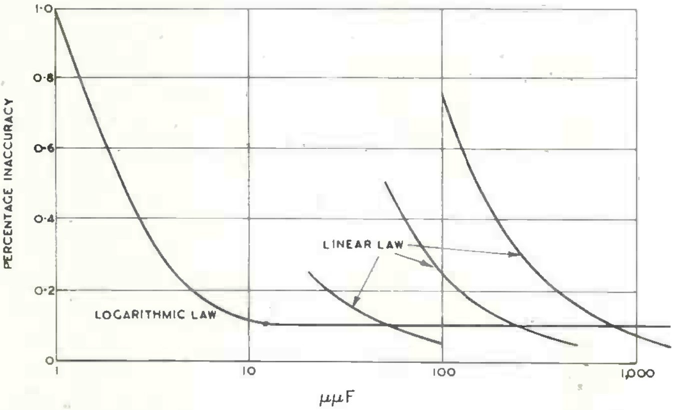

Fig. 23. *The improvement of direct reading scale accuracy of variable condenser standards of the good laboratory type obtained by employing a logarithmic law.*

Finally the curves of Fig. 25 show the effect of frequency upon the inaccuracy of low frequency calibration or adjustment of air standards of variable or fixed capacitance respectively. They are representative of the finest silica insulated standards available and the inaccuracies plotted are those of calibration plus those due to frequency—the long period permanence being considered superior to the calibration accuracy in every case. It should be noted that it is possible to eliminate the frequency errors to a large extent up to reasonably high frequencies by the application of a correction $+\omega^2 C l_r$ to any scale reading or calibration value once a value has been obtained for l_r the residual inductance of the condenser.

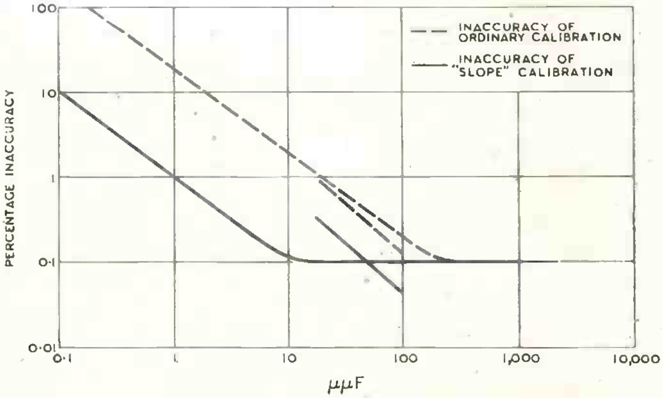

Fig. 24. *The improvement in accuracy of typical variable condensers (in which ordinary insulating materials are employed) by the use of "slope" calibration. Such marked improvement is not obtained in the finest silica insulated standards.*

Shielding

The effect of the stray electric field of the shielded condenser standard is usually taken into account in adjustment and calibration. The change in the value of this stray capacitance with age is always negligible in the case of the finest silica insulated air standards and in mica standards of high capacitance (greater than, say, 2,000 μμF). In low value capacitance standards in which *ordinary* insulating materials are employed for mounting and terminal supports there may be appreciable

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[5] For an explanation of "slope" calibration see "The Measurement of Small Variable Capacities at Radio-frequencies" by the present author. *Experimental Wireless* (now *Wireless Engineer*), Vol. V, No. 59, pp. 452–459.

change of shield capacitance with age, atmospheric conditions and frequency. In such cases the shield capacitance should, if possible, be eliminated by the method of calibration and by the subsequent method of use.

The shields of resistance standards have more effect upon their residual reactances than upon their accuracies of effective resistance. For this reason, particularly in non-reactive resistances of high value, one must be careful to connect the shield in the manner which is appropriate to least reactance. This is not always possible, of course, and the author employs a novel shield capacitance compensating arrangement in decade resistance standards so that the reactance for any value of any decade is maintained at a low and constant value irrespective of changes in the method of shield connection which may be dictated by test conditions.

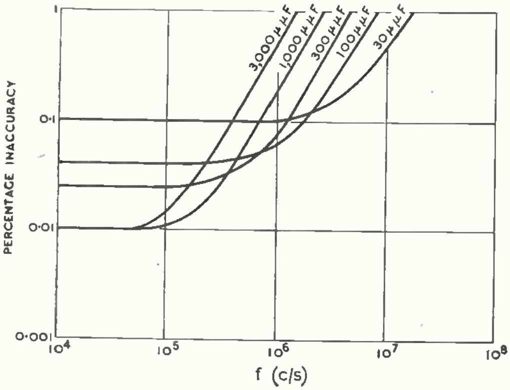

Fig. 25. *The effect of frequency upon the inaccuracy of calibration or adjustment of the finest air condenser standards of variable or fixed value respectively.*

The shielding of air-cored *general purpose* self-inductance standards of the best quality is practically impossible on account of the consequent influence of frequency upon effective self-inductance.

Toroidal coils may, of course, be shielded without undue frequency effect and so also may iron-cored inductances, but these latter may have considerable changes of self-inductance with current even when the core is of the "dust" type of the lowest practicable effective permeability and for this reason the description of this type of coil as a standard has been omitted.

In conclusion, it is hoped that these notes will have provided the reader with a better knowledge of the types of modern standards available—their accuracies and their limitations. Thus armed, there may be some so brave as to contribute to the much needed standardisation of standards.

Appeal to the Industry

A FEW days before his death Lord Hirst issued, on behalf of associations in the wireless and electrical industries, an appeal to employers for the support of the Electrical Industries Red Cross Fund. Within the first few weeks of the issuing of the appeal the contributions totalled over £9,000. The appeal drew special attention to the advantages of entering into a covenant to subscribe annually for seven years or the duration of the war. By this means whatever sum is contributed is doubled (at the present rate of income tax), because the Red Cross are able to recover the tax. The gross amount is credited to the subscriber as his contribution. Of the total amount already subscribed nearly £6,000 has been covenanted.

Contributions should be sent to the Electrical Industries Red Cross Fund, St. James's Palace, London, S.W.1, and other correspondence to the Joint Secretaries, Hugh S. Pocock, M.I.E.E., and V. W. Dale, c/o The E.D.A., 2, Savoy Hill, London, W.C.2.

March Meetings

AT the meeting of the Wireless Section of the Institution of Electrical Engineers to be held on March 3rd, at 5.30, G. Parr and W. Grey Walter, M.A., will deliver a paper on "Amplifying and Recording Technique in Electro-Biology." Special reference will be made to the electro-encephalograph.

The paper to be read at the next meeting of the British Institution of Radio Engineers, on Friday, March 26th, at 6.30, will be "Selective Methods in Radio Reception" by E. L. Gardiner, B.Sc. The meeting will be held at the Institution of Structural Engineers, 11, Upper Belgrave Street, S.W.1.

"Diode as a Frequency Changer"

IT is regretted that the following errors appeared in the above article which was published in the January issue.

The curve in Fig. 7 is $F_1(\alpha)$ and not as indicated.

In equations (19) and (20) for e read $\hat{e}$.

Equation (20) should read $\rightarrow \frac{\pi}{a\hat{e}} \cdot \frac{15}{4\alpha^5}$.

For R_s in eq. (62) read R_i.

For " = " in the denominator of eq. (71) read " + ".

Shot-Effect in Space-Charge-Limited Diodes*

By Lieutenant de Vaisseau M. Surdin, F.F.N., D.Sc.

I. Introduction

THE subject of space-charge reduction of shot-effect in diodes, has been much discussed, its importance may be estimated by the extensive literature on the subject. Until recently there has been a general lack of agreement embracing experimental results as well as theory.

The first attempt to analyse the reduction of shot-effect in space-charge-limited diodes was made by Llewellyn.[1] Unfortunately, experiments show, that the mean-square of the fluctuation of the anode current, as predicted by Llewellyn, is much too small.

Schottky,[2] has analysed the mechanism of space-charge reduction of shot-effect and predicted a higher value for the mean-square of the fluctuation of the anode current than Llewellyn's, though too small as compared with experiment.

Recently, Thompson, North and Harris[3] have published an extensive theoretical and experimental study on the subject. They have considered the microscopic mechanism of space-charge reduction of shot-effect. Thompson, North and Harris claim to be in substantial agreement with Schottky's subsequent work†, which corrected errors and omissions of earlier papers. Recent experiments performed by Williams[4] confirm, at least partly, these theories.

The object of the present paper is to discuss some aspects of space-charge reduction of shot-effect in planar diodes, to which very little consideration has been given hitherto.‡

II. Notations and Fundamental Formulae

m = mass of the electron

ϵ = electronic charge

k = Boltzmann's constant

T = absolute temperature of the cathode

Δf = frequency band-width of the measuring apparatus

I = anode current

J = total emission current

ΔI and ΔJ instantaneous fluctuations in I and in J

$\overline{\Delta I^2}$ and $\overline{\Delta J^2}$ mean square of the fluctuations of I and of J.

S^2 = space-charge reduction factor; it is the ratio of the mean-square of the fluctuation of the anode current in a space-charge limited diode, to the mean-square of the fluctuation of the anode current of a temperature-limited diode having the same mean anode current.

$$\overline{\Delta I^2} = S^2 \,.\, 2 \,.\, \epsilon \,.\, I \,.\, \Delta f \qquad \text{(1)}$$

V_1 = cathode potential with respect to the potential minimum

V_2 = anode potential with respect to the potential minimum

Δv = instantaneous fluctuations in the amplitude of the potential barrier.

c = distance of the potential-barrier from the cathode

d = distance of the anode from the potential-barrier.

The potential distribution between cathode and anode in a space-charge-limited diode is represented in Fig. 1. Owing to the Maxwell-Boltzmann distribution of electrons emitted by the cathode, at a distance *c* from the cathode, a potential minimum, or a potential-barrier is formed.

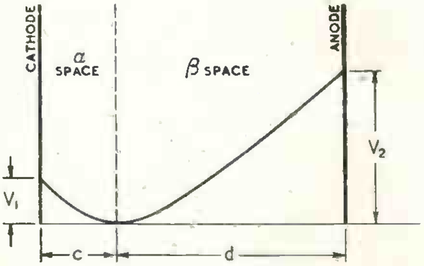

Fig. 1.

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* MS. accepted by the Editor, October, 1942.

† *Vide* ref. (3), page 273.

‡ Flicker-effect, fluctuations due to ionisation and transit-time effects will not be discussed.

One has:

$$I = J \,.\, e^{-\epsilon V_1/kT} \quad \cdots \quad (2)$$

The potential-barrier may be considered as a virtual cathode at the same temperature as the cathode.[5] Let V be the potential in a plane at a distance x from the cathode, Langmuir,[6] has shown that this state of affairs is best described by two non-dimensional variables η and ξ given by

$$\eta = \epsilon V/kT \quad \cdots \quad (3)$$

$$\xi = 4 \,.\left(\frac{\pi}{2kT}\right)^{\frac{3}{4}} .\, m^{\frac{1}{4}} \,.\, \epsilon^{\frac{1}{2}} \,.\, I^{\frac{1}{2}} \,.\, (x - c) \quad (4)$$

The steady-state potential distribution appears as the solution of the following equation:

$$\xi = \int_0^{\eta} \frac{d\eta}{[\phi(\eta)]^{\frac{1}{2}}} \quad \cdots \quad (5)$$

where $\phi(\eta)$ stands for:

$$\phi(\eta) = e^{\eta} - 1 \mp \left(\frac{2}{\sqrt{\pi}}\eta^{\frac{1}{2}} - e^{\eta}\, erf \,.\, \eta^{\frac{1}{2}}\right) \quad \cdots \quad (6)$$

the upper sign corresponds to the α-space, the lower to the β-space, and the error function *erf* is defined by

$$erf \,.\, y = \frac{2}{\sqrt{\pi}} \int_0^{y} e^{-x^2} .\, dx \quad \cdots \quad (7)$$

The solution of eq. (5) has already been effected by mechanical means with the help of series approximations. The following asymptotic series are valuable:

for $\eta \ll 1$, one has

$$\phi^{\alpha}_{\beta}(\eta) = [\eta + \frac{1}{2}\eta^2 + \frac{1}{6}\eta^3 + \ldots] \pm \frac{2}{\sqrt{\pi}}\eta^{\frac{1}{2}}[\frac{2}{3}\eta + \frac{4}{15}\eta^2 + \ldots] \quad (8)$$

for $\eta \gg 1$

$$\phi_{\alpha}(\eta) \sim 2e^{\eta} - \frac{2}{\sqrt{\pi}}\eta - 1 - \frac{1}{\sqrt{\pi}\,\eta^{\frac{1}{2}}}\left[1 - \frac{1}{2\eta} + \frac{3}{4\eta^2} - \frac{15}{8\eta^3} + \ldots\right] \quad \cdots \quad (9)$$

and

$$\phi_{\beta}(\eta) \sim \frac{2}{\sqrt{\pi}}\eta^{\frac{1}{2}}\left[1 + \frac{1}{2\eta} - \frac{1}{4\eta^2} + \frac{3}{8\eta^2} - \frac{15}{16\eta^4} - \ldots\right] - 1 \quad (10)$$

III. Smoothing Effect of the Potential-Barrier

If the potential-barrier were fixed in amplitude and distance, the mean-square of the fluctuation of the anode current would be the same as for the equivalent temperature-limited diode. In fact, a fluctuation in the emission current will produce a fluctuation in the amplitude as well as in the distance of the potential-barrier.

Let us first consider the case $J \gg I$. In this case c may be considered as constant. An instantaneous fluctuation ΔJ, will produce a fluctuation Δv or $\Delta\eta$ and ΔI, such that*:

$$\left.\begin{aligned} \Delta I &= \Delta J \,.\, e^{-\eta_1} - I \,.\, \Delta\eta \\ \Delta I &= 2I \,.\, \Delta\eta/\xi_2[\phi(\eta_2)]^{\frac{1}{2}} \end{aligned}\right\} \quad \cdots \quad (11)$$

Eliminating $\Delta\eta$, squaring and taking the average, yields†:

$$\overline{\Delta I^2} = \overline{\Delta J}^2 \cdot \frac{I^2}{J^2} \cdot \frac{1}{\{1 + \frac{1}{2}\xi_2[\phi(\eta_2)]^{\frac{1}{2}}\}^2} \quad \cdots \quad (12)$$

where subscript 2 is relative to the β - space.

The smoothing of fluctuations by the potential-barrier is drastic, only a minute fraction of the fluctuation in the emission current reaches the anode.

Let us next consider the case, when I is of the order of magnitude of J, i.e., $0 \leq \eta_1 < 1$, where c cannot be considered as invariable. This case generally occurs for $\epsilon V_2 \gg kT$ and sufficiently good approximation is obtained with:

$$I = \frac{\sqrt{2}}{9\pi}\sqrt{\frac{\epsilon}{m}} \cdot \frac{V_2^{3/2}}{d^2} \quad \cdots \quad (13)$$

From eqn. (8) one has:

$$c = \alpha \,.\, d \,.\, V_1^{\frac{1}{2}}/V_2^{\frac{3}{4}}, \quad \alpha = 3/2(4kT/\pi\epsilon)^{\frac{1}{4}} \quad \cdots \quad (14)$$

Taking into consideration that the cathode-

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* All subsequent calculations are made for zero external impedance.

† For $\epsilon V_2 \gg kT$ this formula is equivalent to Llewellyn's equation, namely:

$$\overline{\Delta I^2} = \overline{\Delta J^2} \,.\left(\frac{\partial I}{\partial J}\right)^2$$

inasmuch as:

$$\frac{\partial I}{\partial J} = 3/2 \,.\, \frac{kT}{\epsilon V_2} \cdot \frac{I}{J}$$

(see E. B. Moullin l.c., pp. 134–135).

anode distance is invariable, eqns. (2), (13) and (14), yield :

$$\left\{\begin{aligned} \Delta I &= \Delta J \,.\, e^{-\epsilon V_1/kT} - \frac{\epsilon I}{kT}\Delta v \\ \Delta I &= 3/2\,\frac{I}{V_2}\Delta v - \frac{2I}{d}\Delta d \\ \Delta c &= \alpha\frac{V_1^{\frac{1}{2}}}{V_2^{\frac{3}{4}}}\Delta d + \frac{\alpha}{2}\frac{d}{V_1}\frac{V_1^{\frac{1}{2}}}{V_2^{\frac{3}{4}}}\left[1 - \frac{3}{2}\frac{V_1}{V_2}\right]\Delta v \\ \Delta c + \Delta d &= 0. \end{aligned}\right\} \quad \ldots \quad \ldots \quad (15)$$

Hence, after some straightforward mathematical manipulation :

$$\overline{\Delta I^2} = \overline{\Delta J^2} \,.\, \frac{I^2}{J^2} \,.\, \frac{1}{\left\{1 + \dfrac{2\epsilon V_2}{3kT} \,.\, \dfrac{1}{1 + \dfrac{2}{3}\dfrac{\alpha(1 - 3/2V_1/V_2)}{V_1^{\frac{1}{2}}V_2^{-\frac{1}{4}}(1 + c/d)}}\right\}^2} \quad \ldots \quad \ldots \quad (16)$$

One may generally neglect $3/2 \,.\, V_1/V_2$ and $\alpha \,.\, V_1^{\frac{1}{2}}/V_2^{\frac{3}{4}}$ against 1, thence :

$$\overline{\Delta I^2} = \overline{\Delta J^2} \,.\, \frac{I^2}{J^2} \,.\, \frac{1}{\left\{1 + \dfrac{V_1 V_2}{\alpha kT}\right\}^2} \quad \ldots \quad (17)$$

Thus, when $I \rightarrow J$, $V_1 \rightarrow 0$, one has: $\overline{\Delta I^2} \rightarrow \overline{\Delta J^2}$, i.e. the temperature limited region is obtained.

TABLE I

η_2	ξ_2	$\phi(\eta_2)$	$[\phi(\eta_2)]^{\frac{1}{2}}$	$1 + \frac{1}{2}\xi_2 [\phi(\eta_2)]^{\frac{1}{2}}$	S^2
1	2.352	0.556	0.746	2.25	0.89
2	3.515	0.932	0.966	2.70	0.74
3	4.475	1.23	1.11	3.48	0.57
4	5.327	1.50	1.22	4.25	0.47
5	6.110	1.77	1.33	5.07	0.39
6	6.842	1.99	1.41	5.82	0.36
7	7.535	2.20	1.48	6.58	0.30
8	8.196	2.39	1.55	7.35	0.27
9	8.832	2.57	1.60	8.07	0.24
10	9.447	2.75	1.66	8.84	0.22
15	12.275	3.51	1.87	12.48	0.16
20	14.826	4.17	2.04	16.12	0.12
25	17.193	4.75	2.18	19.75	0.10
30	19.425	5.29	2.30	23.31	0.086
40	23.594	6.23	2.50	30.50	0.065
50	27.474	7.06	2.66	37.44	0.053
70	34.64	8.51	2.92	51.57	0.039
100	44.41	10.32	3.21	72.26	0.029

IV. Mean-Square of the Fluctuation Current in a Space-Charge-Limited Diode.

Only the case where $J \gg I$ will be considered, i.e., a small fraction of the total emission current reaches the anode. In this case, as shown in section III, the smoothing effect of the potential-barrier is such that the transmitted fluctuations to the anode are only a minute fraction of the fluctuations in J. The α region (cathode-potential-barrier) may be assimilated to a diode in thermal equilibrium, where both electrodes are at the same temperature T. It is easily proved that such a diode is equivalent, from the point of view of fluctuations, to a conductor at temperature T and that Nyquist's theorem may be applied to this diode. Thus, the mean energy of fluctuations inside this diode, for a frequency band of Δf, is :

$$\overline{e^2}/R_1 = 4kT\,\Delta f \;(2kT\Delta f \text{ for each emitter}) \quad \ldots \quad \ldots \quad (18)$$

This source of fluctuations, applied in a circuit, the resistance of which is $R_1 + R_2$, where :

$$1/R_1 = \left(\frac{\partial I}{\partial V}\right)_\alpha, \quad 1/R_2 = \left(\frac{\partial I}{\partial V}\right)_\beta \quad \ldots \quad (19)$$

will produce a current fluctuation, the mean-square of which is :

$$\overline{\Delta I^2} \,.\, (R_1 + R_2) = 4kT\Delta f \quad \ldots \quad (20)$$

or

$$\overline{\Delta I^2} = \frac{4kT\Delta f}{R_1} \,.\, \frac{1}{1 + R_2/R_1} \quad \ldots \quad (21)$$

Eqns. (2), (3), (4), (5) yield :

$$1/R_1 = \frac{\epsilon I}{kT} \qquad R_2 = \tfrac{1}{2}\xi_2[\phi(\eta_2)]^{\frac{1}{2}} \,.\, \frac{kT}{\epsilon I}\,. \quad \ldots \quad \ldots \quad (19a)$$

Thence :

$$\overline{\Delta I^2} = \frac{4\epsilon I\Delta f}{1 + \frac{1}{2}\xi_2[\phi(\eta_2)]^{\frac{1}{2}}} \quad \ldots \quad \ldots \quad (20b)$$

and

$$S^2 = \frac{2}{1 + \frac{1}{2}\xi_2[\phi(\eta_2)]^{\frac{1}{2}}} \quad \ldots \quad \ldots \quad (21)$$

Values of S^2 as function of η_2 are tabulated in Table I.

