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ON THE DIELECTRIC CONSTANT OF AN ELECTRONIC MEDIUM AT MEDIUM RADIO-FREQUENCY*

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ABSTRACT. The results of an investigation on the variation of the dielectric constant of an electronic medium in the anode=screen-grid space of a Philips A 442 valve under various conditions for medium radio-frequencies are given in this paper. The measurements of the effective dielectric constant were made by following the no-beat technique of a double heterodyne method The effect of the conductivity of the medium was allowed for in estimating the effective dielectric constant of such a medium.

The experimental results were found consistent with Lorentz's formula for the dielectric constant of a frictionless electronic medium after introducing a multiplying factor to obtain the effect of the time of stay of the electrons in the inter-electrode space. The multiplying factor was found independent of the wavelength of the measuring field and was found to depend only on the transit time.

The *parabolic* variation in the value of the dielectric constant of the electronic medium with the variation in the *magnitude* of the measuring field as reported by Prasad and Verma was not, however, observed in the experiments performed to test any such variation. In some cases a steady variation was found and this has been explained.

INTRODUCTION

Usually the electronic medium under investigation is a high-vacuum space in a thermionic valve filled with electrons from a heated filament under the influence of an electric field. Since the time of stay of the electrons in the inter-electrode space is only a small fraction of the period which corresponds to the radio-frequency of the alternating field, the contribution of the electrons towards the change of the dielectric constant should therefore be correspondingly small. Benner[1] considered this effect of the finite time of transit of the electrons and deduced a correction factor to the well-known Eccles-Larmor expression for the dielectric constant of a purely electronic medium. Recently Hollmann and Thoma[2] criticised Benner's equations. From their theory of the inversion of electrons and using Maxwell's equations they deduced a formula for dielectric constant of electronic medium, which was different from Benner's. Their main result about the dielectric constant was that as the product of frequency and

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transit-time increases from zero, the dielectric constant followed a damped cyclic curve about unity. The dielectric constant of an electronic medium could therefore be less than, equal to, or greater than unity, the value depending on the product of the frequency and the transit-time.

Coming to the experimental determinations of the dielectric constant of space containing electrons, the results of Bergmann and Düring[3] who were the earliest workers on the subject showed that the dielectric constant of the electronic medium in their investigation was less than unity and steadily diminished with increasing electron concentration. Following Bergmann and Düring's experiments Sil[4] observed a decrease, an increase and also no change of dielectric constant at ultra-high frequency. These experimental results were explained as due to the non-uniform distribution of the electrons in the medium and also due to the effect of the time of stay of the electrons as determined from Benner's formula. Some experiments[5,6] on the subject with ultra-high-frequency measuring field were also performed in this laboratory. The following were established :

(1) With a definite ultra-high frequency, the effective dielectric constant of the electronic medium in a screen-grid valve was found less than unity and decreased on the whole nearly proportionately with the increase of the anode current.

(2) When the wevelength was changed keeping the anode and screen-grid voltages and the filament current constant, the effective dielectric constant of the medium decreased steadily with the increase of the wavelength. There was, however, an anomaly beyond a certain wavelength when a gradual increase in the value of the dielectric constant was observed. As the wavelength was further increased, the dielectric constant assumed values greater than unity and after attaining a maximum value at a particular wavelength decreased again with further increase of wavelength. It was also observed that the wavelength at which the dielectric constant of the electronic medium attained a maximum value was distinctly larger for the smaller electron concentration.

These results were explained by supposing that the inductance of the short external connection and the inter-electrode capacity of the valve constituted an oscillatory circuit so that the anomaly appeared in the region of the resonance frequency of such an oscillatory circuit. The condition for this resonance according to Hund[7] is the same as that for the plasma electronic resonance of Tonks and Langmuir. This explained also the observed shift of the peak value of the dielectric constant towards the longer wavelength when electron concentration was reduced. It is, however, significant that neither Benner's nor Hollmann and Thoma's formula was found to agree with these experimental results. Attributing, however, a natural frequency to the electrons corresponding to the resononce of the previously mentioned oscillatory circuit in the valve and introducing a multiplying factor to obtain the effect of the time of stay of the electrons in the inter-electrode space of the valve, the Lorentz expression for the dielectric constant for a frictionless medium was found consistent with these ultra-high frequency measurements.