Now we may proceed to discuss the variation of S^2 as a function of η_2.

When $\eta_2 = 0$, the mean energy of fluctuations is $\overline{\Delta I^2} . R_1 = 2kT\Delta f$; using eqn. (19a), one has :

$$\overline{\Delta I^2} = 2kT\Delta f . \frac{\epsilon I}{kT} = 2\epsilon I \Delta f . \quad .. \quad (22)$$

In this region the mean-square of the fluctuation of the anode current is the same as for the equivalent temperature-limited diode. When η_2 increases and for $\eta_2 > 1$ we obtain region 2, the case discussed in section IV, where S^2 is given by eqn. (21). If η_2 is increased still more, I increases and when J/I is less than, say 20, the considerations of section IV are no more valid. We obtain region 3, about which little is known quantitatively. Then, if η_2 increases more and more, region 4, where $J/I < 3$ is attained. This region is the transition region between space-charge and temperature-limited conditions. The fluctuations of the potential barrier are to be taken into consideration in accordance with eqn. (16).

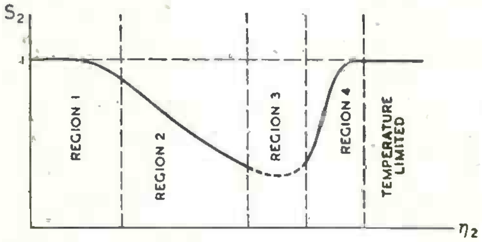

Fig. 2.

Fig. 2 represents the variation of S^2 as function of η_2.

The signal to noise ratio is most favourable when the valve is operated in region 3. These results are in good agreement with experiments by Williams and others.

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Wireless Patents

A Summary of Recently Accepted Specifications

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each

AERIALS AND AERIAL SYSTEMS

548 695.—Frame-aerial coupling comprising a fixed resonant circuit formed of two sets of capacity-coupled frame windings, one of which is in series with an iron-cored variable inductance.

Johnson Laboratories Inc. (assignees of W. A. Schaper). Convention date (U.S.A.) 19th February, 1940.

548 696.—Frame-aerial coupling in which a primary and secondary coil, shunted across the frame, are both tuned by a common powdered-iron core.

Johnson Laboratories Inc. (assignees of W. A. Schaper). Convention date (U.S.A.) 19th February, 1940.

548 965.—Balanced-bridge relay for remotely controlling the length and therefore the tuning of an aerial in accordance with variations in the tuning of a circuit to which the aerial is coupled.

S. Y. White. Convention date (U.S.A.), 29th February, 1940.

549 085.—Construction and arrangement of a vertical tier of half-wave horizontal dipoles and their feed-lines.

Standard Telephones and Cables (assignees of J. F. Morrison). Convention date (U.S.A.), 17th May, 1940.

DIRECTIONAL WIRELESS

548 900.—Phasing device for modulating the two overlapping beams used in radio-navigational systems for marking-out a blind approach path in space.

Aga-Baltic Radio Akt. Convention date (Sweden), 4th January, 1940.

RECEIVING CIRCUITS AND APPARATUS

(*See also under Television*)

548 633.—Aerial coupling circuit designed to provide reception either from a frame or vertical aerial as desired.

Philco Radio and Television Corporation (assignees of W. H. Newbold). Convention date (U.S.A.) 1st May, 1940.

TELEVISION CIRCUITS AND APPARATUS

For Transmission and Reception

548 643.—Television system in which the picture is reproduced by projecting light from an external source through a light-modulating screen with a liquid surface controlled by the electron stream of a cathode-ray tube. (Addition to 543 485).

Ges. zur Forderung &c. Technischen Hochschule (Zurich). Convention date (Switzerland) 30th November, 1940.

548 750.—Optical system for projecting and enlarging the picture produced on the fluorescent screen of a cathode-ray television receiver.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date 12th January, 1942.

548 771.—Speed-control system for a synchronous motor of the phonic wheel type, such as is used in television.

Scophony and P. L. F. Jones. Application date 17th July, 1941.

548 871.—Grid-triggering circuit for controlling the generation of saw-toothed oscillations by a three-electrode gas-filled discharge valve.

Standard Telephones and Cables; I. R. Worsley; and C. T. Daly. Application date, 24th April, 1941.

TRANSMITTING CIRCUITS AND APPARATUS

(*See also under Television*)

548 614.—Velocity modulating an electron stream by means of phase-adjusting electrodes located on each side of a resonant cavity.

Marconi's W.T. Co. (assignees of E. G. Linder). Convention date (U.S.A.) 8th October, 1940.

548 968.—Transmission circuit comprising high-pass and low-pass channels which together cover a wide audio-frequency range and produce a uniform signal output.

Marconi's W. T. Co. (assignees of M. Artzt). Convention date (U.S.A.), 29th February, 1940.

CONSTRUCTION OF ELECTRONIC-DISCHARGE DEVICES

548 644.—Velocity-modulation type of discharge tube with auxiliary electrodes to give efficient rectification.

Standard Telephones and Cables (assignees of F. E. Terman). Convention date (U.S.A.) 8th November, 1940.

548 697.—Cathode-ray tube in which the stream is simultaneously subjected to a magnetic and an electrostatic field, and in which means are provided for minimising undesired lateral movements of the electrons.

H. Miller. Application date 17th March, 1941.

548 725.—Construction and assembly of the electrodes in a velocity-modulating tube comprising hollow resonators. [Addition to 523 712].

The Board of Trustees of The Leland Stanford Junior University. Convention date (U.S.A.) 20th April, 1939.

548 735.—Cathode-ray type of discharge tube in which the beam is first cyclically deflected in two directions and is then intercepted at different points for producing short-wave signals at a high level of power.

Farnsworth Television and Radio Corporation. Convention date (U.S.A.) 23rd February, 1940.

548 792.—Back-coupling arrangement for reducing the input capacitance, or damping, of a valve comprising at least two secondary-emission electrodes in cascade.

Philips Lamps (communicated by N. V. Philips' Gloeilampenfabrieken). Application date 19th September, 1941.

548 918.—High-frequency discharge tube in which a "bunched" stream of electrons excites a concentric-line "tank circuit" mounted externally of the tube.

Marconi's W. T. Co. (assignees of B. Salzberg). Convention date (U.S.A.), 16th May, 1940.

548 948.—Variable-reactance valve in which space-charge effects are used to control the frequency of an oscillator in accordance with applied signal or like voltages.

Sir L. Sterling. Convention date (U.S.A.), 27th April, 1940.

SUBSIDIARY APPARATUS AND MATERIALS

548 742.—Apparatus for measuring a magnitude, such as power, by its modulating effect on a high-frequency circuit.

W. W. Triggs (communicated by Brown, Boverie et Cie). Application date 22nd May, 1941.

548 767.—Electromagnetic driving unit for a mirror oscillograph, such as is used in sound recording systems.

Electrical Research Products Inc. Convention date (U.S.A.) 31st July, 1940.

549 010.—System of facsimile telegraphy utilising frequency modulation.

Standard Telephones and Cables (assignees of W. S. Gorton). Convention date (U.S.A.), 26th April, 1940.

549 047.—Timing relays for responding to trains of impulses used for controlling the position of selective devices, say in automatic systems of telephony.

Automatic Telephone and Electric Co.; R. Taylor; and G. T. Baker. Application date, 28th April, 1941.

549 048.—Construction of tuning control knob, or similar element used, say, in a radio receiver, which allows of adjustment to compensate for thick or thin walled cabinets.

Marconi's W. T. Co. (assignees of F. L. Creager). Convention date (U.S.A.), 1st May, 1940

"Bell System Technical Journal"

The publishers of the *Bell System Technical Journal* advise us that the ban on its export, imposed last year, has been lifted. The only issue to be published after the imposing of the ban was dated June, 1942, and this has now been cleared for export and has been dispatched to subscribers. January, 1943, is the date of the first issue published since the lifting of the ban.

Abstracts and References

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For the information of new readers it is pointed out that the length of an abstract is generally no indication of the importance of the work concerned. An important paper in English, in a journal likely to be readily accessible, may be dealt with by a square-bracketed addition to the title, while a paper of similar importance in German or Russian may be given a long abstract. In addition to these factors of difficulty of language and accessibility, the nature of the work has, of course, a great influence on the useful length of its abstract.

PROPAGATION OF WAVES

684. ON THE QUESTION OF DISTORTIONS IN METALLIC WAVE GUIDES [Analysis of the Deformation of the Amplitude Curve of Amplitude-Modulated Waves arising from the Frequency-Dependence of the Phase Velocity].—H. Samulon. (*Bull. Assoc. suisse des Élec.*, 23rd Sept. 1942, Vol. 33, No. 19, pp. 518–522: in German.)

It is first shown that by a suitable choice of σ and γ (where $\sigma = \Omega/\omega_{\text{lim}}$ and $\gamma = \mu\omega/\omega_{\text{lim}}$: *see* eqn. 9) the non-linear distortion of the amplitude curve can be practically eliminated: but the distortion due to the phase-velocity characteristic remains, and can be very troublesome in certain applications, such as television. The investigation leads to results which are illustrated by two examples, the guide data and the frequencies being selected so as to be unfavourable, so that the distortion should be easily recognised. Thus in both examples the H_1 type of wave is excited in a 5 km length of guide of 10 cm diameter, so that $\lambda_{\text{lim}} = 17$ cm: the carrier frequency is chosen at 3000 Mc/s, so that $\sigma = \Omega/\omega_{\text{lim}} = 1.7$. In the first example the amplitude curve at $z = 0$ is represented by $f(t)_{z=0} = 1 + \sin \omega_N t$: the subscript "N" represents the lowest sideband, taken as 12 Mc/s. By the insertion of these figures in the equation already obtained, the undistorted curve at the start, Fig. 2a, is found at a distance of 5 km to have become the distorted curve of Fig. 2b. In the second example the amplitude curve at the start is taken as a more complex function, representing an almost triangular wave-form, with f_N at 6 Mc/s: at 5 km the amplitude curve of Fig. 3a becomes the distorted curve of Fig. 3b.

685. THE NATURAL WAVES OF THE LOADED CYLINDRICAL CAVITY.—H. Meinke. (*Hochf: tech. u. Elek:akus.*, Aug. 1942, Vol. 60, No. 2, pp. 29–37.)

From the Telefunken laboratories. In most practical cases the cavity resonator does not possess the ideal form dealt with by Borgnis (905 of 1940 and back reference). J. Müller gives a formula from which can be calculated the variations of the natural wavelength for very small changes in the cavity (1379 of 1940), but there have been no theoretical investigations of large changes. The writer designates any cylindrical cavity which departs from the ideal form through the inclusion of any kind of feature, a "loaded" cavity.

"It is obvious that in a cylindrical cavity a cylindrically symmetrical 'loading' at its middle point will, of all the various possibilities, provide the most tractable arrangement. This can be realised approximately by a central 'stamp,' Fig. 1 [illustrating a dumpy cylindrical cavity each of whose disc ends carries at its centre a short cylindrical plug, with a gap between their opposing ends, so that they look, in a diametrical cross section of the cavity, like some kind of punch or stamp: the height h of the cavity is small compared with the wavelength and the external diameter, so that the number of possible oscillation-modes is small]. The effect of such a 'stamp' on the natural wave has been investigated *experimentally* by Barrow (2951 of 1940). In the present work the natural wave of a centrally 'loaded' cylindrical cavity is *calculated*, the 'loading' being for this purpose somewhat idealised. It is however shown by numerous measurements that this idealisation can be applied to practically interesting cases with satisfactory accuracy, particularly to the arrangement of Fig. 1. . . . To help in the elucidation of the results, I develop the analogy between the current and potential relations in the loaded cavity and those in a line shorted at both ends and loaded in the middle by a reactance; such a line can be dealt with mathematically in a simple way and is therefore already known. A cavity loaded centrally by a dielectric plug extending the whole height of the cavity (Fig. 18) has recently been dealt with by Borgnis (2306 of 1942). In section IV I bring his equations into a form which corresponds to my equations for the general case of the centrally loaded cavity, and I give some experimental results. The *eccentrically* loaded cavity (Fig. 23) is not treated theoretically, but its properties are traced purely qualitatively from the analogous relations of an eccentrically loaded line (Fig. 20). Measurements confirm these considerations. Similar investigations on rectangular cavities will be described in a later paper."

686. SHORT-WAVE PHENOMENA: MODIFIED VIEWS ON PROPAGATION [Critical Discussion of Two Recent German Papers (1279 & 2275 of 1942)].—B. Beckmann & others: G. Leithaüser. (*Wireless World*, Jan. 1943, Vol. 49, No. 1, pp. 30–31.) Under the initials "T.W.B."

687. REMARK ON O. SCHRIEVER'S PAPER "THE ASSIMILATION OF ELECTROMAGNETIC REFLECTION AND REFRACTION THEORY TO THE PHYSICAL PHENOMENA."—F. Lettowsky: Schriever. (*Ann. der Physik*, 1st Oct. 1942, Vol. 42, No. 1, pp. 63–64.) *See* also 2600 of 1942.

688. REMARK ON THE PAPERS OF O. SCHRIEVER, J. GROSSKOPF, AND W. PFISTER [on the Zenneck Surface Wave, etc.].—W. Moser. (*Hochf:tech. u. Elek:akus.*, Sept. 1942, Vol. 60, No. 3, pp. 66–67.)

For these papers *see* 375, 2954, & 3199 of 1942. The present writer considers that it is not always remembered that Zenneck's form of solution, and his conclusions, were deliberately based on results which were subject to limiting conditions. He quotes from Cohn's "Lectures on Maxwell's Theory" (the book from which Zenneck took the formal statement and boundary conditions) to show that the wave considered was one whose amplitude decays at right angles to the surface of demarcation, towards both sides: that is to say, a surface wave without reflection at the surface. Such a wave does not actually correspond to the problem of wireless telegraphy, but the results are very useful, for values of σ and ϵ between certain limits, for determining the elliptical polarisation, and particularly the field-inclination in the neighbourhood of the surface of demarcation, the ground. But care must be taken when σ and ϵ take on extreme values: for instance, if σ_2 approaches zero and ϵ_2 is given an arbitrary value, a wave of constant amplitude is obtained: the Zenneck surface wave becomes an ordinary plane wave, for which the incident angle is equal to the Brewster angle. For only then is reflection absent, and the absence of reflection is a characteristic of the Zenneck solution (*see* also footnote "8"). If now ϵ_2 is made to approach unity, the Brewster angle moves towards 45° and remains formally at this value even when ϵ_2 is exactly one, when the surface of demarcation has disappeared physically. At this point the reflection from every other direction will have vanished, so that the "special" incident angle (45°) loses any particular physical distinction from other angles of incidence.

In the strict treatment of the radiation from a straight vertical aerial, first carried out by Sommerfeld for a plane, imperfectly conducting earth, the physical representation is fulfilled in the limiting cases (infinite conductivity in the second medium; also the case where $\epsilon_1 = \epsilon_2$ and $\sigma_1 = \sigma_2$). Schriever (*loc. cit.*) follows this line, supported by Weyl's extension of the Sommerfeld theory: like Strutt, however, he makes use of the simplified ideas of ray optics. His results are therefore only approximate solutions, which no longer hold good in the case where the source of radiation approaches the point of observation or the surface of demarcation: in fact, in the precise case considered by Grosskopf & Vogt. His formula for the inclination of the field lines has been repeated recently by Pfister (*loc. cit.*).

The appearance of an elliptical rotating field is no special property of the Zenneck surface wave. The general integral from the Sommerfeld theory yields it as a whole, not merely for a surface wave split in some particular manner. This emerges especially clearly from formula 35a given by Sommerfeld (reference "10"), which represents the behaviour of the field component distinguished by him as "space wave," in the neighbourhood of the separating surface and at a great distance from the source of radiation. This formula appears again in a paper by Grosskopf (964 of 1942: formula 9) under the name "modified Zenneck wave," but it has nothing in common with the Zenneck surface wave except the polarisation properties in the vicinity of the surface of separation.

The writer concludes by pointing out that a recent paper by Ott discusses the whole question of the propagation of radiation from a vertical dipole over an imperfectly conducting earth, on the basis of Sommerfeld's theory: *see* 18 of January. Sommerfeld's results are there used for the derivation of various approximate formulae which describe in a practically useful and clear form the behaviour of the field for all ranges of magnitude of the parameters concerned, namely ϵ_2, σ_2, and the relative positions of the point of observation, source, and surface.

689. EFFECTS OF SOLAR ACTIVITY ON THE IONOSPHERE AND RADIO COMMUNICATION.—H. W. Wells. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, p. 254: summary only.)

690. THE TOTAL SOLAR ECLIPSE OF OCTOBER 1, 1940 [Summary of National Geographic Society's Monograph].—(*Nature*, 31st Oct. 1942, Vol. 150, pp. 512–513.)

691. REACTANCE AND SKIN EFFECT OF CONCENTRIC TUBULAR CONDUCTORS [with Formulae & Curves for Three-Phase & Single-Phase Circuits: Formulae derived from Asymptotic Expansions of Bessel Functions for

High Frequencies : Penetration Formula].—H. B. Dwight. (*Elec. Engineering*, July 1942, Vol. 61, No. 7, Transactions pp. 513–518.)

692. High-Frequency Coaxial-Line Calculations [Transmission-Line Relations : Voltage Relations : Efficiency of Transmission : with Formulae, Tables, & Curves].—H. H. Race & C. V. Larrick. (*Elec. Engineering*, July 1942, Vol. 61, No. 7, Transactions pp. 526–530.)

693. Standing Waves on Transmission Lines : a Method of Line-Matching based on Graphical Comparison.—P. A. Gadwa. (*QST*, Dec. 1942, Vol. 26, No. 12, pp. 17–21.)

694. Radio Data Charts : No. 3 (3rd Series)—The Characteristic Impedance of Transmission Lines.—J. McG. Sowerby. (*Wireless World*, Jan. 1943, Vol. 49, No. 1, pp. 10–12.)

695. The Determination of High-Frequency Transmission Line Constants by Measurements at Special Frequencies [Calculation of Attenuation Constant, Characteristic Impedance, & Phase Constant, from Input-Impedance Measurements at Resonance Frequencies].—Simmonds. (*See* 839.)

696. The Variation, with Weather Conditions, of the Attenuation along Overhead Lines, for Higher [Wire-Broadcasting] Frequencies.—Klein & others. (*See* 910.)

697. Coppered-Steel Wire for Carrier-Frequency Overhead Lines.—Klein. (*See* 911.)

698. Propagation of Sound Waves in the Atmosphere [Effect of Humidity on Velocity : of Wind on Path : etc.].—Gutenberg. (*See* 823.)

699. The Propagation of Light in Hollow Guides [Investigation prompted by Wave-Guide Technique].—Mathieu. (*See* 966.)

700. Propagation of Electromagnetic Waves in a System of Parallel Layers of Isotropic Substances : *also* Observations on Low-Reflecting Bi-Layer Films of Metals and Dielectrics : *and* Optical Characteristics of Metallic and Dielectric Bi-Layer Films on the Basis of Maxwell's Equation.—R. K. Luneburg : H. Osterberg : M. C. Troutman. (*Journ. Opt. Soc. Am.*, Oct. 1942, Vol. 32, No. 10, pp. 630–631 : p. 631 : p. 631 : summaries only.) From the Spencer Lens Company.

701. Coherency Relations for the Light scattered by Colloids [Experimental Confirmation of Theoretical Conclusions].—H. Mueller & G. J. Yevick. (*Journ. Opt. Soc. Am.*, Oct. 1942, Vol. 32, No. 10, pp. 631–632 : summary only.)

702. Fresnel Reflection of Diffusely Incident Light [Computations & Curves of Reflectance (as Function of Relative Index of Refraction) for Three Angular Conditions of Incidence : Other Influences].—D. B. Judd. (*Journ. of Res. of Nat. Bur. of Stds.*, Nov. 1942, Vol. 29, No. 5, pp. 329–332.)

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY

703. Remarks on a Lightning Photograph [on Front Cover : the Difficulty in explaining the Frequent Strokes with No, or only Occasional, Streamers, by the Reasoning which makes Streamer-Formation understandable].—H. L. Rorden. (*Elec. Engineering*, Oct. 1942, Vol. 61, No. 10, pp. 541–542.)

704. Effect of Lightning on Thin Metal Surfaces [and the Use of Such Surfaces to obtain Data regarding Lightning].—K. B. McEachron & J. H. Hagenguth. (*Elec. Engineering*, Aug. 1942, Vol. 61, No. 8, Transactions pp. 559–564.)

705. Modern Impulse Generators for testing Lightning Arresters [and Methods of Approximate Calculation, with Curves, for Selection of Circuit Constants to produce the Various Required Current Waves].—Th. Brownlee. (*Elec. Engineering*, Aug. 1942, Vol. 61, No. 8, Transactions pp. 539–544.)

706. Modern Cathode-Ray Oscillograph for testing Lightning Arresters.—E. J. Wade & others. (*Elec. Engineering*, Aug. 1942, Vol. 61, No. 8, Transactions pp. 549–553.) A summary was dealt with in 3072 of 1942.

707. "Die Messung von Erderwiderständen" [Measurement of Earth-Connection Resistances : Book Review].—V. Fritsch. (*Hochf: tech. u. Elek:akus.*, Aug. 1942, Vol. 60, No. 2, p. 60.) For recent papers *see* 3517 of 1942.

708. Characteristics of Driven Grounds [Letter criticising Treadway's Mathematical Deductions as to the Response to Surge Voltages, prompted by Bellaschi's Paper (25 of 1942) : Importance of Tagg's Results (Reference "1") on Relation of A.C. to D.C. Specific Resistances, confirming Smith-Rose's Earlier Work (1934 Abstracts, p. 609) : the Question of Ground Rods in Parallel : etc.].—H. G. Taylor. (*Elec. Engineering*, Nov. 1942, Vol. 61, No. 11, p. 584.)

709. Study of Driven Grounds and Counterpoise Wires in High-Resistance Soil on Consumers Power Company 140-kV System.—J. G. Hemstreet & others. (*Elec. Engineering*, Sept. 1942, Vol. 61, No. 9, Transactions pp. 628–633.)

710. Practical Design of Counterpoise for Transmission-Line Lightning Protection.—E. Hansson & S. K. Waldorf. (*Elec. Engineering*, Aug. 1942, Vol. 61, No. 8, Transactions pp. 599–603.)

PROPERTIES OF CIRCUIT

711. A Transformation Theorem for Loss-Free Quadripoles, and Its Application to the Experimental Investigation of Decimetric- and Centimetric-Wave Circuits.—A. Weissfloch. (*Hochf:tech. u. Elek:akus.*, Sept. 1942, Vol. 60, No. 3, pp. 67–73.)

From the Julius Pintsch laboratories. The loss-free quadripoles here considered are such as conform with the "inversion" law; they contain no valves or other elements with directional or non-linear properties, but otherwise they may be complicated and extensive. It is assumed further that the quadripoles are connected both at the input (generator side) and at the output (load side) to homogeneous lines (concentric or parallel-wire lines) which may be different: it is also postulated that the parallel-wire lines should oscillate only symmetrically with respect to earth, since otherwise the circuit would become a six- or eight-terminal network instead of a quadripole. Examples of such quadripoles are illustrated in Fig. 1: thus (a) represents a concentric line in which the inner conductor is interrupted by a short ceramic insertion. Hitherto, wherever quadripoles for the decimetric- and centimetric-wave regions have been considered, the circuit components, so far as the writer is aware, have been almost exclusively of such a kind that their transformation properties could be derived, either by calculation or at least graphically, from the theory: partly by "idealising" and the use of equivalent circuits. But as shorter and shorter waves are used, quadripoles emerge more and more whose properties cannot be pre-calculated: and even where a calculation is made by the assumption of a lumped inductance or capacitance, it proves to be only a rough approximation in actual practice owing to the disturbing waves which occur.

It is, however, possible in many such cases to determine the transformation properties of the quadripoles used in a circuit, by experimental measurements. In this way it is possible to study the effect of alterations in the circuit and the causes or possible occurrence of disturbing effects. The transformation theorem developed in the present paper "allows a very simple theoretical and practical working-out of the test results." The measuring method is shown diagrammatically in Fig. 2: the homogeneous lines at the beginning and end of the quadripole under test must be at least so long that at the points where the measurement is made and where (on the other side of the quadripole) the known impedances are added, the electromagnetic field corresponds only to that of the homogeneous line, the disturbing waves having practically disappeared.

If the "output" line is provided with a sliding bridge or piston forming a complete short-circuit, the measurement involves merely the determination of the dependence of the distance y (between the potential minimum on the "input" line and an arbitrary point D) on the distance x (between the short-circuiting bridge and an arbitrary point C, on the "output" line), for a constant frequency. This dependence is then plotted as a curve (Fig. 3) which passes alternately above and below a straight-line axis inclined at 45°, and one of whose points of maximum steepness is at $x=0$, $y=0$. If m (a real number) is the slope at this point, and Z_1 & Z_2 are the input- and output-line characteristic impedances, then k is defined as mZ_1/Z_2, and the "transformation theorem for loss-free quadripoles" is stated as follows:—"If an arbitrarily complex and extensive loss-free circuit structure fulfils the requirements of the 'inversion' law, and is connected at input and output to homogeneous lines, then by the addition of suitable lengths of the attached homogeneous lines up to the points x_0 and y_0 (Fig. 1) this structure can always be extended to form a quadripole having the properties of an ordinary transformer with the transformation ratio $\ddot{u}=\sqrt{k}$. Any arbitrary impedance $\mathfrak{R}_2$ attached at x_0 (that is, an impedance on the output side, having a value $\mathfrak{R}_2$ referred to the point x_0) appears at y_0 as an impedance $\mathfrak{R}_1 = k\mathfrak{R}_2$. Again, in a reversed connection of the quadripole, any impedance $\mathfrak{R}_2$ connected at y_0 will appear at x_0 under the value $\mathfrak{R}_1 = \mathfrak{R}_2/k$. In the above, x_0, y_0, and k are, in general, dependent on frequency." The theorem is illustrated at the end of section I by application to the simple case of the quarter-wave "transforming section" shown in Fig. 1b.

Section II gives some further information on the measurement of transformation properties. The direct determination of the slope m from the curve is somewhat inaccurate, especially when m is large: it is therefore better to calculate it from the distance a (Fig. 3) between the tangents, which are inclined 45° to the X-axis, by means of eqn. 5 at the top of p. 70. It is often preferable, experimentally, to displace the quadripole itself instead of the short-circuiting bar. This can be done, for example, if the transformation properties of a ceramic or Trolitul disc are to be measured: *see* Fig. 4 and adjacent text. Since it was shown originally (top of p. 68, r-h column) that the transformation properties could be determined by the introduction of at least 3 known impedances (to solve eqn. 1 for the 3 unknowns a, b, and c), it would be expected that the curves of Figs. 3 & 4 could be determined from three arbitrary points: this question is discussed on p. 70, l-h column, where also the effects of losses in the quadripole or in the short-circuiting bar are considered.

Section III opens by discussing the case represented by Fig. 4 as applied to the often-employed short section for tuning purposes, where by the displacement of an insulating disc the use of sliding metallic contacts can be eliminated: the correct design can be obtained by a preliminary plotting of the curve. It goes on to extend the technique to tubular guides without any inner conductor: *see* Fig. 7, for the measurement of the transformation properties of the junction of a concentric line to a tubular cavity. Section IV describes some actual measurements on various circuit elements, and finishes by discussing, in this connection, Schmidt's investigations (at longer wavelengths) of the irregularities of lines (1933 Abstracts, p. 222). Finally, section V gives the mathematical derivation of some of the points assumed, such as eqn. 5.

712. The Laws of Similitude of the Electromagnetic Field, and Their Application to Valves [at Ultra-High Frequencies].—König. (*See* 774.)

713. The Natural Waves of a Loaded Cylindrical Cavity.—Meinke. (*See* 685.)

714. High-Frequency Coaxial-Line Calculations.—Race & Larrick. (*See* 692.)

715. Reactance and Skin Effect of Concentric Tubular Conductors.—Dwight. (*See* 691.)

716. A Note on Send Elements [simulating a Generator of Given Internal Resistance] and Insertion Loss.—J. C. Simmonds. (*Electronic Eng:g*, July 1942, Vol. 15, No. 173, p. 75.)

717. Transmission-Line Equations [Letter on the Conventions involving the Use of the *A* and *D* Constants and the Difficulties arising when Power Flow is Reversed: Need for Consistent Expressions & Better Designations].—V. J. Cissna. (*Elec. Engineering*, Nov. 1942, Vol. 61, No. 11, p. 587.)

718. Differential Negative Resistances of Retarding-Field Type [as opposed to Secondary-Emission Type].—A. Pinciroli. (*Alta Frequenza*, Aug./Sept. 1942, Vol. 11, No. 8/9, pp. 355–368.)

In the field of electrical communications these circuits (of the type shown in Fig. 1) find ever-increasing and fruitful application, owing to the fact that they offer the possibility of solving, particularly simply, a number of problems such as frequency stabilisation, frequency conversion in receivers, the design of calibrated negative resistances for radioelectric measurements, piezoelectric oscillators, etc: *see* for example the same writer, 2686 of 1941 and back reference, 2636 of 1942, and 118 of January: also Francini, 719, below [and 2637 of 1942]. In all these applications it is essential that the differential negative resistance should be constant, and this can be attained if the various electrodes are given the correct voltages as determined from a knowledge of the shape of the resistance characteristics as functions of these various voltages. The writer, in Figs. 2–6, gives curves experimentally derived for a type EF6 pentode, from which it is seen that for $V_2 > 100$ v and $|V_1| < 2$v, the absolute value of the resistance varies little with V_2 (Fig. 2): for a given value of V_a (ranging from 9 to 35 v) it varies little with V_2 (Fig. 3): for a given value of V_2, as V_a is increased the absolute value of resistance diminishes, passes through a minimum, and increases (Fig. 4). A similar curve is given for a variation of V_3 (Fig. 5): finally, the resistance as a function of V_1 (starting from $V_1 = -0.8$ v, where grid current begins to flow, up to a few volts negative) varies to a limited degree, the curve being steepest for the lowest value of V_2 (100 v) and flattest for the highest (130 v: Fig. 6).

In the subsequent sections the writer essays the interpretation of the behaviour represented by the above characteristics by means of an approximate treatment of the course of the potential and distribution of electrons in the inter-electrode spaces. Two final conclusions reached on p. 366 are that to obtain the smallest differential negative resistance (corresponding to the greatest distances between adjacent curves of the $I_2 = f(V_a)$ family of Fig. 12) the voltage V_a must be increased as V_3 is decreased, in the algebraic sense: and that the smallest absolute value of the resistance, and the width of the region over which the resistance is practically constant, depend on both the voltages V_a and V_3.

719. Amplifying Valves with Negative Transconductance [and Their Applications as Phase Inverters (*e.g.* for Push-Pull Stages: Advantages over Triode Inverter and over Centre-Tap Transformer), as Aperiodic Frequency-Doublers, & as D.C. Voltmeters].—G. Francini. (*Alta Frequenza*, Aug./Sept. 1942, Vol. 11, No. 8/9, pp. 369–382.)

Mentioned by Pinciroli, 718, above. Author's summary:—"Negative-transconductance valves are examined as to their behaviour as amplifiers, a comparison with triodes being made. It is shown that the presence of a screen grid may yield a characteristic similar to that of a pentode: in this case the internal resistance may be taken as constant, even in the non-linear régime. Some applications are indicated, in which an essential point is the property of such valves to give an output voltage in phase with the input voltage."

720. Circuit for the Production of a Continuously Variable Inductance [for tuning an Oscillatory Circuit: Valve with Wattless Retroaction, and Grid Bias derived from Potential-Divider consisting of Condenser *C* (Fig. 8) & (in Anode Circuit) Indirectly Heated Temperature-Dependent (Urdox) Resistance *R*].—A. Agricola. (*Hochf:tech. u. Elek:akus*, Aug. 1942, Vol. 60, No. 2, p. 57.) A.E.G. patent, D.R.P. 717 260.

721. High-Sensitivity D.C. Amplifier: Another Application of the Cathode-Ray Tuning Indicator [the More Complicated Circuit referred to in 1464 of 1942, with Great Increase in Sensitivity: Whole or Part of One Bridge-Arm Resistance replaced by Target/Cathode Space, giving Positive Feedback: for Biological Research, etc.]—G. A. Hay. (*Wireless World*, Jan. 1943, Vol. 49, No. 1, p. 9.)

722. Correction to "Designing a Resistance-Capacity Oscillator covering Frequencies from 40 to 13 000 c/s in Four Ranges" [366 of February].—R. C. Whitehead. (*Wireless World*, Jan. 1943, Vol. 49, No. 1, p. 29.)

723. On Periodically Intermittent Self-Oscillations.—H. Barkhausen & K. Bose. (*Hochf:tech. u. Elek:akus.*, Aug. 1942, Vol. 60, No. 2, pp. 37–44.)

When an amplifier with a power amplification ratio *V* is brought to self-oscillation by a retroaction *K*, a stationary régime occurs in which KV must equal unity: if it is greater or smaller, the oscillation amplitude will increase or decrease. As a pure circuit magnitude, *K* is in general independent of the oscillation amplitude, but *V* includes also the valve properties, and especially the characteristic slope *S* which varies with the amplitude. The stationary condition $KV = 1$ is therefore only stable if *V* decreases with increasing amplitude and increases with decreasing amplitude. Otherwise it is unstable: if the amplitude decreases a little, V becomes smaller: KV becomes less than unity and the amplitude therefore diminishes still more, in general down to zero. Similarly, in the unstable case a slight increase in amplitude brings about an increase in V, so that KV becomes greater than unity and the amplitude increases further, until the valve is strongly over-controlled and V is consequently reduced again till finally $KV=1$: from then, the amplitude remains constant.

To avoid this over-control by too large self-excited amplitudes, an automatic amplitude-limiting circuit is often used, similar to the a.v.c. circuit of broadcast receivers: the simplest form of circuit employed is seen in Fig. 1, where the resistance R_g with its shunting condenser C_g is connected in the lead to the first grid (of a pentode) from the retroactive-coupling coil L_g, to form the amplitude control by its rectifying action. This arrangement would be expected to give continually stable oscillations, since the grid-control process automatically regulates the amplitude to a definite value. Such is, in fact, the case when the grid condenser C_g is made so small that the control process can follow every change: but if C_g is increased above a critical value, an effect of intermittent self-excitation sets in, in which the oscillations decay rather suddenly, generally down to zero, and then after a short time build themselves up again, and so on. It is impossible, in these conditions, to obtain a stationary self-excited amplitude. The object of the present work is to investigate the conditions in which this phenomenon occurs. Analysis of the stability conditions, and experimental confirmation of the influence of the circuit values and the valve values, followed by analysis and experimental confirmation of the influence of the first-grid alternating current, show that no stability is attainable so long as the time constant of the grid control is greater than the time constant with which the oscillations would increase in the absence of the control: and that the control time constant is determined less by the resistance R_g than by the reciprocal of the slope of the rectification characteristic (Fig. 6).

724. New "Kipp" Circuits for the Generation of Saw-Tooth Voltages.—Johannsen. (*See* 871.)

725. Evaluating Determinants [Note on Crout's "Short Method" (3543 of 1942): Its Use as a Very Systematic & General Form of "Network Reduction," with Special Advantages].—W. H. Huggins: Crout. (*Elec. Engineering*, Sept. 1942, Vol. 61, No. 9, p. 497.)

726. Criticism of "Laplacian Transform Analysis of Circuits with Linear Lumped Parameters."—W. V. Lyon: J. Millman. (*Elec. Engineering*, Aug. 1942, Vol. 61, No. 8, p. 445.)

"I have found from a detailed study of a number of typical conditions involving second- and fourth-order equations that, on the average, *more* arithmetical computation is necessary when the transform method is used than when the classical method is used effectively. . . ." Millman's paper was in the April 1941 issue.

727. On Effect of Resistance Component in Wave-Filter Elements, and Performance of Non-Ideal Filter Sections [Theoretical & Experimental Investigation].—W. Ahmed. (*Indian Journ. of Phys.*, Aug. 1942, Vol. 16, Part 4, pp. 229–239.)

728. Coupling-Free Networks.—W. Bader. (*T.F.T.*, July 1942, Vol. 31, No. 7, pp. 177–189.)

Further development of the investigations dealt with in 2940 of 1940 and 3226 of 1942. Recent investigations have led to the design of reactance quadripoles of various types with prescribed working characteristics. But some of these networks demand ideal transformers, some demand impossible accuracy in the fulfilment of calculated values in their components, while in others the matching of two windings on a single core is a troublesome affair, and the neglected inter-winding capacity causes a departure from the calculated value. On the other hand, networks free from mutual inductances—"coupling free" networks—are insensitive to constructional errors and easy to balance: such a network consists of a chain of reactance bipoles without magnetic coupling between them, as in Fig. 4 on p. 183. The following two questions are therefore of practical and not merely theoretical interest: (a) what working characteristics may be prescribed for a reactance quadripole in order that it may be carried out in the form of a coupling-free network? and (b) how can such a network be calculated? The present paper is the first of a short series designed to answer these questions.

729. Template Method for the Design of Electrical Wave Filters on the Basis of the Wave Parameters.—E. Rumpelt. (*T.F.T.*, Aug. 1942, Vol. 31, No. 8, pp. 203–210.)

Time-saving graphical methods of obtaining the characteristic curves of attenuation and phase for filters of prescribed properties have been developed, for instance, by Haase and by Laurent (1307 of 1942: 1339 of 1938 and 960 of 1940). The latter starts from the simplest all-pass section and calculates its attenuation at negative imaginary frequencies: this, plotted against a logarithmic frequency scale, has a curve whose shape is independent of the position of the attenuation "pole" (*see* 46 of 1940) and can therefore be represented by a template. With this attenuation curve as a basic building element, Laurent then constructs, by graphical frequency transformations, practically realisable attenuation curves of symmetrical filters for physical frequencies; he also uses a similar procedure for obtaining the phase curves of symmetrical filters.

The present writer carries this work further by deriving the template functions and the frequency transformations necessary for various types of filter. For symmetrical filters his results are necessarily the same as Laurent's: but the frequency transformations are carried out by calculation, more accurately and conveniently than by the graphical method used by Laurent; the whole operation is simpler than Laurent's; and it is *not* limited to symmetrical filters.

730. On the Calculation of the Distributed Capacitance of Coils [Letter prompted by Sacco's Paper (2119 of 1941) and a Comparison with Palermo's 1934 (*Proc. I.R.E.*) Formula, leading to a Suggested New Formula (" 3," on p. 399) : Sacco's Replies].—A. Colino : L. Sacco. (*Alta Frequenza*, Aug./Sept. 1942, Vol. 11, No. 8/9, pp. 397–403.)

731. The Optimum Damping of Coils with Compressed-Powder Cores [Vigorous Riposte in Contest dealt with in 3537 of 1942].—J. Labus : Lohrmann. (*Hochf:tech. u. Elek:akus*, Aug. 1942, Vol. 60, No. 2, pp. 54–55.)

Among other points, Labus remarks " The *Radio Experimenter* [from which he had quoted Arguimbau's paper] is not, as Herr Lohrmann maintains, a ' little-known amateur journal,' but is published by the well-known instrument firm, General Radio Company."

732. On Eddy Currents in a Rotating Disc [*e.g.* Damping Disc in Instruments : Method of deriving Paths & Torque, based on " Little Known " Formula given by Maxwell].—W. R. Smythe. (*Elec. Engineering*, Sept. 1942, Vol. 61, No. 9, Transactions pp. 681–684.)

733. The Effect of Initial Conditions on Subharmonic Currents in a Non-Linear Series Circuit [with Saturable Inductor].—S. J. Angello. (*Elec. Engineering*, Sept. 1942, Vol. 61, No. 9, Transactions pp. 625–627.)

734. Amplifying Properties of Remanence-free Generators [" Charlet " Generator].—Steffenhagen : Charlet. (*See* 971.)

TRANSMISSION

735. Corrections to " Transit-Time Oscillation at Large Amplitudes " [3229 of 1942].—W. Kleinsteuber. (*Hochf:tech. u. Elek:akus.*, Sept. 1942, Vol. 60, No. 3, p. 73.) Correction to eqn. 22 and to the last statement in the author's summary.

736. On the Question of the Mechanism of Retarding-Field Oscillation at Large Alternating-Voltage Amplitudes [as in Resotank Generators].—H. H. Klinger. (*Funktech. Monatshefte*, Aug. 1942, No. 8, pp. 112–113.)

Although combinations of retarding-field valves with cavity resonators, such as the Resotank, behave differently from the original B–K circuits, the writer considers that it is unnecessary to abandon the " electron swinging " and " sorting-out " pictures drawn by Barkhausen and H. G. Möller and to adopt an entirely new idea of the oscillation mechanism, as has been done by recent workers (*see* Kockel, 3230 of 1942 and back references). The real difference between the new and old behaviours is due to the much larger amplitudes of oscillation now obtained, which exert a much greater back-influence on the " sorting-out " process, only feebly carried out in the ordinary B–K circuit. Such hastened elimination of the out-of-phase electrons must also occur, for large amplitudes, in magnetrons, and should diminish the troublesome back-heating of the filament. It is suggested that phase-focusing, such as is used in klystrons, could be employed to increase efficiency by compressing the correct-phase electrons into space-charges as dense as possible, to influence the charges on the electrodes.

737. The Influence of the Supply Parameters on the Frequency of Oscillations in a Split-Anode Magnetron.—E. P. Sytaya. (*Journ. of Tech. Phys.* [in Russian], No. 8, Vol. 11, 1941, pp. 762–766.)