SCOPE OF THE PRESENT INVESTIGATION

The object of the present investigation was to extend the measurements of dielectric constant of electronic medium to much lower frequencies. Prasad and Verma[8] had previously published some experimental results with medium radio-frequencies between 3.7×10^6 and $.58 \times 10^6$ cycles per sec. (wavelength 51 m. to 512 m.). Following the double-beat method they found the dielectric constant of an electronic medium inside a screen-grid valve always less than unity within the range of the concentrations and the wavelengths employed in their investigations. They showed that (1) the dielectric constant decreased with increasing concentration and that (2) it also decreased with increasing wavelengths. Their measurements of dielectric constant and the theoretical deductions from these measurements were, however, vitiated by the fact that in determining the dielectric constant of the electronic medium the effect of the conductivity of the medium was not considered at all.

The usual experimental procedure is to measure the capacity between the two electrodes inside a valve with and without electrons filling the inter-electrode space. When the space is filled with electrons there are generally two effects: (1) a change in the dielectric constant of the medium and (2) a conductivity effect. For both of these effects it is expected to obtain a change in the capacity of the oscillating system in the measurement circuit. If the dielectric constant is less than unity, the change in the capacity is a decrease, whereas the effect of the conductivity due to the electrosn, short-circuiting, so to say, the two electrodes in their transit from the filament to the anode of the experimental valve is *always* an increase in the effective capacity necessary to restore the resonance condition of the oscillating system. This latter effect is sometimes appreciable and can be directly tested by putting a high resistance across the two electrodes. Accurate measurements of the effective dielectric constant of the electronic medium for medium radio-frequencies were therfore felt necessary by considering the effect of the conductivity of the medium and investigations were accordingly undertaken. The experiments were arranged in three main parts:

I. Variation of the effective dielectric constant of the electronic medium in the inter-electrode space of a screen-grid valve with the thermionic current through the valve for a definite frequency of the alternating field.

II. Variation of the effective dielectric constant of the similar electronic medium with the frequency of the alternating field for a definite electron concentration.

III. Dependence of the effective dielectric constant of the electronic medium inside a screen-grid valve on the time of stay of electrons in the inter-electrode space.

EXPERIMENTAL ARRANGEMENTS AND PROCEDURE

The experimental condenser consisted of the screen-grid and the anode of a Philips A 442 valve. This condenser of capacity C_V was in parallel with the tuning condenser of capacity C of the oscillatory circuit of a suitable Hartley oscillator. The change in the capacity of C_V when the inter-electrode space was filled with electrons was balanced by changing the capacity of an accurately calibrated small variable vernier air condenser C_A in parallel with C_V and C, so that the total capacity $(C_V + C + C_A)$ remained constant. The high-frequency signal from the oscillator was received by an oscillator-detector valve-circuit which was exactly similar to the oscillator circuit. When the detector circuit was nearly in tune with the oscillator, the familiar heterodyne whistle was heard in the telephones placed in the anode circuit of the receiver. The audio-frequency voltage developed across the telephone was then amplified by a three-valve amplifier of the conventional type and fed into a loudspeaker which gave a loud musical note. On introducing into the same loudspeaker an audio-frequency current from an audio-oscillator capable of producing an intense note of fixed frequency, beats were heard by suitably adjusting the heterodyne frequency. A variable resistence was placed in series with the secondary coil of the audio-oscillator to match the intensity of the heterodyne whistle with that of the audio-frequency note. Adjustments of the variable vernier condenser C_A in the oscillator to produce *no* beats were then made successively *first* when the inter-electrode space was devoid of electrons and *next* when the same space was filled with electrons. In other words, the change in the capacity of C_A was noted with the filament of the experimental valve off and on after having given suitable high voltages to the anode and the screen-grid. To this was added a correction to allow for the effect of the conductivity of the medium. From a knowledge of this corrected change of capacity and the inter-electrode capacity of the valve, the effective dielectric constant of the medium was calculated. The procedure adopted to obtain the conductivity correction will be described in a subsequent section.

The diagram of the entire arrangement is shown in fig. 1. The anode of the experimental valve was given a suitable high voltage from a separate dry battery; the screen-grid was also given *practically* the same voltage from the same battery through the inductance coil of the Hartley oscillator. The filament of