Experiments were carried out in which the effect of the anode voltage U_a, magnetic field intensity $H_э$, and emission current $I_{эm}$ on the wavelength λ generated by a split-anode magnetron was investigated. The magnetrons were operated on wavelengths from 66 to 92 cm ; U_a was varied from 100 to 880 v and $H_э$ from 500 to 1600 oersteds. The intensity of oscillations under various operating conditions was also observed. The following main conclusions were reached :—(1) λ increases with $H_э$ until the latter becomes approximately 1.5 times the critical value H_{KP} : from 1.5 H_{KP} to 2 H_{KP}, approximately, λ decreases and then remains constant. (2) With $H_э$ up to 1.7 H_{KP} approx., the variation of U_a causes a variation of the same sign in λ. The greater $H_э$ the smaller is the effect of U_a on λ. With fields above 1.7 H_{KP}, U_a has no effect on λ. (3) A rise in $I_{эm}$ at first increases λ, which then remains almost independent of $I_{эm}$.

738. A 25-Watt 2½-Metre M.O.P.A. [Master-Oscillator-Power-Amplifier] : Linear Tanks in a Simple Transmitter of Improved Stability.—J. A. Bailey. (*QST*, Dec. 1942, Vol. 26, No. 12, pp. 41–43 and 116.)

739. Method of Multiple Transmission on Ultra-Short Waves. — Schussler. (*See* 902.)

740. On Periodically Intermittent Self-Oscillations.—Barkhausen & Bose. (*See* 723.)

741. Organs for the [Remote] Tuning of Transmitters and Receivers [Some Mechanical Devices for Distances Not Great Enough for Servo-Motor Control].—H. B. R. Boosman & R. P. Wiriz. (*Alta Frequenza*, Aug./Sept. 1942, Vol. 11, No. 8/9, pp. 418–421 : summary, from *Philips Transmitting News*, March 1941, p. 3 onwards.)

RECEPTION

742. Interference-Suppression in Amplitude Modulation and Frequency Modulation.—H. J. Reich. (*Communications*, Aug. 1942, Vol. 22, No. 8, pp. 7 and 16..20.) Analysis successfully used in teaching senior electrical engineering students.

743. On the Permissible Value of the Heterodyning Voltage appearing at the Input of Superheterodyne Receivers, from the Viewpoint of Interference with Neighbouring Receiving Sets in

the Broadcast and Short-Wave Bands.—R. Moebes. (*T.F.T.*, Aug. 1942, Vol. 31, No. 8, pp. 217–222.)

Re-radiation interference by "straight" receivers is, thanks to the screening carried out in modern receivers, limited to the single-circuit type of equipment. Even then it only occurs when the set is wrongly adjusted, so that as listeners become more expert the trouble disappears. In fact, although the number of single-circuit receivers in use has increased, the cases of interference, at one time extremely frequent, have decreased from year to year, and will diminish still further as the single-circuit type is replaced by larger apparatus. It is therefore superfluous to lay down regulations regarding the construction of the "straight" receiver. With the superheterodyne type, on the other hand, the position is entirely different. The continuously acting oscillator voltage reaches, at the mixing valve, values of 5 to 15 v, and in a receiver without a h.f. input stage and a single input circuit will produce at the receiver input terminals something like 10 mv in the broadcast band and 100 mv in the short-wave band [*see* also 3314 of 1941, of which the present paper appears to be an extension, though the earlier paper is not mentioned here]. The superheterodyne with a single input circuit is just the design which has been specially popular for some years, and is quite likely to remain so for a long time to come. It is therefore of considerable importance to ascertain whether the interference it causes is tolerable, or how high the heterodyne voltage appearing at the input terminals may be allowed to be.

The present theoretical and experimental investigation deals, among other things, with the case where a community aerial system is involved, including the modern "wide-band" type which takes in also the 5–20 Mc/s short-wave band; and also with the case where separate aerials are insufficiently spaced or are "supplemented" by common systems such as gas mains, central heating, or "mains" antennas. The results are summed up as follows:—"Two interference possibilities must be distinguished: in the first, the heterodyne frequency of the disturbing set coincides with the frequency being received on the neighbouring set. In this case, in both wave-bands in question, and both with community-aerial systems (having the decoupling conditions mentioned) and with separate aerials spaced from 4 to 10 metres, the heterodyne voltage at the input of the disturbing receiver must be kept below 1 mv if interfering beat notes are to be avoided. In the broadcast band the occurrence of such interference, with the present-day customary i.f. of 470 kc/s, is fairly rare, and it may perhaps be advisable to allow voltages up to 10 mv and to counter the trouble by an alteration to the wave-allocation of the broadcasting station or by a slight shifting of the intermediate frequency.

"In the second interference possibility the disturbing heterodyne frequency acts on the heterodyne frequency of the neighbouring receiver or on the image frequency of its setting. The former case particularly, where both receivers are tuned to the same station, is of importance, since in the same neighbourhood there is a tendency to listen to the same station. The interfering voltage in the neighbouring receiver is reduced by the attenuation of the input circuit, in the broadcast band at least by 1 : 100, in the short-wave band by only 1 : 3 or 1 : 4. In the former band, in these circumstances, the voltage at the disturbing-receiver input could be allowed to be some 10 mv, but in the short-wave band it would have to be reduced below 1 mv."

On the whole it seems advisable to neglect the one type of interference on the broadcast band and to counter the other type by the methods suggested above: so that in this wave-band the common re-radiation values of 10–20 mv may be regarded as tolerable. In the short-wave band, on the contrary, steps ought certainly to be taken to reduce the customary 100 mv to below 1 mv (which incidentally would usually reduce the broadcast-band voltages also). A high-frequency input stage may be necessary. In the last paragraph it is mentioned that on short waves the harmonics of the heterodyne frequency may cause interference with u.s.w. services: this point is being investigated.

744. Prevention of Mutual Interaction between Broadcast or Wire-Broadcast Receivers connected to a Common Distribution System [Use of Pairs of Parallel Opposed Rectifiers as Voltage-Dependent Resistances across Each Input, combined with Series Resistances].—W. Hagen. (*Hochf:tech. u. Elek:akus.*, Aug. 1942, Vol. 60, No. 2, p. 57.) C. Lorenz patent, D.R.P. 717 065.

745. Hum Disturbance of Special Kinds [in Receivers & Microphone or Gramophone Amplifiers: particularly the Hum due to Magnetic Leakage acting on the Valves Themselves].—O. Stephani. (*Funk* [Berlin], 1st Jan. 1942, No. 1, p. 5.)

746. Use of Loudspeaker Fields as Filter Chokes [Necessity for "Hum-Bucking" Coil in series with Voice Coil: Analysis showing Considerable Distortion resulting from This Arrangement: Cross Products cause Noticeable Blurring of Tone].—K. A. Pullen, Jr. (*Elec. Engineering*, July 1942, Vol. 61, No. 7, pp. 388–389.) "Use of the speaker field as a choke is not warranted if quality of reproduction is of primary importance."

747. Current-Economising Circuit for Receivers using Screen-Grid Valves [Current Economising is Simple in A.C. Receivers, Less Simple in Universal: Defects of Existing Methods for These: New Method utilising Screen-Grid Currents led through Common Short-Circuitable Resistance: Additional Development using Auxiliary Winding for Loudspeaker Field Coils (acting also as Smoothing Choke) as This Resistance, so that S.G. Currents make up for Decrease in Field Excitation due to Current Economy].—(*Funk* [Berlin], 1st May 1942, No. 9, pp. 125–126.)

748. Load-Equalising Circuit for Receivers with Automatic Volume Control [to avoid Various Disturbing Effects of Sudden

Large Interference Pulse which produces Sudden Change in Control-Valve Current].—F. Krebs. (*Funk* [Berlin], 1st May 1942, No. 9, pp. 117–120.)

749. Organs for the [Remote] Tuning of Transmitters and Receivers.—Boosman & Wiriz. (*See* 741.)

750. Basic Considerations in the Remote Switching of Broadcast Receivers [Survey of Recent Papers published in *Funk*].—W. Böhrnsen. (*Funk* [Berlin], 1st July 1942, No. 13, pp. 177–179.)

751. The Position of Russian Broadcast Technique [Valves, Components, Wire Broadcasting, Receivers, etc: Comments by Two German Soldiers on East Front].—W. Mangel & M. Klimek. (*Funk* [Berlin], 15th June 1942, No. 12, pp. 164–167.)

752. Suggestions for the Utilisation of the Components of Foreign Broadcast Receivers [which cannot have Their Valves replaced].—E. Bottke. (*Funk* [Berlin], 1st July 1942, No. 13, pp. 183–184.)

753. The Conversion of Mains-Driven Receivers to Battery Drive [in War-Time].—E. Frank. (*Funk* [Berlin], 15th July 1942, No. 14, pp. 191–192.)

754. The "Filament-Heating" Condenser [Series Resistance in "Universal" Receivers, Frequency Meters, etc., economically replaced by Condenser, particularly for Modern German Valves].—H. Kämmerer. (*Funk* [Berlin], 15th July 1942, No. 14, pp. 195–197.)

755. Practical Notes on Receiver Design: Part I.—G. T. Clack. (*Electronic Eng:g*, July 1942, Vol. 15, No. 173, pp. 70–72 and 74: to be contd.)

756. Designs for "Pocket" and Other Small Receivers, *and* Circuits for "Pocket" Receivers.—E. W. Stockhusen. (*Funk* [Berlin], 15th Jan. 1942, No. 2, pp. 19–21: 1st June 1942, No. 11, pp. 155–156.)

757. A Small Single-Circuit Receiver with High Output [4 Watts: Combination of UY11 Rectifier & UCL11 Tetrode to give Universal Receiver, and Other Variations].—E. Bleicher. (*Funk* [Berlin], 15th July 1942, No. 14, pp. 189–190.)

758. The Telefunken 166 WK [Export Receiver] with Short-Wave Band Spread.—R. Hildebrandt. (*Funk* [Berlin], 15th March 1942, No. 6, pp. 78–79.)

In the short-wave band the rotating condenser is electrically disconnected, but its spindle still does the tuning by a disc mounted eccentrically on it and acting simultaneously on the input and oscillator inductances. Another special point in this receiver is the automatic reduction of the low notes, for weak signals where increased selectivity tends to cut the higher frequencies and make the reproduction too drummy.

759. A Receiver with Push-Pull Output Stage [Opposed-Phase Modulating Voltages derived directly from Duo-Diode Detector, dispensing with Centre-Tapped Transformer or Phase-Reversing Circuit, thus giving Reduced Non-Linear Distortion].—W. Rentsch. (*Funk* [Berlin], 1st Feb. 1942, No. 3, p. 31.)

760. The 16th Swiss Radio Exhibition, Zurich, 1942.—(*Bull. Assoc. suisse des Élec.*, 23rd Sept. 1942, Vol. 33, No. 19, pp. 523–524: in German.) A short note only.

AERIALS AND AERIAL SYSTEMS

761. Aerials for 324 Mc/s Link in Don Lee Outside Television Broadcasts, and the Importance of Their Positions.—Lubcke. (In paper dealt with in 824, below.)

762. A Circular Antenna for Ultra-High-Frequencies [evolved from the Helderberg "Cubical" Television Aerial: Simple Mechanical Structure, No Insulation from Earthed Metal Pole].—M. W. Scheldorf. (*QST*, Nov. 1942, Vol. 26, No. 11, pp. 19–22.)

Summary of I.E.E. Summer Convention paper. A short summary was given in *Proc. I.R.E.*, May 1942, Vol. 30, No. 5, p. 253.

763. Polar Diagrams of Ultra-Short-Wave Horizontal Transmitting Aerials [of Length λ, $3\lambda/4$, $\lambda/2$, & $\lambda/4$, where $\lambda = 3$–7 m: Measurements at Short Distances, and Comparison with New Equations derived by "Induced E.M.F." Method: the Dependence of the Polar Diagrams on Length of Aerial & on Distance of Measuring Point from Input End].—S. S. Banerjee & G. C. Neogi. (*Indian Journ. of Phys.*, Aug. 1942, Vol. 16, Part 4, pp. 211–218.)

764. Beam Aerial System for Ultra-Short Waves [consisting of at least Four Half-Wave Dipoles with Trombone or Other Phase Adjusting Devices].—Hasler Company. (*Hochf:tech. u. Elek:akus*, Sept. 1942, Vol. 60, No. 3, p. 80.) Swiss patent, No. 217 898.

765. The Measurement of Radiative Coupling [in Aerial Systems].—H. Brückmann. (*T.F.T.*, June 1942, Vol. 31, No. 6, pp. 158–161.)

The literature contains accurate details for the calculation of such coupling, and methods for its measurement have been given (Brown, 1782 of 1937): "but there are lacking not only comparisons between measurement and calculation but also critical judgments on the measuring methods. It is the object of the following paper to fill in these gaps." The first method examined is the current-measuring method, without and with a supplementary known ohmic resistance in the secondary aerial (giving the so-called "radiative-coupling coefficient," or better "radiative-coupling impedance," by eqn. 7a), or in a simpler version with a known supplementary reactance ΔB whose introduction into the secondary aerial reduces the current ratio, with respect to that at the tuning point, in the proportion 1 : $\sqrt{2}$: the required radiative-coupling impedance is then equal to $(I_2/I_1)_{\max} . \Delta B$. In this first method the phase displacement must be measured separately: this was done with the help of a Telefunken goniometer device described by W. Berndt & W. Moser (reference "2"). The second method involves impedance measurements on the primary aerial with various reactances in the secondary, and dispenses with separate phase measurements, since the required phase displacement as well as the coupling impedance can be derived from the resulting vector diagram (Fig. 1: for an example of the procedure *see* Fig. 3).

Table 1 shows the calculated results, and the measured results found by the current-and-phase-measurement method on the one hand and by the impedance-measurement method on the other. Except for the special "triangular-surface" aerial (three T-aerials joined) all measurements were for a 303.3 m wave: for it, a 176 m wave was taken. The spacing between the exciting and excited aerials was generally 45 m. Both methods of measurement show quite good agreement with the calculated values.

766. INVESTIGATIONS ON UMBRELLA AERIALS [Vertical Insulated Mast with Radiating Wire Extensions].—G. Rösseler & K. Vogt. (*T.F.T.*, June 1942, Vol. 31, No. 6, pp. 161–166.)

Extension of two previous papers, 4088 of 1937 and 3564 of 1939. The inclination γ of the wire extensions was varied from 90° (horizontal "roof") to 10°, their length r from 2 m to 8 m, and their number n from 2 to 16: for 8 and 16 wires the effect of a ring joining the far ends was examined also (denoted in the curves by "8 mR" and "16 mR" respectively). Fig. 3 shows how the static capacity of the aerial, measured by an a.f. bridge, varies as a function of r/l (l being the height of the vertical mast) when the extension wires are horizontal: the effect of the ring is seen clearly: the uppermost curve (∞) is for the limiting case of a disc of wire netting replacing the radiating extension wires. Figs. 4 a–d show the variation of the static capacity with the angle γ, for various values of r and n: particularly for large r values (*e.g.* 8 m, Fig. 4d) the capacity varies very little as the angle changes from 60° to 90°. For $r = 4$ and 8 m the capacities were calculated by Howe's 1914/15 method: the calculated results were on the average 10% below the measured values—a satisfactory agreement in view of the approximate nature of the calculation.

Section II deals with the characteristic impedance and virtual aerial-height ($l + l_v$, where l_v is the virtual increase of the vertical l due to the action of the extension wires). For all the arrangements in question the frequency-dependence of the reactance measured at the mast-foot, B_F, can be represented by the simple relation $B_F = -z_m . \cot \alpha (l + l_v)$, where z_m is the characteristic impedance of the aerial and $\alpha = 2\pi/\lambda$. Figs. 5 & 6 show the variation of the characteristic impedance (calculated by the above equation from the reactance measurements) with r, n, and γ: for clarity, the impedance is plotted as the ratio to that of the vertical part without top-loading. Similarly Figs. 7 & 8 show the variation of the virtual aerial-height $l + l_v$ (as the ratio to the length of the vertical part) with r/l, n, and γ. Among other points, it is mentioned that the characteristic impedance z_m can be calculated also from the static capacity and virtual aerial-height by the formula $z_m = 1/c.C$, where C is $C_{\text{stat}} / (l + l_v)$, the mean capacity per unit length in Farad/cm: the agreement between the values of z_m obtained from the reactance curves by the previous formula and those obtained by this last formula is remarkably good, the largest discrepancy being 3%.

Section III calculates the radiation resistance and efficiency. "For the simple calculation of the radiation resistance of an umbrella aerial, from voltage measurements in a vertical receiving aerial at ground level, a semicircular vertical radiation diagram is postulated: this is justified for the aerials now considered, their horizontal radiation being negligibly small compared with the vertical. The vertical radiation diagram and radiation resistance were calculated for the resonance case $\alpha (l + l_v) = 90°$ of an aerial with 16 wires 8 m long at right angles to the vertical mast, with a ring joining their ends: in this case $l + l_v = 35.5$ m, and the resonance frequency was 2110 kc/s. Only for angles above 60° did the diagram depart slightly from the semicircular diagram. The radiation resistance was found to be 5.6 ohms. Measurement gave 5.9 ohms, while the calculated value neglecting the radiation of the disc was 6.0 ohms . . ." The variations of radiation resistance with γ, measured on all the different aerials, are seen in Figs. 9 a–c, all for the case of resonance. As γ is decreased from 90° the radiation resistance decreases to a minimum and rises again to 30.6 ohms, the value for the aerial without top-loading. The minimum is more and more marked as the length of the wires is increased: for $r = 8$ m it is very deep, lying just below $\gamma = 30°$. The effect is due to the screening action of the sloping "roof." If the radiation resistance is calculated with neglect of the radiation from the extension wires, the results for all lengths of wire agree well with measurements when $\gamma = 90°$; but for smaller angles, especially with the longer wire lengths, the measured values are always smaller than the calculated, even when the screening effect of the cone (height h_s in Fig. 1) is taken into account. This discrepancy is produced by the coupling between the umbrella and the vertical part, neglected in the approximate calculation: it also produces a rise in radiation resistance at very small values of γ, compared with the vertical radiator without top-loading.

Defining the efficiency η as the ratio of the radiation resistance to the dissipative resistance (sum of radiation and earth-loss resistances), the writer has calculated η for all the aerials considered, for the case of resonance. If η_0 represents the efficiency of the vertical part without top-loading, at the same frequency, then η/η_0 provides a measure of the influence of aerial shape on earth losses. According to theory, for low aerials ($l < \lambda/4$, corresponding to the aerials investigated here with the longer wires) the efficiency for a given frequency and a given earth-conductivity depends chiefly on the radius of the earth system (cylindrical earth) and only little on the aerial form: so that

η/η_0 would be expected to be unity. For a flat-plate earth, such as was used in these investigations, no exact calculations are available, but it might be guessed that a concentration of current under the plate would produce losses larger than those with a cylindrical earth. Measurements for all wire lengths, number of wires, and inclinations, gave a mean value of 0.9 for η/η_0, with deviations of $\pm 5\%$.

767. SCREENED AERIAL-LEADS [Prevention of "Sheath Waves," due to Aerial Reaction on Outside of Sheath, by Cylinder (of Magnetic Material with High Electrical Loss) Short compared with Wavelength and surrounding Aerial End of Lead].—H. Roosenstein. (*Hochf:tech. u. Elek:akus.*, Sept. 1942, Vol. 60, No. 3, p. 80.) Telefunken patent, D.R.P. 718 695.

768. STANDING WAVES ON TRANSMISSION LINES: A METHOD OF LINE-MATCHING BASED ON GRAPHICAL COMPARISON, *and* RADIO DATA CHARTS: THE CHARACTERISTIC IMPEDANCE OF TRANSMISSION LINES.—Gadwa: Sowerby. (*See* 693 & 694.)

769. STUB-FEEDER CALCULATIONS [Short Sections of Open or Closed Lines used, at High Frequencies, to terminate the Transmission Line, for Matching: Derivation of Formulae for Lengths].—H. A. Brown & W. J. Trijitzinsky. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, p. 251: summary only.)

770. BRIEF DISCUSSION OF THE DESIGN OF A 912-FOOT UNIFORM-CROSS-SECTION GUYED RADIO-TOWER [at WNAX, South Dakota: Necessary Study of Meteorological Data: Empirical Estimate of Effect of Anticipated Wind Velocities: etc.].—A. C. Waller. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, pp. 253–254: summary only.)

771. CHARACTERISTICS OF DRIVEN GROUNDS.—Taylor. (*See* 708.)

772. POLES AND POLE TREATMENT [Pole Use & the Drain on the Forest: Manufacture & Treatment: Strength: etc.].—R. H. Colley. (*Elec. Engineering*, Sept. 1942, Vol. 61, No. 9, Transactions pp. 685–691.)

VALVES AND THERMIONICS

773. A THREE-ELECTRODE METAL VALVE FOR THE DECIMETRIC-WAVE RANGE.—N. D. Devyatkov, M. D. Gurevich, & V. K. Khokhlov. (*Journ. of Tech. Phys.* [in Russian], No. 8, Vol. 11, 1941, pp. 756–761.)

A metal valve type "DCM-1" suitable for operation with coaxial circuits on decimetric waves has been developed in Russia. The construction of the valve is described in detail and a test report with a number of experimental curves is also given. It appears from this that the valve can be used as a heterodyne oscillator on wavelengths of 25 to 30 cm, and as a self-excited oscillator with an output of 1 to 4–5 watts on wavelengths from 30 to 60 cm. The valve can also be used as a straight amplifier with amplification factors of 3 to 4 and 6 to 7 on wavelengths of 25 and 40 cm respectively, and as a regenerative amplifier with amplification factors of 10 and 15 on wavelengths of 25 and 40 cm respectively. Reference is made to the design of Samuel & Sowers, 1798 of 1937 and 126 of 1938.

774. THE LAWS OF SIMILITUDE OF THE ELECTROMAGNETIC FIELD, AND THEIR APPLICATION TO VALVES [particularly at Ultra-High Frequencies].—H. König. (*Hochf:tech. u. Elek:akus.*, Aug. 1942, Vol. 60, No. 2, pp. 50–54.)

In decimetric-wave technique it is often of advantage to reverse the usual practice with models and to make the model larger than the device which it is to represent. In this, as in the ordinary case, the laws of similitude are involved. These laws, as applied to electromagnetic fields in stationary arrangements, were dealt with by the writer in a previous paper (1304 & 3522 of 1942), whose final results are now summarised in Section II. In Section III, by the use of the Lorentz field equations instead of the Maxwell equations employed for the stationary case, the treatment of the laws of similitude is extended to the case of moving charge-carriers, and finally in Section IV to actual valves of various kinds: the fact that the motion itself takes place under the influence of the field is taken into account by the use of the force law $d\mathfrak{v}/dt = K(\mathfrak{E} + \mu_0[\mathfrak{v}\,\mathfrak{H}])$ to extend the field equations.

As examples of the application of the results, it is shown how the laws throw light on the decrease in efficiency of a triode at a definite lower limit of wavelength, and on the problem of what changes must be made to a klystron or a magnetron in order that it may work on another wavelength without any serious change in efficiency.

775. FREQUENCY MULTIPLICATION AND VOLTAGE TRANSFORMATION FOR THE GENERATION OF ULTRA-SHORT WAVES [Split-Anode Magnetron (17, 18, Fig. 3) supplies Oscillating Voltage to Special Electrode System (5, 6) in Same Bulb, producing Electron Bunches which Spiral & encounter Catcher Electrodes (10, 11)].—J. Hengstenberg & H. Bühler. (*Hochf:tech. u. Elek:akus.*, Aug. 1942, Vol. 60, No. 2, p. 56.) D.R.P. 716 218.

776. SPLIT-ANODE MAGNETRON WITH INNER AND OUTER GROUPS OF ELECTRODES, PARALLEL & SYMMETRICAL TO THE FILAMENT, AND WORKING IN PUSH-PULL [as Amplifier or Generator].—K. Fritz. (*Hochf:tech. u. Elek:akus.*, Aug. 1942, Vol. 60, No. 2, p. 56.) Telefunken patent, D.R.P. 717 541.

777. A MAGNETRON VALVE WITH CLOSELY WOUND FLAT-STRIP SPIRAL AS ANODE AND INDUCTANCE.—H. E. Hollmann. (*Funk* [Berlin], 15th Jan. 1942, No. 2, p. 25.) Telefunken patent, D.R.P. 663 309.

778. A NEW TYPE OF TUNGSTEN CATHODE FOR MAGNETRONS [and perhaps for High-Power Valves].—M. D. Gurevich. (*Journ. of Tech. Phys.* [in Russian], No. 8, Vol. 11, 1941, pp. 753–755.)

It is pointed out that the life of a tungsten filament in a magnetron is 10 to 15 times less than in other thermionic apparatus. This is due to the fact that some of the electrons return to the filament under the action of the magnetic field and heat it by bombardment. The process of the burning-out of a filament is discussed in detail and a new type of tungsten cathode is proposed. This consists of a main tungsten filament round which an additional tungsten filament of a smaller diameter is wound (Fig. 3). The main filament is thus protected from electron bombardment and a more equalised temperature-distribution is achieved. It is stated that magnetrons with this type of cathode were operated for 150–200 hours without damaging the cathode, while the average life of similar magnetrons using ordinary tungsten cathodes is of the order of 40 to 50 hours. Moreover, the new type is more economical since it permits the filament current to be reduced by 2 to $2\frac{1}{2}$ times. It is also suggested that this cathode could be used in high-power radio valves. In conclusion, methods are indicated for designing the cathode.

779. Cooling of Valves in Aircraft Ultra-Short-Wave Sets [by Wind from Tubular Aerial].—E. Steudel. (*Hochf:tech. u. Elek:akus.*, Sept. 1942, Vol. 60, No. 3, p. 77.) A.E.G. patent, D.R.P. 718 277.

780. Amplifying Valves with Negative Transconductance [and Their Applications].—Francini. (*See* 719.)

781. Noises due to the Type CL4 Valve [Experiences with Push-Pull Output Stage: Trouble in Control-Grid Connection (led through Bulb) due to Corrosion Layer: Precautions to avoid Overheating which probably caused This].—W. Krebs. (*Funk* [Berlin), 15th June 1942, No. 12, p. 176.)

782. Valve Replacement in Broadcast Receivers of Foreign Make.—E. Bottke. (*Funk* [Berlin), 15th Feb. & 15th May 1942, Nos. 4 & 10, pp. 43–45 & 137–139.) *Cf.* 3596 of 1942.

783. Valve Replacement with the Help of Foreign Valves [Use of Russian & American Valves in German Receivers].—Frank. (*Funk* [Berlin], 1st May 1942, No. 9, pp. 120–121.) Converse of 3596 of 1942 and 782, above.

784. The Position of Russian Broadcast Technique [Valves, etc.].—Mangel & Klimek. (*See* 751.)

785. Spectrographic Analysis in the Manufacture of Radio Tubes.—S. L. Parsons. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, p. 252: summary only.)

786. Spectroscopic Detection of Thorium Traces in Tungsten Wires [which for Certain Uses must be completely Free from Thorium].—N. C. Beese. (*QST*, Nov. 1942, Vol. 26, No. 11, p. 22: paragraph only.)

787. Observations on Melting Tungsten Single-Crystal Wires [when Heated till they Fuse, under some Compression: Formation of Swellings representing Slip Effects (as in Geological "Faults")].—I. N. Stranski & R. Suhrmann. (*Naturwiss.*, 23rd Oct. 1942, Vol. 30, No. 43, p. 662.)

788. The "Filament-Heating" Condenser.—Kämmerer. (*See* 754.)

DIRECTIONAL WIRELESS

789. Adcock-System Direction Finder [Superheterodyne Receivers connected to Two Aerials are supplied with Heterodyning Oscillations from Central Aerial excited by Oscillator: I.F. Oscillations thus produced are radiated to Goniometer connected to Another Central Aerial]. — Telefunken. (*Hochf:tech. u. Elek:akus.*, Sept. 1942, Vol. 60, No. 3, p. 80)., D.R.P. 718 517.

790. Some Telefunken Patents in Direction-Finding Technique.—W. Runge & others. (*Hochf:tech. u. Elek:akus.*, Aug. 1942, Vol. 60, No. 2, pp. 58–59.)

791. A Product-Ratio Meter.—Lorenz. (*See* 851.)

ACOUSTICS AND AUDIO-FREQUENCIES

792. Theoretical and Experimental Investigations on Telephone Receivers (Magnetic Converters).—K. Braun. (*T.F.T.*, June & July 1942, Vol. 31, Nos. 6 & 7, pp. 151–158 & 190–198.)

Author's summary:—"The electro-magnetic and electrodynamic receivers are dealt with theoretically in the same manner. Simple formulae for the calculation of the transmission equivalent and attenuation of a receiver are given. The constants of the receiver were determined by simple and partially new measuring methods, consisting mainly in the measurement of length, weight, resonance-frequency, and resistance. The calculation of the transmission equivalent, from the constants thus measured and the formulae just derived, gives very good agreement (within less than 0.1 neper [in, say, 6 nepers: *see* Fig. 10 for the electro-magnetic type and Fig. 16 for the moving-coil type]) with the measured values.

"At low frequencies the acoustic attenuation is about 0.5 N and the electrical about 2.0 N: at the resonance frequency the corresponding values are −1 and 0.3 [for the moving-coil type, Fig. 15: the values are slightly different for the electro-magnetic type, Fig. 11], so that at the resonance frequency the attenuation becomes negative. By reducing the volume between diaphragm and ear from 6.5 to 1 cm^3 an attenuation gain of 0.9 N can be obtained. In the electro-magnetic receiver an increase of 1/100 mm in the magnet/diaphragm gap of 0.1 mm produces a rise of 0.2 N in the attenuation: moreover, there is a fixed relation between the smallest possible gap and the stiffness of the diaphragm, so that the improvement of this type of receiver in its present form is limited, unlike the case of the moving-coil type.

"The equivalent diagram of the magnetic converter corresponds to a transformer with extremely large leakage, high winding capacitance, large copper resistance, and poor insulation [*see* Fig. 5 and adjacent text]: current corresponds to sound pressure, voltage to sound flux. The electromagnetic receiver behaves more as a choking-coil, the electrodynamic receiver more as an ohmic resistance, than as a converter [*see* p. 197, r–h column]. To improve the magnetic converter the air-gap must be as small as possible, the utilisation of the air-gap volume by the winding must be as complete as possible, and the permanent magnet must be as strong as possible. In this way a considerable reduction in attenuation can be obtained, which among other results may lead to the use of the magnetic converter as a microphone." Improvements are discussed on pp. 197–198 with the help of the long list of data, measured or calculated, given in Table 3 for the electro-magnetic and moving-coil receivers investigated. It is now up to the practical man to develop the suggestions: extremely high-class precision work will be involved, but the result will be worth the cost and trouble.

793. A NEW TELEPHONE SET FOR THE HARD OF HEARING. — A. Herckmans. (*Bell Lab. Record*, Oct. 1942, Vol. 21, No. 2, pp. 45–48.)

794. HEARING AID "DANGERS" [Continuation of Correspondence dealt with in 89 of January]. —(*Wireless World*, Jan. 1943, Vol. 49, No. 1, p. 27.)

795. CANCELLATION OF THE ELECTRICAL COCHLEAR RESPONSE WITH AIR- AND BONE-CONDUCTED SOUND [Result supporting Belief that Both Types stimulate the Same Elements].—K. Lowy. (*Journ. Acous. Soc. Am.*, Oct. 1942, Vol. 14, No. 2, pp. 156–158.)

796. AN EXPERIMENTAL STUDY OF SUBJECTIVE TONES PRODUCED WITHIN THE HUMAN EAR [under Single- & Dual-Tone Excitation: Differences found between Even and Odd Subjective Harmonics indicate that Organ (or Set of Organs) producing Non-Linearity is Not the Same as the Source of Asymmetry: etc.].—C. R. Moe. (*Journ. Acous. Soc. Am.*, Oct. 1942, Vol. 14, No. 2, pp. 159–166.)

797. METHOD FOR THE STATISTICAL ANALYSIS OF THE ACOUSTIC INTENSITY OF SPEECH [Paper based on the Researches of A. Gemelli].—Gemelli. (*Alta Frequenza*, Aug./Sept. 1942, Vol. 11, No. 8/9, pp. 429–431: summary, from *Commen. Pontificiae Acad. Sci.*) For Gemelli's work *see*, for example, 2321 of 1941.

798. A NEW TYPE OF PRACTICAL DISTORTION METER [Bridged-T A.F. Bridge Circuit with Inductance Element replaced by Reactance-Valve Circuit: Flexibility thus obtained gives Wide Range: Non-Linearity, Noise, etc., Improved by Negative Feedback].—J. E. Hayes. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, p. 252: summary only.) From the Canadian Broadcasting Corporation.

799. FREQUENCY-RESPONSE RECORDER [for Microphones, Loudspeakers, Filters, etc: Magnetic-Disc & Sliding-Carriage Principle].—(*Review Scient. Instr.*, Oct. 1942, Vol. 13, No. 10, pp. 464–465.)

800. FREQUENCY-MODULATION DISTORTION IN LOUDSPEAKERS [Type of Distortion due to Doppler Effect: Derivation of Equations, and Confirmatory Measurements].—G. L. Beers & H. Belar. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, p. 250: summary only.)

801. USE OF LOUDSPEAKER FIELDS AS FILTER CHOKES.—Pullen. (*See* 746.)

802. HUM DISTURBANCE OF SPECIAL KINDS [in Receivers & Microphone or Gramophone Amplifiers].—Stephani. (*See* 745.)

803. SOME POINTS ON IMPROVEMENTS IN MOVING-COIL LOUDSPEAKERS [Lowering of Low-Note Resonance (Cone Design & Fixing: Design of M.C. Spider: Cup acting as Air Cushion: etc.): Improvement in High-Note Reproduction (Choice of Profile-Curvature for "Nawi" Cone: Other Means of Stiffening: Fixed "Dispersing Cone" for High Notes): Improvements in Efficiency & Non-Linear Distortion].—H. E. W. Kristiansen. (*Funk* [Berlin], 1st Jan. 1942, No. 1, pp. 1–4.)

804. THE "INFINITE" BAFFLE [French Loudspeaker-Cabinet Design with Same Object as American "Labyrinth": with Dimensions].—(*Funk* [Berlin], 15th June 1942, No. 12, p. 172: summary only.)

805. ON THE REDUCTION OF AN OSCILLATING ROD TO AN 8-POLE SYSTEM.—S. G. Mileykovski. (*Journ. of Tech. Phys.* [in Russian], No. 8, Vol. 11, 1941, pp. 726–735.)

Back in 1934 both Cremer and Lindsay derived equations determining an 8-pole electric system (Fig. 1) equivalent to a rod oscillating under the action of a periodic force. No attempt, however, has been made to apply the method to practical problems. In this paper, equations 9–12 similar to those of Cremer and Lindsay are derived in a somewhat different manner, and also equation (14) determining the impedance of the system. From this equation it is possible to determine the equivalent mass and elasticity of the rod for different types of end fixing, and also the resonant frequency of the system. The discussion is illustrated by the following examples: (a) a cantilever with a periodic force applied at the end (Fig. 4); (b) a beam with rigidly fixed ends and with a periodic force applied in the middle (Fig. 5); (c) as (b) but with the ends freely supported (Fig. 8); and (d) a more general case: a cantilever with a periodic force at the end, the other end being elastically fixed (Fig. 9).

806. ON THE OPERATION OF DIRECTIONAL [Sound] RADIATORS OVER A FREQUENCY RANGE.—M. I. Karnovski. (*Journ. of Tech. Phys.* [in Russian], No. 8, Vol. 11, 1941, pp. 736–745.)

The operation of sound radiators is discussed from the standpoint of the constancy of their directional characteristics over a range of frequencies. A general equation (1) for the directional characteristic of a radiator is written down, and methods are indicated for determining the value of ΔS which is used for estimating the "stability" of the radiator when the operating frequency is changed by an amount $\Delta\omega$. The discussion is applied to the following cases: (a) a group of two point-radiators; (b) a rectangular diaphragm (line); (c) a ring radiator; and (d) a system of point-radiators disposed on a straight line. As a result of this discussion a number of practical conclusions are reached.

807. EQUIVALENT CIRCUITS AND CHARACTERISTICS OF SPHERICAL SOUND RADIATORS.—A. A. Kharkevich. (*Journ. of Tech. Phys.* [in Russian], No. 8, Vol. 11, 1941, pp. 746–752.)

The main relationships arrived at by Stokes and Rayleigh in their investigations of spherical sound radiators are quoted, and from them transition formulae (eqns. 8) are derived for determining the equivalent electric circuits for spherical radiators of any order (the order of the radiator depends on eqn. 2 determining the radial velocity on the surface of the sphere). As can be seen from Fig. 1, in which equivalent circuits of radiators of zero to the 5th orders are shown, these circuits are of the high-pass filter type. Methods are indicated for calculating the frequency/radiation-resistance characteristics and the total radiated power. The change with time of the potential and pressure of the field of a radiator is also determined. In an appendix a method is proposed for calculating the roots of Stokes' polynomials.

808. SOME RECENT DEVELOPMENTS IN RECORD-REPRODUCING SYSTEMS [for Lateral-Cut Records: Experimental Reproducing System employing Frequency-Modulation Pick-Up].—G. L. Beers & C. M. Sinnett. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, p. 250: summary only.)

809. MEASURING TRANSCRIPTION-TURNTABLE-SPEED VARIATIONS.—H. E. Roys. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, p. 253: summary only.)

810. A RECORDING HEAD WITH HEIGHTENED NATURAL FREQUENCY, FOR FOIL DISCS [to avoid the Usual Poor Reproduction of the Higher Frequencies: Armature Resonance around 4500 c/s, Adequate Sensitivity (28 mm Light-Band Width for 3 Watts Load): records Frequencies up to 8000 c/s: Disadvantages of requiring Mains-Supplied Field Coil, Damping Not Independent of Temperature, Weight 360 gms]. — O. Stephani. (*Funk* [Berlin], 1st April 1942, No. 7, pp. 87–92.)

811. HOW RECORDINGS ARE MADE: NO. 5—TESTS AND TROUBLE-SHOOTING [including the "Christmas-Tree Pattern" (Light-Diffraction) & Other Optical Tests: Temperature & Humidity Effects: etc.).—C. B. De Soto. (*QST*, Dec. 1942, Vol. 26, No. 12, pp. 51–55 and 90, 92, 106.)

812. RECORDING STANDARDS.—I. P. Rodman. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, p. 253: short summary.) *Cf.* 458 of February.

813. "THE AMPLIFICATION AND DISTRIBUTION OF SOUND: REVISED EDITION" [Book Review].—A. E. Greenlees. (*Electrician*, 18th Dec. 1942, Vol. 129, p. 665.)

814. PLAYER-PIANO *versus* GRAMOPHONE.—"Cathode-Ray." (*Wireless World*, Jan. 1943, Vol. 49, No. 1, pp. 28–29.) Extinguishing the discussion dealt with in 80 of January.

815. COMPARISON BETWEEN A HASKELL ORGAN PIPE AND A SIMPLE OPEN PIPE [Differences in Harmonic Structure attributable to Frictional Effect].—R. C. Binder & A. S. Hall. (*Journ. Acous. Soc. Am.*, Oct. 1942, Vol. 14, No. 2, pp. 140–142.)

816. EDGE TONES [and Their Division into Two Types: Experiments & Conclusions].—A. T. Jones. (*Journ. Acous. Soc. Am.*, Oct. 1942, Vol. 14, No. 2, pp. 131–139.)

817. THE ACOUSTICS OF THE NEW AUDITORIUM OF THE UTRECHT MUNICIPAL THEATRE [and the Collaboration between Architect & Philips Specialists].—R. Vermeulen. (*Alta Frequenza*, Aug./Sept. 1942, Vol. 11, No. 8/9, p. 429: summary, from *Rev. tech. Philips*, Jan. 1942.)

818. VARIABLE REVERBERATION [Paper based largely on American Work: including Polycylindrical Diffusers (1409 of 1942)].—K. F. Darmer: F. W. Dodge. (*Alta Frequenza*, Aug./Sept. 1942, Vol. 11, No. 8/9, pp. 404–405: summary only.)

819. NOTES ON ACOUSTIC IMPEDANCE MEASUREMENT [now prominent in Development of Acoustical Materials: Data for the Design of an Impedance Tube (Fixed Length, Sound Source, & Frequency, and Movable Sound-Cell Microphone as Pressure Detector)].—H. J. Sabine. (*Journ. Acous. Soc. Am.*, Oct. 1942, Vol. 14, No. 2, pp. 143–150.)

820. SUGGESTIONS FOR THE IMPROVEMENT OF MAINS-DRIVEN BEAT-NOTE OSCILLATORS.—Fr. Endres. (*Funk* [Berlin], 1st April 1942, No. 7, pp. 92–95.)

821. CORRECTION TO "DESIGNING A RESISTANCE-CAPACITY OSCILLATOR COVERING FREQUENCIES FROM 40 TO 13 000 c/s IN FOUR RANGES" [366 of February].—R. C. Whitehead. (*Wireless World*, Jan. 1943, Vol. 49, No. 1, p. 29.)

822. THE OPTICAL EXAMINATION OF THE SOUND FIELD OF A QUARTZ PLATE OSCILLATING AS A PISTON [with Photographic Records].—K. Osterhammel. (*Alta Frequenza*, Aug./Sept. 1942, Vol. 11, No. 8/9, pp. 415–418.) Long abstract, from *Akust. Zeitschr.*, March 1941, p. 73 onwards. For previous work *see* 1694 of 1941.