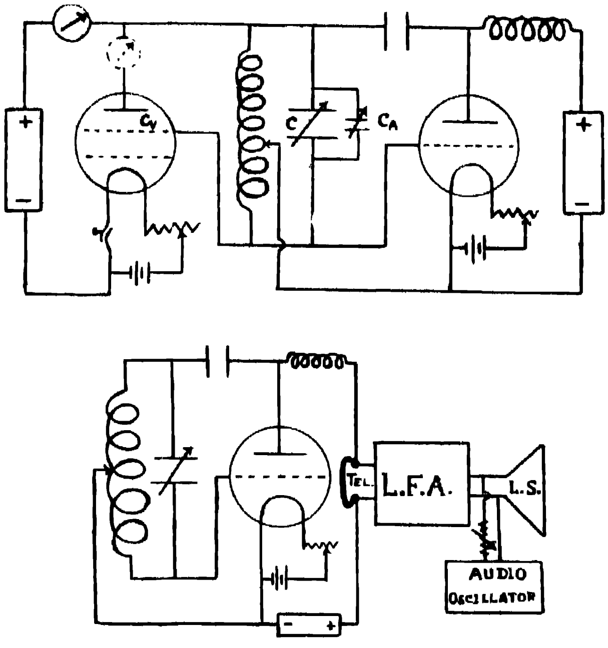

FIGURE 1

the experimental valve was fed by a low tension battery and the filament current was suitably controlled by a rheostat. The variation of the thermionic current through the valve was made by varying the filament current only, the anode and the screen-grid voltages having been kept fixed. The constancy of these voltages ensured the constancy of the time of stay of the electrons in the inter-electrode space, so that the variation of the dielectric constant of the electronic medium with varying thermionic currents (keeping the frequency constant) and the similar variation (for a constant thermionic current) with varying frequencies of the measuring field were studied for a definite value of the transit-time of the electrons.

CORRECTION FOR THE CONDUCTIVITY OF THE ELECTRONIC MEDIUM

In correcting for the conductivity effect the following procedure was adopted.

Let us first consider the set of experiments where the change in the anode-screen-grid capacity of the experimental valve was observed for each different thermionic current through the valve for a definite frequency of the measuring field. Immediately after this set of experiments, the H. F. series-resistance of the electronic medium was measured by the distuning method for each different thermionic current through the valve, the anode and the screen-grid voltages remaining exactly the same as in the preceding experiment. For these

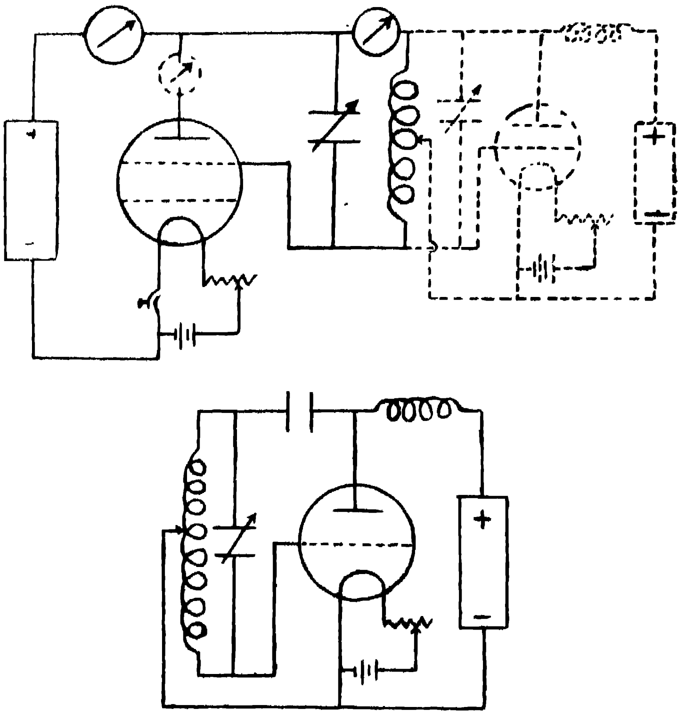

FIGURE 2

measurements the valve of the Hartley oscillator was not worked and only the tuning condenser C of the oscillatory circuit (or the small variable balancing condenser C_s whichever was suitable) and the anode=screen-grid capacity C_v each in parallel with the inductance were used with a radio-frequency thermal galvanometer in the circuit as shown in fig. 2. The detector-oscillator unit was used as a mere oscillator to induce currents into the neighbouring oscillatory circuit. A pair of resonance curves were constructed showing current against the capacity-value, first where the filament was off and next when the filament was on. Pairs of such resonance curves for different thermionic currents through the experimental valve were constructed. From each pair of such resonance curves, the H. F. series-resistance r of the electronic medium was determined by the usual formula. The corresponding shunt resistance R was then calculated for each different thermionic current through the valve by the standard formula