823. PROPAGATION OF SOUND WAVES IN THE ATMOSPHERE [Effect of Humidity on Velocity; of Wind on Path: Amplitude as Function of Distance, and Relative Importance of the Various Quantities (Absorption Factor, Curvature Changes due to Changes of Wind & Temperature, etc.)].—B. Gutenberg. (*Journ. Acous. Soc. Am.*, Oct. 1942, Vol. 14, No. 2, pp. 151–155.)

PHOTOTELEGRAPHY AND TELEVISION

824. Portable Television Pickups [Don Lee Broadcasting System's Apparatus, Technique, & Routine for Outside Television Broadcasting: Standardised "Pitchfork" & "Vee" Aerials, and the Importance of Their Placement (324 Mc/s Link: Window-Cleaner, who raised Window-Frame carrying Transmitting Aerial, doubled Signal Strength): etc.].—H. R. Lubcke. (*Communications*, Aug. 1942, Vol. 22, No. 8, pp. 8–11 and 39.) *See* also 1432 of 1941.

825. The Focusing-View-Finder Problem in Television Cameras.—G. L. Beers. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, p. 250: summary only.)

826. High-Power Television Transmitter [40 kW Visual and 20 kW Aural Transmitters at WRGB, Helderberg Mountains].—H. B. Fancher. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, p. 251: summary only.)

827. Mercury Lighting for Television Studios [WRGB Studios at Schenectady].—C. A. Breeding. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, p. 250: short summary.)

828. A Television Relay System.—Keister. (*See* 901.)

829. Automatic Frequency and Phase Control of Synchronisation in Television Receivers [to overcome Difficulties due to Noise: Perfect Interlacing given by the New System: Maximum Resolution also attained].—K. R. Wendt & G. L. Fredendall. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, pp. 254–255: summary only.)

830. A New Step in Television: Elimination of the Rotating Disc [Recent Demonstration of Colour & Stereoscopic Receivers].—J. L. Baird. (*Electrician*, 1st Jan. 1943, Vol. 130, p. 7.)

831. Stereo-Movies without Camera Accessories [Method & Some Results, in Monochrome & Colour Working].—G. L. Walls. (*Journ. Opt. Soc. Am.*, Nov. 1942, Vol. 32, No. 11, pp. 693–694.)

"Stereopsis plus colour is rather disappointing . . . Properly illuminated Kodachrome scenes have a depthy quality which binocular stereopsis does not materially enhance."

832. The Temperature Coefficient of Selenium-Cadmium Photocells with Blocking Layers.—E. Putseyko. (*Journ. of Tech. Phys.* [in Russian], No. 8, Vol. 11, 1941, pp. 777–782.)

Continuing previous work (*ibid.*, Vol. 7, 1937) experiments were made with selenium-cadmium photocells which have shown that the temperature coefficient of the current when the cell is short-circuited has a positive value. This is due to a change in the spectral characteristic of the cell with temperature.

MEASUREMENTS AND STANDARDS

833. An Electrometer for measuring Voltages in the Metric Wave Range.—A. L. Khodakov. (*Journ. of Tech. Phys.* [in Russian], No. 8, Vol. 11, 1941, pp. 767–774.)

A new type of electrometer suitable for measuring voltages up to 70 v on wavelengths from 10 to 3 m is described. The meter is essentially a Lecher system consisting of two Wollaston filaments of 10μ diameter to which two leading-in platinum wires of 1 mm diameter are connected (Figs. 1 and 3). The voltage to be measured is applied to the platinum wires and is determined by observing through a microscope the displacement of one of the Wollaston filaments. By increasing the tension of the filaments, voltages up to 300 v can be measured. Using the telegraph equations (1) and (2), the theory of the meter is discussed and a formula (32) is derived for determining the error introduced by the non-quasi-stationary voltage distribution along the Lecher conductors. It is shown that on wavelengths down to 3 m this error does not exceed 1% and can therefore be neglected. The total error of the meter on wavelengths from 10 to 3 m will then not exceed 1–1.5%. The theoretical conclusions were checked indirectly by investigating the effect of frequency on the dipole conductivity of water. The thermometric method of Malsch was used in these tests, and close agreement between the theoretical and experimental results was obtained.

834. Equipment for Measuring Technique in the Ultra-Short-Wave Range [Preliminary Investigations leading to Design of Signal Generator to deliver at least 5 Volts over Range 20–300 Mc/s: Four-Valve Circuit with Metal EF14 (9.3–19 Mc/s) in Electron-Coupled First Stage: Constructional Details].—H. Rückert. (*Funktech. Monatshefte*, Aug. 1942, No. 8, pp. 105–111.)

835. High Frequencies: the Status of High-Frequency Standards and Measurements [including Ultra-High Frequencies].—H. R. Meahl. (*Gen. Elec. Review*, Nov. 1942, Vol. 45, No. 11, pp. 617–619.)

836. Temperature-Indicating Crayons [as Alternative to Colour-Changing Paints].—J. M. Steel & Company. (*Engineering*, 11th Dec. 1942, Vol. 154, p. 466.) *Cf.*, for example, 1792 of 1942 (u.h.f. temperature-rise in insulators).

837. Cable Testing: Measuring the Electrical Properties of Cables and Insulating Materials at High and Ultra-High Frequencies, *and* Power Factor: Progress in the Development of Improved Measuring Methods and Equipment.—H. C. Anderson: H. W. Bousman. (*Gen. Elec. Review*, Nov. 1942, Vol. 45, No. 11, pp. 621–623: pp. 625–627.)

838. Terminal Corrections for Temperature Tests on Short Samples [of Wires, Cables, etc: Simple Method to show that No Correction is Needed, or to estimate Proper Sample Lengths].—F. Bauer & J. J. Taylor. (*Elec. Engineering*, Nov. 1942, Vol. 61, No. 11, pp. 584–585.)

839. The Determination of High-Frequency Transmission Line Constants by Measurements at Special Frequencies [Simple Calculation of Attenuation Constant, Characteristic Impedance, & Phase Constant, from Input-Impedance Measurements at Resonance Frequencies: Effect of Reactive Component of Characteristic Impedance on Resonance Frequencies: on Expression for Characteristic Impedance: Errors introduced by measuring the Open- and Closed-Circuit Impedances at the Same Frequency: Measurements at Odd Multiples of One-Eighth of a Wavelength (and Their Advantages at High Frequencies)].—J. C. Simmonds. (*Phil. Mag.*, Dec. 1942, Vol. 33, No. 227, pp. 904–909.) *Cf.* Langer, 502 of February.

840. The Measurement of Radiative Coupling.—Brückmann. (*See* 765.)

841. Circuit for the Field-Strength Measurement of a Transmitting Station [Meter connected to Tappings on Two Resistances each in the Circuit of Different Electrodes of a Hexode: Resistances & Interelectrode Spaces form Balanced Bridge, Variations of Filament Heating or Electrode Voltages remain Ineffective].—H. Hofmann. (*Hochf:tech. u. Elek:akus.*, Aug. 1942, Vol. 60, No. 2, p. 58.) C. Lorenz patent, D.R.P. 717 699.

842. On the Calculation of the Distributed Capacitance of Coils.—Colino: Sacco. (*See* 730.)

843. Wavemeter [Direct-Reading in Frequencies between 0.5 and 150 Mc/s: Type 566-A, replacing Types 574 & 358: with Slow-Motion Drive, Lamp Indicator].—General Radio. (*Review Scient. Instr.*, Nov. 1942, Vol. 13, No. 11, p. 506.)

844. Multivibrators: Extending the Frequency Range [Cazaly's Implied Upper Limit around 200 kc/s applies only to Particular Circuit: Another Circuit giving 800 kc/s].—R. Copsey: Cazaly. (*Wireless World*, Jan. 1943, Vol. 49, No. 1, p. 28.) Prompted by 499 of January. *Cf.* Johannsen's work, 534 of February and back references, and 871, below.

845. On the Mode of Operation of the Multivibrator.—R. Theile & R. Filipowsky. (*Funk* [Berlin], 15th April 1942, No. 8, pp. 101–108.) A fuller treatment was dealt with in 2423 of 1942.

846. Differential Negative Resistances of Retarding-Field Type.—Pinciroli. (*See* 718.)

847. A New Type of Practical Distortion Meter.—Hayes. (*See* 798.)

848. Application of Guard Electrodes in Dielectric Measurements [Short Survey of Practical Technique: Accurate Measurements possible on Small Samples].—E. W. Greenfield. (*Review Scient. Instr.*, Nov. 1942, Vol. 13, No. 11, pp. 489–492.)

849. Surge Testing: in the Field, in the Laboratory, and in Production.—C. M. Foust. (*Gen. Elec. Review*, Nov. 1942, Vol. 45, No. 11, pp. 629–632.)

850. Tolerances: Considerations governing the Fixing of Limits for Radio Components.—J. T. Terry. (*Wireless World*, Jan. 1943, Vol. 49, No. 1, pp. 19–22.)

851. A Product-Ratio Meter.—J. Lorenz. (*E.T.Z.*, 22nd Oct. 1942, Vol. 63, No. 41/42, pp. 489–494.)

A D.V.L. paper (Institute for Aircraft Instruments & Navigation). "The electrical power-meter shows the product, the quotient meter shows the ratio, of two currents. The principles at the bottom of both types of instrument lead to the product-ratio meter . . . If two power-meters are so coupled that their torques act against each other; and if their moving parts are so constructed that their torques are determined only by the currents, without external restoring forces; and finally if the torque of at any rate one of these devices is made dependent on the deflection; then such an arrangement will show the ratio of two current products—it will constitute a product-ratio meter." The four currents forming the quantity measured, $i_Z I_Z / i_N I_N$, may of course be functions of any quantities whatever, or may be the quantities themselves. If at least two of these currents, which form a ratio in themselves, arise from the same source of e.m.f., the reading is independent of any fluctuations which the latter may undergo.

The theory of such an instrument is dealt with fully, and an experimental model is described. After some faults in design had been eliminated (magnetic leakage fields were a serious trouble at first) an instrument with an over-all error of ±1.9% was arrived at: this error could be reduced to ±1.1% by a special treatment of the magnet circuit, which however made the instrument usable only on one polarity. The application of the new instrument will be dealt with in a later paper.

852. A New Moving-Magnet Instrument for Direct Current [with Characteristics comparing favourably with Those of a D'Arsonval Instrument: Application (*e.g.*) to Battery-Testing Voltmeter: Controlling Torque from Magnet of Ag–Al–Mn Alloy (Potter, Faus)].—H. R. Faus & J. R. Macintyre. (*Elec. Engineering*, Aug. 1942, Vol. 61, No. 8, Transactions pp. 586–588.)

853. On the Deflection Process of a "Double Galvanometer," *and* On the Measuring Limits with a "Double Galvanometer" [Investigations on the Possibility or Impossibility of measuring Smaller Currents

by Magnifying a Galvanometer Deflection by Thermoelectric or Photoelectric Devices controlling a Second Galvanometer: the Question of Brownian Movement, Choice of Primary-Galvanometer Damping, etc.].—G. Passoth. (*Ann. der Physik*, 1st Oct. 1942, Vol. 42, No. 1, pp. 35–48: pp. 49–62.)

854. Overhauling Moving-Coil Meters: Some Further Hints.—W. R. Bishop. (*Wireless World*, Jan. 1943, Vol. 49, No. 1, pp. 27–28.) Prompted by the article referred to in 128 of January.

855. Universal Shunts for Multi-Range Meters: Some Factors affecting Their Design.—E. B. Swift. (*Electronic Eng:g*, July 1942, Vol. 15, No. 173, pp. 76–77.)

856. Rectifier Protecting Device for Thermoelectric Meters [which must not be overloaded more than 75%].—H. Lennartz & H. Boucke. (*Funk* [Berlin], 15th May 1942, No. 10, p. 139.)

857. On an Amplitude Error in Thermoelectric Ammeters.—B. Fleischer. (*Hochf:tech. u. Elek:akus.*, Aug. 1942, Vol. 60, No. 2, pp. 44–49.)

Some firms give 1 Mc/s as the upper frequency limit for the frequency-independence of their instruments with, say, a full-scale reading of 500 mA, while other makers give 80 Mc/s for an instrument of the same range. Zinke, on the other hand, gives in his book a rule-of-thumb stating that multiplication of the scale range in amperes by 4 gives the wavelength (in metres) at which the error just about exceeds 5%. For the meters mentioned above this would give a limiting frequency around 150 Mc/s, which ought to apply equally to both makes of instrument. Exploratory tests by the writer, however, indicated that this rule-of-thumb had only a limited validity, and prompted him to investigate the whole rather complex question, beginning with measurements at 5.8, 39.2, 89, & 106 Mc/s on the two meters which were quoted as examples, above. The results are seen in Figs. 2 to 5: the expected error due to skin effect was found. The error was not, however, constant over the whole measuring range, as was expected, but displayed a marked dependence on amplitude; it decreased with increasing amplitude, but only at full deflection did it come down to less than 5% over a wide frequency range, about agreeing with Zinke's value. Thus in using such a meter at a frequency above the maker's limit it is not enough to make a measurement near the full-scale deflection, in order to determine the percentage departure from the true value: the calibration must be carried out over the whole scale.

Author's summary:—"The fact that thermoconverters show, in the presence of skin effect, an amplitude-dependent error has led to an investigation of the question of the change that occurs in the course of the temperature at the surface of a hot wire, when the distribution of the sources of heat is a function of position [for Fischer's work, here made use of, *see* 2358 of 1938 and back reference]. The solution of the thermal-conduction equation on the assumption of heat sources distributed in a plane leads to the fact that in this case a fundamental change occurs in the temperature relations at the surface, compared with d.c. heating. The relation thus derived between heating current and wire temperature leads to complete agreement with the experimental results."

858. A New Jewel for Indicating Instruments [Search for Jewel which could be Produced in Quantity, to replace Sapphire "Vees": Hot-Formed Jewels & Their Success].—F. K. McCune & J. H. Goss. (*Elec. Engineering*, Sept. 1942, Vol. 61, No. 9, Transactions pp. 673–676.)

859. Magnetic Measurements: Core-Loss Testers, Permeameters, etc.—A. E. Kettner. (*Gen. Elec. Review*, Nov. 1942, Vol. 45, No. 11, pp. 633–636.)

860. Magnetostriction made Visible: Rapid Measurements to a Fraction of a Millionth of an Inch made a Routine Procedure [by Everest's Optical-Measurement Lever Arm Method: Associated Equipment].—S. C. Leonard: A. W. Everest. (*Gen. Elec. Review*, Nov. 1942, Vol. 45, No. 11, pp. 637–641.)

861. An Electronic Method of Measuring Molecular Lifetimes [Electron-Multiplier/C.R.O. Combination for Decay-Time Measurements (10^{-2} to 10^{-7} Second) of Fluorescence (using Kerr Cell to generate Square Light-Pulses) and of Nitrogen Discharge, etc.].—R. D. Rawcliffe. (*Review Scient. Instr.*, Oct. 1942, Vol. 13, No. 10, pp. 413–418.) *Cf.* 950, below.

862. New Thermo-Mechanical Radiation-Receivers for "Alternating" Light.—R. Schneiderreit. (*Zeitschr. f. tech. Phys.*, No. 8, Vol. 23, 1942, pp. 208–217.)

"To avoid the difficulties in measuring long-wave radiation due to the passage through the zero point and to stray radiation, 'alternating'-light methods have been devised. These demand a receiver as free as possible from inertia. Photocells are unsuitable because of their dependence on the spectrum and above all because of their infra-red limit; the usual thermoelements and bolometers are handicapped by their inertia and by their extremely low efficiency, resulting from their low ohmic resistance, unless dealt with by Fahrentholz's technique" [3118 of 1936: very small resistance changes measured by frequency-unstable oscillating circuits]. The present paper describes an experimental investigation of the possibilities of employing the bimetallic-foil effect, the bending of single metal films, and the "gas thermometer" principle, for the construction of 'alternating'-light receivers. The bending of metal foils has already been used by Michelson (in 1908: reference "3") in the construction of actinometers, and Hayes (2854 of 1936 [for later work *see* 4519 of 1940]) developed a gas thermometer as a radiation receiver, but the present writer complains that no data were given as to its sensitivity for 'alternating' light or as to its frequency-dependence. For the measurement of small displacements by a capacity-microphone technique, Whiddington used a beat-note method, while Dowling (and later Gustafsson) employed the dependence of anode current on the coefficient of back-coupling. For the present purposes neither method is suitable, because the membranes used are so easily moved, and the electrostatic forces so small, that such a condenser cannot be used in a frequency-determining circuit. The writer therefore employs the circuit of Fig. 1 (also used in condenser-microphone practice) more or less free from these difficulties: the circuit containing the pick-up condenser is excited by a fixed frequency near to its natural frequency, so that the working point is on one of the rising branches of the resonance curve: rectification yields voltage changes, proportional to the mechanical displacements, which are taken through an amplifier (with a d.c. amplification of 50 000) to a cathode-ray oscillograph. Owing to the high sensitivity of the equipment (at its maximum, a 1 cm movement on the screen corresponds to a diaphragm movement of 0.3 mμ) a valve-voltmeter would have a high noise level, and for 'alternating' light the amplitudes are read directly off the screen. For continuous-light measurements the voltages, compensated with the help of the circuit K, are applied to the amplifier, and their variations are indicated by the anode current of the output valve. The frequency characteristic of the whole equipment is seen in Fig. 2: it is practically flat from 0 to 2000 c/s. The apparatus, boxed, stands on a lead plate supported on an air-cushion. The condenser pick-up, with provision for alternative diaphragms, is seen in Fig. 3: these last are made up from rolled metal foils or from films deposited *in vacuo*: the thicknesses of the latter are measured by an interference-line technique. The structure of the various diaphragms is shown in Fig. 4: lampblack/metal, bismuth-black/cellulose/metal, bismuth-black/metal/cellulose, and lampblack/metal with an air-filling are the types shown, but a simple bismuth-black/metal combination forms a satisfactory bimetal. Sinusoidally modulated light was obtained by the rotation of a perforated disc in front of a screen with a specially shaped aperture (Fig. 9): for frequencies above 300 c/s interrupted light was obtained by the use of a toothed wheel. Continuous-light measurements were also made, but only on the rolled-foil diaphragms, the air-filled and deposited-film types being unsuitable for the necessary prolonged exposure.

Exhaustive tests were made, the influence of various factors such as foil thickness and tension, diaphragm/fixed-electrode spacing, etc., being investigated at various frequencies, the maximum range being 0 to 2000 c/s. Taking a deflection of 2 mm on the screen as the lowest limit, the values for the smallest measureable intensities of radiation at 400 c/s were about 2.5×10^{-5} and 1.3×10^{-5} watt/cm^2 for the bimetallic and "gas" types respectively, these values being roughly doubled at 545 c/s. According to a Schaefer-Matossi calculation the figure for a thermoelement/galvanometer combination is 4×10^{-7} watt/cm^2, while for a similar combination with photocell relay Bergmann gives 2×10^{-9} watt/cm^2, so that the new receivers are from 2 to 4 orders of magnitude behind the most sensitive radiation receivers of the past: but, as pointed out earlier, the latter are only suited to continuous radiation. The high sensitivity of the "gas" receiver compared with the bimetallic type is due to resonance oscillations of the enclosed air mass. The influence of the tension of the stretched foils disappears at frequencies above 400 c/s.

SUBSIDIARY APPARATUS AND MATERIALS

863. Minimising Aberration of Electron Lenses [Theoretical Investigation of the Possibilities of reducing Spherical Aberration: Geometrical Analogy between Electron Paths & Geodesics on a "Characteristic" Surface, and Deductions therefrom: Necessary & Sufficient Conditions for Focusing sharp to within Various Orders].—Poritsky. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, pp. 252–253: summary only.)

864. On the Limiting of the Resolving Power of the Cathode-Ray Tube.—Knoll. (*T.F.T.*, Aug. 1942, Vol. 31, No. 8, pp. 213–216.)

The writer begins by citing 27 papers by various workers dealing with theoretical and experimental investigations of the various phenomena and constructional properties which restrict this resolving power. They fall into six classes: the finite size of the cathode surface and the limitations on anode voltage, etc: errors due to the electron lenses: those due to the deflecting system: the space-charge effect: the scattering of light and electrons in the fluorescent layer: and the total reflection of the light at the boundary surfaces of a transparent carrier of the fluorescent material. He then remarks that these researches nevertheless leave undecided the question to what extent the resolving power of the cathode-ray tube is actually limited by the above effects taken all together.

The investigations now described were therefore undertaken by a scanning method with all possible precautions in compensating aberrations due to the electron-optical organs, and in preparing the fluorescent screen. The conclusions were that with a screen of usual size such a cathode-ray tube can render visible some 10^6 picture elements, or 10^4 elements per sq. centimetre. Thus its resolving power is considerably better than that of the finest screen in printing, and it seems possible to extend it to the limits of resolution of the photographic plate. The attainment of this end seems to depend less on electron-optical improvements than on perfecting the fluorescent screen.

865. Modern Cathode-Ray Oscillograph for testing Lightning Arresters.—Wade & others. (*See* 706.)

866. The Determination of the Harmonic Content of A.C. Curves [by Runge's Simple Process (*E.T.Z.*, 1905) for Analysis of Cathode-Ray-Tube Records, etc: with Tables].—(*Funk* [Berlin], 1st Feb. 1942, No. 3, pp. 37–40.)

867. Additions to "The Electron Microscope and Its Uses" [Discussion of Rayleigh's & Abbe's Formulae for Limit of Resolution

of Optical Instruments].—Barnes & Burton. (*ASTM Bulletin*, Oct. 1942, No. 118, p. 12.) *See* 3348 of 1942.

868. A SCANNING ELECTRON MICROSCOPE.—Zworykin, Hillier, & Snyder. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, p. 255: summary only.) For the full paper *see* 139 of January.

869. MULTIVIBRATORS: EXTENDING THE FREQUENCY RANGE.—Copsey: Cazaly. (*See* 844.)

870. ON THE MODE OF OPERATION OF THE MULTIVIBRATOR.—Theile & Filipowsky. (*Funk* [Berlin], 15th April 1942, No. 8, pp. 101–108.) A fuller treatment was dealt with in 2423 of 1942.

871. NEW "KIPP" CIRCUITS FOR THE GENERATION OF SAW-TOOTH VOLTAGES.—Johannsen. (*Hochf:tech. u. Elek:akus.*, Sept. 1942, Vol. 60, No. 3, pp. 61–66.)

In a previous paper (3344 of 1942: for later work *see* 136 of January and 534 of February) the writer dealt with multivibrator circuits of the basic type seen in Fig. 1, which has one valve more than the commonly used thyratron time-base circuit made up of one thyratron and one charging valve. Those investigations were extended to find whether the basic multivibrator circuit could be so simplified that it involved only the same number of valves as the thyratron circuit, in which case the advantages of the multivibrator principle would be attainable without additional outlay. The present paper reports on some circuits developed in the course of these researches.

In the earlier work a particularly useful step had been found to be the blocking of the charging valve R_L (Fig. 1 again) during the current-passing time of the discharging valve E: *see* for example the first section of 136 of January. This is arranged with the help of the coupling condenser C'_K and grid resistance R'_G, in the same way as the blocking of the control valve S with the help of C_K and R_G. In this way, during the discharge of the "kipp" condenser C through E, the flow of a charging current, which at this moment would only be detrimental, is prevented. Now the similarity of the current-flow rhythm of R_L and that of S suggests the possibility of altering the circuit so that the functions of the control valve S are taken over by the charging valve R_L: the main function of S is to determine the lower "kipp" point, and for this the necessary voltage variations can be obtained with the help of the screen-grid resistance of R_L (in the new circuit of Fig. 2) as it was with the help of the anode resistance of S in Fig. 1. In certain conditions the suppressor grid of R_L can be used instead: the anode circuit is unavailable because of the "kipp" condenser in it.

The various oscillograms of Figs. 3–7 show that with the adjustment mentioned in the adjacent text the two-valve circuit of Fig. 2 is thoroughly suitable for the generation of linear saw-tooth voltages: and it not only has the same number of valves as the thyratron circuit but also saves the higher cost of the thyratron. The synchronising valve which is necessary if an effective decoupling between test circuit and time base is to be carried out can be provided by the triode system of a multiple valve (ECL 11) whose tetrode system plays the part of R_L.

The writer deals next with the rather similar two-valve circuit of Kurokawa & Tanaka (1917 of 1936) which requires a biasing battery (Fig. 8): this can be eliminated by a modification of the circuit (Fig. 9). It has the unusual attribute that the fly-back voltages, also, consist of relaxation oscillations, of smaller amplitude but much higher frequency than the main oscillation. Examination of this circuit shows that it will work, but only with critical adjustment unless a coupling condenser C_K is added (this is already included in Fig. 9), whose action is described at the end of p. 63 and over the page. The functioning of this two-valve circuit is illustrated by Figs. 10 & 11. A still simpler circuit, in which again the fly-back is made up of oscillations, is the single-valve circuit of Fig. 12, with the charging valve replaced by an ohmic resistance. Here, as before, the relaxation-oscillatory fly-back, thanks to the high frequency of the oscillations, appears as a band, usually faint or invisible (Fig. 13). Owing to the ohmic resistance the voltage rise is exponential, but it can be made linear by forming the resistance out of a pentode (Fig. 14, oscillogram Fig. 15). This last two-valve arrangement is discussed at considerable length. "To sum up it may therefore be said that the circuits of Figs. 12 and 14 also represent new arrangements which permit the generation, in a simple way and with a good efficiency, of very high frequencies."

872. LUMINESCENCE AND COLOUR [Summaries of Papers read at Physical Society Colour Group Meeting].—Strange, Jenkins, & others. (*Nature*, 16th Jan. 1943, Vol. 151, pp. 73–75.)

873. IGNITOR-EXCITATION CIRCUITS AND MISFIRE-INDICATION CIRCUITS.—Mittag & Schmidt. (*Elec. Engineering*, Aug. 1942, Vol. 61, No. 8, Transactions pp. 574–577.)

874. SEALED-TUBE IGNITRON RECTIFIERS.—Morack & Steiner. (*Elec. Engineering*, Aug. 1942, Vol. 61, No. 8, Transactions pp. 594–599.)

875. REGULATED RECTIFIERS IN TELEPHONE OFFICES ["Magnitude" Control: Phase-Shift Control: Booster, Series-Tube, & Shunt-"Thermistor" Controls: Thyratron Rectifier-Inverter: etc.].—Trucksess. (*Elec. Engineering*, Aug. 1942, Vol. 61, No. 8, Transactions pp. 613–617.)

876. RECTIFIER TERMINOLOGY AND CIRCUIT ANALYSIS.—Willis & Herskind. (*Elec. Engineering*, July 1942, Vol. 61, No. 7, Transactions pp. 496–498.)

877. SELENIUM RECTIFIERS FOR HIGHER VOLTAGES.—Levison. (*Journ. of Tech. Phys.* [in Russian], No. 8, Vol. 11, 1941, pp. 775–776.)

It was pointed out in a previous paper (173 of January) that after depositing the upper electrode on a selenium plate, a voltage somewhat exceeding the working voltage should be applied to the plate in the reverse direction for 1 or 2 hours in order to reduce the reverse current. During this "forming" process a film of poor conductivity is apparently formed between the selenium and the upper electrode. The author therefore decided to prepare a rectifier with an "artificial" blocking layer, without "forming," by immersing the plate into shellac or other suitable substance and then depositing the upper electrode on it. A rectifier so produced has a greater forward resistance (5 to 10 times that of an ordinary rectifier), but it can withstand considerable higher voltages in the reverse direction, so that the working voltage can be increased from 15 to 32 v. Comparative volt/ampere characteristics of ordinary and specially prepared rectifiers are shown.

878. ELECTRONIC VOLTAGE REGULATOR FOR PRECISE DENSITOMETRIC MEASUREMENTS [5% Fluctuation gives 0.4% Densitometer Change].—Dietert & Hasler. (*Journ. Opt. Soc. Am.*, Oct. 1942, Vol. 32, No. 10, pp. 633–634: summary only.) Using a photo-tube bridge illuminated by one lamp operating on the output voltage and another operating on the input voltage.

879. THE APPLICATION OF VOLTAGE REGULATORS TO AIRCRAFT GENERATORS [Special Requirements, including Absence of Radio Interference: a Device & Its Performance, including Suitability for High Production Methods].—Thompson & Crever. (*Elec. Engineering*, July 1942, Vol. 61, No. 7, p. 360: summary only.)

880. MOTOR AND GENERATOR MAINTENANCE [Practical Hints for Routine, etc.].—Cisler. (*Communications*, Aug. 1942, Vol. 22, No. 8, pp. 12–15 and 22, 30, 36, 39.) From the General Electric Company.

881. APPLICATION OF APPARATUS AND CONDUCTORS UNDER VARIOUS AMBIENT-TEMPERATURE CONDITIONS, *and* MOTOR INSULATION, HEAT, AND MOISTURE.—Hellmund & McAuley: McAuley. (*Elec. Engineering*, Aug. 1942, Vol. 61, No. 8, Transactions pp. 553–558: Oct. 1942, No. 10, Transactions pp. 707–712.)

882. INFLUENCE OF MEASUREMENTS ON DEVELOPMENT OF MAGNET WIRE [Formex Wire with Formvar Resin Insulation].—Wilson & Wek. (*Gen. Elec. Review*, Nov. 1942, Vol. 45, No. 11, pp. 612–614.)

883. CONCENTRICITY: RAPID TESTING OF ENAMEL-FILM CONCENTRICITY BY ELECTRONIC TESTER [on Capacitance-Variation Principle].—Hansen. (*Gen. Elec. Review*, Nov. 1942, Vol. 45, No. 11, pp. 615–616.)

884. THE DEVELOPMENT OF ENAMELLED WIRES WITH SYNTHETIC RESIN ENAMELLING [Special Tests necessary for War-Time Substitutes: State P.O. Developments of Oil-Free Type satisfactory Electrically & Mechanically].—Spitzer. (*E.T.Z.*, 22nd Oct. 1942, Vol. 63, No. 41/42, p. 496: short summary.) *See* also pp. 503–504.

885. ELECTRICAL PROPERTIES OF POLYSTYRENE [Investigation primarily for Its Use in Instruments for Radiological Work: Electrometer Measurements on D.C. Conductivity gives Values of at least 3×10^{20} for Specific Resistance: Reduction (perhaps by 10^8) by Passage of X-Rays: Need for Full Interpretation].—Farmer. (*Nature*, 31st Oct. 1942, Vol. 150, p. 521.)

886. DIPOLE-CLUSTER FORMATION AND DIELECTRIC POLARISATION [Writer's Cluster-Formation Theory yields Equation for Orientation-Polarisation & Its Dependence on Concentration, agreeing with van Arkel & Snoek's Empirical Relation].—Hartmann. (*Naturwiss.*, 23rd Oct. 1942, Vol. 30, No. 43, p. 662.)

887. THE DIELECTRIC STRENGTH AND LIFE OF IMPREGNATED-PAPER INSULATION: III, *and* STABILITY OF IMPREGNATED-PAPER INSULATION.—Whitehead. (*Elec. Engineering*, Aug. 1942, Vol. 61, No. 8, Transactions pp. 618–622: Nov. 1942, No. 11, pp. 554–555.)

888. FACTORS AFFECTING THE MECHANICAL DETERIORATION OF CELLULOSE INSULATION.—Clark. (*Elec. Engineering*, Oct. 1942, Vol. 61, No. 10, Transactions pp. 742–749.)

889. THE THERMAL CONDUCTIVITY OF LAC AND LAC-MOULDING COMPOSITIONS, *and* THE EFFECT OF SURROUNDING MEDIUM ON THE DIELECTRIC STRENGTH OF LAC AND LAC-MOULDED MATERIALS.—Bhattacharya. (*Indian Journ. of Phys.*, Aug. 1942, Vol. 16, Part 4, pp. 249–259: pp. 261–270.)

890. RECORDING PLASTOMETER FOR ORGANIC PLASTICS.—Biondi. (*Bell Lab. Record*, Sept. 1942, Vol. 21, No. 1, pp. 18–19.)

891. RADIO STRAIN INSULATORS FOR HIGH VOLTAGE AND LOW CAPACITANCE, *and* IMPROVED INSULATORS FOR SELF-SUPPORTING OR SECTIONALISED TOWERS.—Austin. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, p. 250: summaries only.)

892. BREAKDOWN OF COMPRESSED GASES IN INHOMOGENEOUS FIELDS.—Hochberg & Oksman. (*Science Abstracts*, Sec. B, Oct. 1942, Vol. 45, No. 538, p. 152.) "The transition from formation of positive corona to breakdown at high gas pressure is connected with some elementary process (cumulative ionisation ?) not satisfying the similarity principle." For previous work *see* Bonch-Bruevich & others, 577 of 1941.

893. SYNTHETIC SUBSTANCES AS SUBSTITUTE MATERIALS.—Vieweg. (*Schweizer Arch. f. angew. Wiss. u. Tech.*, Sept. 1942, Vol. 8, No. 9, pp. 291–298.)

894. PURE MERCURY [Practical Notes].—Wichers. (*Review Scient. Instr.*, Nov. 1942, Vol. 13, No. 11, pp. 502–503.) From the National Bureau of Standards.

895. On Eddy Currents in a Rotating Disc [*e.g.* Damping Disc in Instruments].—Smythe. (*See* 732.)

896. The Optimum Damping of Coils with Compressed-Powder Cores.—Labus: Lohrmann. (*See* 731.)

897. Papers on Magnetic Measurements and Factory Magnetostriction Tests.—Kettner: Leonard. (*See* 859 & 860.)

898. A Silver–Aluminium–Manganese Alloy, Unique among Permanent-Magnet Materials in Its High Coercive Force.—Potter: Faus. (In paper dealt with in 852, above.)

899. Powder Metallurgy [and Some Recent Sintered Materials].—Kelley. (*Elec. Engineering*, Sept. 1942, Vol. 61, No. 9, pp. 468–475.)

900. An Analytic Approach to the Hysteresis Loop [through Use of the Error Function: the Necessary Set-up of the Differential Analyser].—Weygandt & Charp. (*Elec. Engineering*, July 1942, Vol. 61, No. 7, pp. 387–388.)

STATIONS, DESIGN AND OPERATION

901. A Television Relay System [Repeater Station 130 Miles away from, and over a Mile below Line of Sight of, Station WNBT originating the Programme: Novel System of Output-Frequency Control, and Other Special Features].—Keister. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, p. 252: summary only.)

902. Method of Multiple Transmission on Ultra-Short Waves [Frequency-Modulation by a Fixed Frequency yields Large Number of Sideband Frequencies of Equal Amplitude, which can be Separated-Out and Modulated, Each with a Separate Message].—Schüssler. (*Hochf:tech. u. Elek: akus.*, Sept. 1942, Vol. 60, No. 3, p. 77.) Telefunken patent, D.R.P. 718 078.

903. Ultra-Short-Wave Telephone Equipment for the Fire Service [just introduced in Berne].—(*Bull. Assoc. suisse des Élec.*, 7th Oct. 1942, Vol. 33, No. 20, pp. 546–547.) Short note only.

904. Frequency-Modulation Transmitter–Receiver for [High-Fidelity] Studio–Transmitter Relay.—Goetter. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, pp. 251–252: summary only.)

905. A Simple Transmitter–Receiver for War Emergency Work [on 112 Mc/s].—Rand. (*QST*, Nov. 1942, Vol. 26, No. 11, pp. 23–26.) Beginning with a discussion of the comparative advantages and disadvantages of the transmitter–receiver (with separate oscillating circuits) and the transceiver (such as 593 of February).

906. A Battery Transceiver for 112 Mc/s for Field Work [2773 of 1940]: Improvements to Frequency Stability, Output, etc.—Mitchell. (*QST*, Dec. 1942, Vol. 26, No. 12, p. 70.)

907. WERS Gear 1942 Style: Kansas City Group overcomes Parts Shortage [Fifteen 2½ m Transmitters built from Very Little: Improvised Compression-Type Mica-Insulated Condensers as Main Tuning Condensers: etc.].—Hieronymus. (*QST*, Nov. 1942, Vol. 26, No. 11, pp. 36–39.)

908. Akron and the WERS: the First City with a WERS Licence puts the Plan to Work.—Brown & Moody. (*QST*, Dec. 1942, Vol. 26, No. 12, pp. 11–16 and 116..120.)

909. Semlin, the Belgrade Short-Wave Station [Short Description].—Möller. (*Funk* [Berlin], 1st April 1942, No. 7, p. 98.)

910. The Variation, with Weather Conditions, of the Attenuation along Overhead Lines, for the Higher Frequencies [Wire-Broadcasting Frequencies]. — Klein, Spang, & Fritsche. (*T.F.T.*, July 1942, Vol. 31, No. 7, pp. 198–201.)

The dependence of overhead-line attenuation on the weather, and in particular its large increase for sleet-laden wires (often to many times its ordinary value), is well known, but hitherto the data have all referred to the note-frequency or at most the intermediate-frequency band, up to say 50 kc/s. With the spread of wire broadcasting these lines often have to carry frequencies from 150 to 250 kc/s, and already difficulties have made their appearance in such systems as a result of weather effects. A thorough investigation in this frequency band therefore became necessary, so that repeater-spacings, the positions and characteristics of automatic transmission-level controls, and so on, could be determined. Tests were made over a 20 km line of hard copper of 3 mm diameter, running over various types of country, during four autumn and winter months.

The "maximum" (*see* p. 199, r-h column) attenuation values for dry weather were 0.022 N/km at 150 kc/s and 0.029 N/km at 250 kc/s. In wet weather or snowfall the corresponding values were 0.044 and 0.074 N/km, while for sleet the figures rose to 0.10 and 0.16 N/km respectively. On the basis of the whole series of measurements an empirical formula was derived: $\beta=\beta_R+\beta_G=R/2Z+\frac{1}{2}GZ$, where the wave attenuation β is made up of β_R, the resistance attenuation, and β_G, the leakance loss, and where R = resistance/km, G = leakance/km, and Z is the characteristic impedance. The frequency dependence of β_R, by Küpfmüller's methods, is given by eqn. 3 for this particular line: the values of β_R, calculated by this formula and plotted against the square-root of the frequency, give the broken straight line marked β_R in Fig. 6, which does not pass through the zero point. The full line marked β represents the measured attenuation for the dry line. The difference between the values of β and β_R in this diagram is the leakance loss β_G: it is found that β_G is about proportional to the frequency. From β_G the kilometric leakance, G, is derived, also proportional to f, so that we may put $G=g.f$. The proportionality factor g may be termed the " weather factor " : then the total attenuation of an overhead line, up to the highest frequency considered, for any wire diameter, can be calculated by equation 5, $\beta = (R_o/8Z) . (1+d\sqrt{\pi\kappa\mu} . \sqrt{f}) + \frac{1}{2}gZf$. Values of g, derived from the above measurements in different weathers, are tabulated, and from these (and eqn. 5) the attenuation of lines of different materials and different sizes, in various weathers, can be calculated.

911. Coppered-Steel Wire for Carrier-Frequency Overhead Lines.—Klein. (*T.F.T.*, Aug. 1942, Vol. 31, No. 8, pp. 210–212.)

Such bimetallic wires were experimented with some time ago, but were unsatisfactory owing to the fact that at the low frequencies then involved the wire had to be considerably thickened to give the same results as the solid copper wire: also, the imperfect manufacturing technique led to the copper coating peeling off. Now, however, carrier-frequency working along overhead lines has changed the position completely, for at frequencies like 150 kc/s the coppered-steel wire has the same resistance as the hard-copper wire of the same size, and is much stronger: it has a lower resistance than the similarly strong bronze wire: and it saves a lot of copper (in 3 mm wire steel replaces about 70% of the copper).

Skin-effect theory for a thin-walled tube, combined with measurements on coppered-steel wires, shows that practically the whole current flows in the copper sheathing if the thickness x of the latter is 1.2 times the thickness δ (" equivalent conducting layer," a measure of the penetration depth : $\delta = \sqrt{\rho/\pi\mu f}$). Applying the values of ρ and μ for copper, the " Mantelfrequenz " f_M (that is, the frequency above which the bimetallic wire behaves like a solid copper wire of the same external diameter) is found to be given by $f_M = 6.3/x^2/\text{mm}^2$ kc/s. Instead of the layer thickness x, which is difficult to measure, it is usual to deal with the copper content of the wire in percentages of weight: the relation between this percentage and the layer thickness x is shown in the curves of Fig. 1 for 2, 3, and 4 mm wires, and Fig. 2 shows for the same wires the variation of the " sheath frequency " f_M with this percentage.

The two carrier-current systems which to-day are the chief users of the coppered-steel lines have maximum carrier frequencies of 156 kc/s and 60 kc/s. For various reasons a wire with a 3 mm external diameter and a 30% copper percentage (average coating thickness 0.22 mm) has been standardised: the critical " sheath frequency " for this is seen in Fig. 2 to be about 130 kc/s, so that for the second system mentioned a certain reduction of range would be caused, but this is tolerable for the system in question. The wire used by the Russians has an external diameter of 4 mm, so that its " sheath frequency " is about 40 kc/s, suiting the Russian three-channel CMT34 system with its maximum carrier frequency of 38.5 kc/s: for the German systems the sheath would be unnecessarily thick.

The penultimate section deals with the resistance at low frequencies, where the current flows partly in the copper and partly in the steel. Here the calculation is difficult, but the derivation of a simple approximate formula (eqn. 7) is quoted from a 1940 Russian book (footnote " 3 ") : it is reasonably accurate for frequencies to about 10 kc/s. The final section considers the measurement of the quality of such bimetallic wires. The kilometric attenuation of a two-wire circuit is not a convenient measurement to make, particularly for an acceptance test (it would need long lengths and would, also, be affected by weather conditions—*cf.* 910, above), so it is preferable to measure the dissipative resistance, which is the main factor in the resistance attenuation and can thus form the basis of a test. The resistance of a convenient length of such a wire (say 20 m) at high frequencies is not too simple; Fig. 3 shows that at 150 kc/s, for instance, it amounts only to about 0.4 ohm. The bridge method adopted is seen in Fig. 5 : the usual difficulty in measuring such low values, the provision of a satisfactory standard resistance, is overcome by the use for this purpose of an exactly similar loop of solid copper wire (arranged so as to have no mutual influence on the test loop) whose resistance is calculated from table 1.

912. Prevention of Mutual Interaction between Broadcast or Wire-Broadcast Receivers connected to a Common Distribution System.—Hagen. (*See* 744.)

913. Maintenance of Broadcasting Operations during Wartime.—Ouimet. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, p. 252 : summary only.) From the Canadian Broadcasting Corporation.

914. Post-War Broadcasting : Transmitter Volume Compression [" Difficult Problems " which Must be Faced after the War : Absurdity of Contrast Expansion as used at present].—Hughes : King. (*Wireless World*, Jan. 1943, Vol. 49, No. 1, p. 29.) Prompted by 605 of February.

915. Broadcast Programme Failure Alarm : an Unusual Automatic Monitoring Device providing a Visual–Aural Alarm when the Carrier, Programme Line, or Programme Fails.—O'Brien. (*Communications*, Aug. 1942, Vol. 22, No. 8, pp. 5–6 and 38.)

916. Motor and Generator Maintenance [Practical Hints for Routine, etc.].—Cisler. (*Communications*, Aug. 1942, Vol. 22, No. 8, pp. 12–15 and 22, 30, 36, 39.) From the General Electric Company.

917. Device prevents Enemy from Jamming Wireless [Key Plates, in Duplicate at Transmitter & Receiver, vary Frequency in Irregular Way].—Henroteau. (*Sci. News Letter*, 7th Nov. 1942, Vol. 42, No. 19, p. 297.) U.S. Patent 2 298 562.

GENERAL PHYSICAL ARTICLES

918. The Force required to give a Small Acceleration to a Slowly-Moving Sphere carrying a Surface Charge of Electricity.—Searle. (*Phil. Mag.*, Dec. 1942, Vol. 33, No. 227, pp. 889–899.)

919. SOME ASPECTS OF THE ELECTROMAGNETIC FIELD [and the Impact of Relativity].—Leigh Page. (*Elec. Engineering*, Oct. 1942, Vol. 61, No. 10, pp. 511–516.) "If the relativity principle had been recognised in Coulomb's time, the experimental investigations of Oersted and Ampère, Henry and Faraday, would have been unnecessary . . ."

920. FLUORESCENCE, LIGHT SCATTERING, AND THE RAMAN EFFECT [Indian Symposium].—(*Nature*, 19th Dec. 1942, Vol. 150, pp. 741–742: summary, from *Proc. Indian Acad. Sci.*)

MISCELLANEOUS

921. CRITICISM OF "LAPLACIAN TRANSFORM ANALYSIS OF CIRCUITS WITH LINEAR LUMPED PARAMETERS."—Lyon: Millman. (*See* 726.)

922. EVALUATING DETERMINANTS [Note on Crout's "Short Method"].—Huggins: Crout. (*See* 725.)

923. THE DETERMINATION OF THE HARMONIC CONTENT of A.C. CURVES [by Runge's Simple Process (*E.T.Z.*, 1905) for Analysis of Cathode-Ray Tube Records, etc: with Tables].—(*Funk* [Berlin], 1st Feb. 1942, No. 3, pp. 37–40.)

924. A PRODUCT-RATIO METER.—Lorenz. (*See* 851.)

925. USE OF THE MECHANICAL MULTIHARMONOGRAPH FOR GRAPHING TYPES OF FUNCTIONS AND FOR SOLUTION OF PAIRS OF NON-LINEAR SIMULTANEOUS EQUATIONS.—Leroy Brown & Wheeler. (*Review Scient. Instr.*, Nov. 1942, Vol. 13, No. 11, pp. 493–495.)

926. "EINFÜHRUNG IN DIE THEORETISCHE ELEKTROTECHNIK" [Third Edition: Book Review].—Küpfmüller. (*T.F.T.*, Aug. 1942, Vol. 31, No. 8, p. 228.) "Such a valuable contribution . . . that the appearance of a third edition provides an occasion to consider the whole book anew."

927. A NOTE ON TWO COMBINATORIAL PROBLEMS HAVING APPLICATIONS IN THE THEORY OF DESIGN OF EXPERIMENTS [including Much Simpler Solutions than Bhattacharya's].—Bose. (*Sci. & Culture* [Calcutta], Oct. 1942, Vol. 8, No. 4, pp. 192–193.)

928. QUALITY CONTROL AND THE WAR [Experience of the U.S. Army Ordnance Department.]—Simon. (*Elec. Engineering*, Sept. 1942, Vol. 61, No. 9, pp. 449–452.)

929. TOLERANCES: CONSIDERATIONS GOVERNING THE FIXING OF LIMITS FOR RADIO COMPONENTS.—Terry. (*Wireless World*, Jan. 1943, Vol. 49, No. 1, pp. 19–22.)

930. CONFERENCE ON "SCIENTISTS OF THE UNITED NATIONS AND THE WAR EFFORT."—Association of Scientific Workers. (*Nature*, 9th Jan. 1943, Vol. 151, pp. 58–59: summary.)

931. SYNTHETIC GENIUS AND THE AMATEUR [Editorial prompted by *Gen. Elec. Review* Comment].—(*QST*, Nov. 1942, Vol. 26, No. 11, pp. 11–12.) "The most fertile source of 'synthetic genius' a science or art may have lies in the amateur devotees it sponsors."

932. A WORLD LANGUAGE [Advantages of a Systematic Sign Language over a Spoken Language: Need for Development of a Two-Dimensional Script].—Paget: Gregory. (*Nature*, 16th Jan. 1943, Vol. 151, p. 80.) Prompted by Gregory's address, 653 of February.

933. A WORLD AUXILIARY LANGUAGE [Leading Article].—(*Nature*, 23rd Jan. 1943, Vol. 151, pp. 89–91.) *See* also 653 of February.

934. RUSSIAN SCIENTIFIC AND TECHNICAL PERIODICALS IN GREAT BRITAIN [Note on Survey for 1939/42].—A.S.L.I.B. (*Nature*, 16th Jan. 1943, Vol. 151, p. 77.)

935. MICROFILM PERIODICALS [Announcement from Microfilms, Inc.].—(*Review Scient. Instr.*, Oct. 1942, Vol. 13, No. 10, p. 444.)

936. LITERARY PROPERTY IN BROADCAST MATERIAL [Case of French Authors' Rights Society *versus* Restaurant Proprietor].—Mestre. (*Génie Civil*, May 1942, Vol. 119, No. 14, p. 161.)

937. WRITING A TECHNICAL PAPER.—Ketcham. (*Elec. Engineering*, Sept. 1942, Vol. 61, No. 9, pp. 494–495.)

938. THE NAVY TRAINS RADIO TECHNICIANS.—(*QST*, Nov. 1942, Vol. 26, No. 11, pp. 13–18 and 116..120.)

939. THE TRAINING OF THE WAR-DISABLED AS RADIO MECHANICS.—(*Funk* [Berlin], 15th June 1942, No. 12, p. 172.)

940. WIND POWER: CAN IT BE HARNESSED SUCCESSFULLY? [including the 1000 kW Plant on "Grandpa's Knob" and the Deutschlandsender's Announcement of German Developments].—Warrilow. (*Distribution of Electricity*, Jan. 1943, Vol. 15, No. 149, pp. 76–77.)

941. REMOTE-CONTROLLED AEROPLANES [English Developments—"Queen Bee" & "Queen Wasp"—and Their Assumed Failure].—Zuerl. (*Funk* [Berlin], 15th June 1942, No. 12, p. 171.)

942. AIR-RAID ALARM DEVICE [to save Waste of Man-Power in Monitoring for 1000-Cycle Warning Tone from Key Station].—Vickerson & Gray. (*Elec. Engineering*, Sept. 1942, Vol. 61, No. 9, p. 496.) *Cf.* 635 of February.

943. THE EARTH AS CONDUCTOR IN DISTANT TRANSMISSIONS [Best Types of Earths: Extent necessary for a Transmission Current of 500 Amperes: No Danger (anticipated by Other Workers) of Drying-Up the Moisture: the

Limited Spread of the Current Flow: etc.]. Häberli: Rump. (*E.T.Z.*, 22nd Oct. 1942, Vol. 63, No. 41/42, p. 494: summary of two papers in *Brown-Boveri Mitteil.*, Vol. 28, 1941.)

944. "Die Messung von Erderwiderständen" [Measurement of Earth-Connection Resistances: Book Review].—Fritsch. (*Hochf: tech. u. Elek. akus.*, Aug. 1942, Vol. 60, No. 2, p. 60.) For recent papers *see* 3517 of 1942.

945. Water Divining: Its Alleged Electrical Basis.—Shipley. (*Distribution of Electricity*, Jan. 1943, Vol. 15, No. 149, pp. 80–82: to be concluded.)

946. Secondary Radiation from X-Ray Filters: I—Single-Metal Filters [Measurements of Forward-Transmitted Secondary Rays: Effect a Real Hindrance with Some Such Filters].—Wrenshall & Nichols. (*Canadian Journ. of Res.*, Nov. 1942, Vol. 20, No. 11, Sec. A, pp. 185–194.) Part II will deal with the reduction of the action by the use of compound filters composed of laminae of various single metals.

947. An X-Ray Method for determining the Thickness of Coatings: Part I.—Palatnik. (*Journ. of Tech. Phys.* [in Russian], No. 23/24, Vol. 10, 1940, pp. 1975–1980.)

A theoretical discussion is presented of a method for determining the thickness of a uniform crystalline coating deposited on a massive crystalline foundation. The method is based on the same principle as the one used in the approximate determination of the concentration of crystalline phases in an alloy, namely the comparison between the intensities of Debye lines of the two layers.

948. An Automatic X-Ray Diffraction Apparatus [using Geiger-Müller Counters to detect the Diffracted Lines].—Harding & others. (*Phys. Review*, 1st/15th Sept. 1942, Vol. 62, No. 5/6, p. 296: summary only.)

949. A Theory of the Initial Avalanche in the Breakdown of a Discharge Counter in Helium [and the Successful Prediction of Threshold Voltages].—Brown. (*Phys. Review*, 1st/15th Sept. 1942, Vol. 62, No. 5/6, pp. 244–254.)

950. A New Method of determining Half-Value Periods [10^{-4} to 1.0 Second] from Observations with a Single Geiger Counter.—Ward. (*Proc. Roy. Soc.*, Ser. A, 31st Dec. 1942, Vol. 181, No. 985, pp. 183–197.) *Cf.* 861, above.

951. High-Sensitivity D.C. Amplifier: Another Application of the Cathode-Ray Tuning Indicator [for Biological Research, etc.].—Hay. (*See* 721.)

952. The Encephalophone: a New Method for investigating Electro-Encephalographic Potentials [in Clinical Applications, where Recording is Not Essential: Potential Changes converted into Beat-Note Variations.]—Fürth & Beevers. (*Nature*, 23rd Jan. 1943, Vol. 151, pp. 110–111.)

953. A Continuous Electronic Pulse-Rate Indicator and Recorder [Cardiotachometer: suitable also for any Quasi-Periodic Phenomenon (20–400 per Minute) providing an Impulse around 1 Millivolt].—Schwarzschild & Shelesnyak. (*Review Scient. Instr.*, Nov. 1942, Vol. 13, No. 11, pp. 496–501.)

954. The Oximeter, an Instrument for Measuring Continuously the Oxygen Saturation of Arterial Blood in Man [by Bichromatic Colorimetry of Fully Flushed Ear: Unit (slipping over Shell of Ear) containing Lamp, Filters, & Two Photocells].—Millikan. (*Review Scient. Instr.*, Oct. 1942, Vol. 13, No. 10, pp. 434–444.)

955. Colour Analysis [and the Increasing Industrial & Medical Importance of the Recording Photoelectric Spectrophotometer].—Barnes. (*Gen. Elec. Review*, Nov. 1942, Vol. 45, No. 11, pp. 645–648.)

956. Photoelectric Microphotometer with Oscillating Mirror [specially for the Accurate Discovery of Points of Equal Blackening in Photographically Recorded Spectra.].—Bodforss. (*Zeitschr. f. Instr: kunde*, Oct. 1942, Vol. 62, No. 10, pp. 332–333: summary only.)

957. An Electronic Method of Measuring Molecular Lifetimes.—Rawcliffe. (*See* 861.)

958. The "Giant" R-1000 Self-Generating Photocell [nearly 8 Inches in Diameter, 4000 μA Output at 100 Foot-Candles].—Emby Products. (*Communications*, Aug. 1942, Vol. 22, No. 8, p. 26.)

959. On the Deflection Process of a "Double Galvanometer," *and* On the Measuring Limits with a "Double Galvanometer."—Passoth. (*See* 853.)

960. Electronics of the Fluorescent Lamp.—Townsend. (*Elec. Engineering*, Aug. 1942, Vol. 61, No. 8, Transactions pp. 607–612.)

961. Photographic Analysis of Motion.—Davies. (*Nature*, 26th Dec. 1942, Vol. 150, p. 765: summary of Royal Institution lecture.)

962. Glascote for War-Time Applications [Transparent Liquid Coating for Glass (Bulbs, etc.), for Protective Purposes].—(*Elec. Engineering*, Sept. 1942, Vol. 61, No. 9, Advt. p. 26.) Cf. *Review Scient. Instr.*, Oct. 1942, Vol. 13, No. 10, p. 467.

963. Papers on the Propagation of Electromagnetic Waves in a System of Parallel Layers of Isotopic Substances, Observations on Low-Reflecting Bi-Layer Films of Metals and Dielectrics, etc.—Luneburg & others. (*See* 700.)

964. The Properties of Optical Glasses with Chemically Treated Surfaces: II [Reversible & Irreversible Changes with Time: Effects of Heat: etc.].—Schröder. (*Zeitschr. f. tech. Phys.*, No. 8, Vol. 23, 1942, pp. 196–208.) For I *see* 2612 of 1941.

965. New Thermo-Mechanical Radiation-Receivers for "Alternating" Light.—Schneiderreit. (*See* 862.)

966. The Propagation of Light in Hollow Guides.—Mathieu. (*Schweizer Arch. f. angew. Wiss. u. Tech.*, Sept. 1942, Vol. 8, No. 9, pp. 288–291.)

The development of wave-guide technique for "hyperfrequency" radio waves suggests the desirability of examining the basic possibilities of a practical use (for example, for communications) of wave guides for optical waves. The writer therefore makes such a theoretical examination: the table on p. 290 shows as the best possible calculated kilometric attenuation, for a 10 cm-diameter straight tube with a silver reflecting surface, the value of 5 db/km: this is some three times more severe than that given by Vilbig for a wide-band cable. On the whole, the writer concludes that for communication purposes optical methods will only be useful where no kind of guide can be laid: but that short light guides might be useful in special circumstances, such as for illumination in spots where it is undesirable to lay electric cables.

967. Automatic Control: Development of Industrial Designs and Applications.—(*Electrician*, 11th Dec. 1942, Vol. 129, pp. 633–635.)

968. Process Lags in Automatic-Control Circuits [Definition & Use of Terms "Controllability" & "Recovery Factor": Suggestions for Improvement in Design of Such Systems].—Ziegler & Nichols. (*Journ. Roy. Aeron. Soc.*, Dec. 1942, Vol. 46, No. 384, Abstracts p. 482.)

969. Radio-Frequency Oscillator Apparatus and Its Application to Industrial Process-Control Equipment.—Cohen. (*Proc. I.R.E.*, May 1942, Vol. 30, No. 5, p. 251: summary only.) From Wheelco Instruments Company.

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The National Interest demands Standardisation

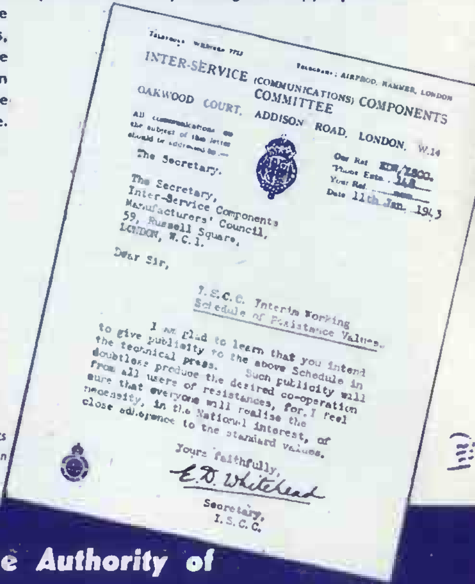
These "Standard Values" cover every Resistance Value from 10 ohms to 10 Meg.

±20%	±10%	★±5%	±20%	±10%	★±5%	±20%	±10%	★±5%
10	10	10	1000	1000	1000	100000	100000	100000
		11			1100			110000
	12	12		1200	1200		120000	120000
		13			1300			130000
15	15	15	1500	1500	1500	150000	150000	150000
		16			1600			160000
	18	18		1800	1800		180000	180000
		20			2000			200000
22	22	22	2200	2200	2200	220000	220000	220000
		24			2400			240000
	27	27		2700	2700		270000	270000
		30			3000			300000
33	33	33	3300	3300	3300	330000	330000	330000
		36			3600			360000
	39	39		3900	3900		390000	390000
		43			4300			430000
47	47	47	4700	4700	4700	470000	470000	470000
		51			5100			510000
	56	56		5600	5600		560000	560000
		62			6200			620000
68	68	68	6800	6800	6800	680000	680000	680000
		75			7500			750000
	82	82		8200	8200		820000	820000
		91			9100			910000
100	100	100	10000	10000	10000	1.0 Meg.	1.0 Meg.	1.0 Meg.
		110			11000			1.1 Meg.
	120	120		12000	12000		1.2 Meg.	1.2 Meg.
		130			13000			1.3 Meg.
150	150	150	15000	15000	15000	1.5 Meg.	1.5 Meg.	1.5 Meg.
		160			16000			1.6 Meg.
	180	180		18000	18000		1.8 Meg.	1.8 Meg.
		200			20000			2.0 Meg.
220	220	220	22000	22000	22000	2.2 Meg.	2.2 Meg.	2.2 Meg.
		240			24000			2.4 Meg.
	270	270		27000	27000		2.7 Meg.	2.7 Meg.
		300			30000			3.0 Meg.
330	330	330	33000	33000	33000	3.3 Meg.	3.3 Meg.	3.3 Meg.
		360			36000			3.6 Meg.
	390	390		39000	39000		3.9 Meg.	3.9 Meg.
		430			43000			4.3 Meg.
470	470	470	47000	47000	47000	4.7 Meg.	4.7 Meg.	4.7 Meg.
		510			51000			5.1 Meg.
	560	560		56000	56000		5.6 Meg.	5.6 Meg.
		620			62000			6.2 Meg.
680	680	680	68000	68000	68000	6.8 Meg.	6.8 Meg	6.8 Meg.
		750			75000			7.5 Meg.
	820	820		82000	82000		8.2 Meg.	8.2 Meg.
		910			91000			9.1 Meg.
						10.0 Meg.	10.0 Meg.	10.0 Meg.

★ See note (1) in Text

In the Fixed Composition Resistor Field "STANDARD VALUES" is the Solution

For a long time now the range of values demanded in Fixed Composition Resistors has been increasing until it has now reached an uneconomic and wasteful figure exceeding 800. This position has produced unavoidable delays in delivery because of the time expended in special sorting and colour-coding, and the consequential hold-ups in the manufacture and servicing of important equipment. In order to regularise the position the Services, the Manufacturers, their Engineers and Laboratories have co-operated in rationalising the range to the 255 STANDARD VALUES, listed in the accompanying table, without any loss of efficiency. Tolerance ± 20% should be used wherever possible: ± 10% should be used only where essential: whilst for (1) ± 5% prior authorisation is required and should be sought by the Development Authority through the appropriate Supply Department Design Authority. The schedule applies only to new development projects, and not to existing contracts, spares for same or repeat orders for either. Your co-operation in using only STANDARD VALUES of resistance is vital if your demands are to be met on time.



INTER-SERVICE (COMMUNICATIONS) COMPONENTS COMMITTEE
OAKWOOD COURT, ADDISON ROAD, LONDON, W.14
Telegrams: AIRPROD, HAMMER, LONDON

All communications on the subject of this letter should be addressed to:—
The Secretary.

Our Ref. [illegible]
Phone Extn. [illegible]
Your Ref. —
Date 11th Jan. 1943

The Secretary,
Inter-Service Components
Manufacturers' Council,
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Dear Sir,

I.S.C.C. Interim Working Schedule of Resistance Values.

I am glad to learn that you intend to give publicity to the above Schedule in the technical press. Such publicity will doubtless produce the desired co-operation from all users of resistances, for I feel sure that everyone will realise the necessity, in the National interest, of close adherence to the standard values.

Yours faithfully,
E.D. Whitehead
Secretary,
I.S.C.C.

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- Increased Production
- Quicker Delivery
- Speedy Servicing

SAVE
- Valuable Raw Materials
- Labour
- Dangerous Delays

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