$$R=\frac{1}{\omega^2 C^2 r},$$

where ω is the angular frequency of the field and C the capacity in farads, across which the shunt resistance R is supposed to work. A graph was then plotted showing $1/R$ against the thermionic current. Next in a separate experiment the anode and the screen-grid electrodes of the experimental valve were shunted by different non-inductive metal film high resistances (of negligible self-capacity) and the corresponding increase in the effective capacity of the oscillating system (with no electrons inside the inter-electrode capacity) due to leakage for each different shunt resistance to restore resonance condition of system was accurately measured by following again the no-beat technique of the double-heterodyne method already described in the previous section. Another graph was then constructed from the observed data showing the increase in the capacity against the reciprocal of the actual shunt-resistance employed. With the help of these two graphs it was possible to obtain the increase in the value of the effective capacity of the oscillating system due to the conductivity of the medium in the inter-electrode capacity. To take an example, let us find the conductivity correction for a definite thermionic current. From the $1/R$ = current graph it is possible to obtain the value of $1/R$ which corresponds to the desired value of the current. The other graph (showing the increase in the capacity of the oscillating system for each actual resistance shunted across the inter-electrode capacity) enables us to obtain the increase in the capacity corresponding to this value of $1/R$ which, as we have already seen from the previous graph, corresponds to the desired value of the thermionic current.

The conductivity correction $(\Delta C)_\sigma$, obtained in this way, was then added to the observed decrease of the anode = screen-grid capacity ΔC for the respective value of the thermionic current through the valve. The change in the capacity due to the dielectric constant change for this value of the current was then given by

$$(\Delta C)_\epsilon = \Delta C + (\Delta C)_\sigma .$$

The dielectric constant was thus calculated from

$$\epsilon = 1 - \frac{(\Delta C)_\epsilon}{C_v} .$$

In the set of experiments where the frequency of the measuring field was varied by keeping the thermionic current constant and the change in the anode = screen-grid capacity observed with the filament of the valve off and on, the procedure for the conductivity-correction was as follows. Working with the circuit diagram shown in fig. 2, pairs of resonance curves were constructed with the same constant thermionic current on and off for various wavelengths within the range of our observations. From each pair of such resonance curves the H. F. resistance r of the medium (with a definite electron concentration) was determined. Thus the corresponding equivalent shunt resistance R as calculated from the series-resistance was obtained for each wavelength λ. A graph was then plotted showing $1/R$ against λ. Next, the anode = screen-grid electrodes were shunted as described before by different non-inductive hgih resistances of negligible self-capacity and the increase in the effective capacity of the oscillating system to restore resonance was determined for each such shunt resistance for the required range of wavelengths by following the no-beat technique of the double-heterodyne method in the way described before. Different graphs were thus obtained showing the increase of effective capacity against the reciprocal of the actual shunt resistance for different wavelengths. The conductivity corrections $(\Delta C)_\sigma$ corresponding to the various equivalent shunt resistances for respective wavelengths (as known from the previous $1/R=\lambda$ graph) were then determined from these graphs. Each of these corrections was then added to the observed value of ΔC. The dielectric constant of the medium for each different wavelength was thus calculated from the ratio of this total change of capacity to the electron-free inter-electrode capacity

EXPERIMENTAL RESULTS

Variation of the effective dielectric constant of the electronic medium for different thermionic currents for a fixed frequency of the measuring field :

In table I are given the results of a typical set of measurements of the dielectric constant for varying thermionic currents employing a measuring field of 399.9 kc. frequency ($\lambda=750$ m.) These are graphically shown in fig. 3 Two other typical sets of similar measurements for frequencies, 608.5 kc. and

TABLE I

Frequency: 399.9 kc./sec. ($\lambda=750$ m.), Anode = screen-grid capacity = $8\mu\mu f$

Thermionic current	ΔC $\mu\mu f$	Correction $(\Delta C)_\sigma$ $\mu\mu f$	$(\Delta C)_\epsilon$ $\mu\mu f$	ϵ	$\delta=1-\epsilon$	$\frac{\delta}{1-a\delta}$ Lorentz term $a=\frac{1}{3}$
.25 m.a × k	·3	·04	·34	.96	.04	.041
.5 ,, ,,	.63	.10	·73	.92	08	.082
·75 ,, ,,	1.1	.16	1.26	.84	.16	17
1.00 ,, ,,	1.4	.22	1 62	·79	.21	'23
1.25 ,, ,,	2.1	28	2.38	·70	30	33
1.5 ,, ,,	2.6	.36	2.96	.63	·37	·42
1.75 ,, ,,	3.2	.48	3.68	·54	46	·54
2.0 ,, ,,	3 7	.64	4·34	·46	·54	.66
2.25 ,, ,,	4 3	·74	5 04	·37	.63	.80
2 5 ,, ,,	5.6	.81	5.81	.28	·72	·94

811 kc. ($\lambda=493$ m. and $\lambda=370$ m.), are illustrated in fig. 4. In both the figures the values of dielectric constant ϵ of the electronic medium are plotted against

various values of the anode current. In fig. 3 are also shown the values of $\delta\ (=1-\epsilon)$ and of $\frac{\delta}{1-a\delta}$ against the different values of the anode current for

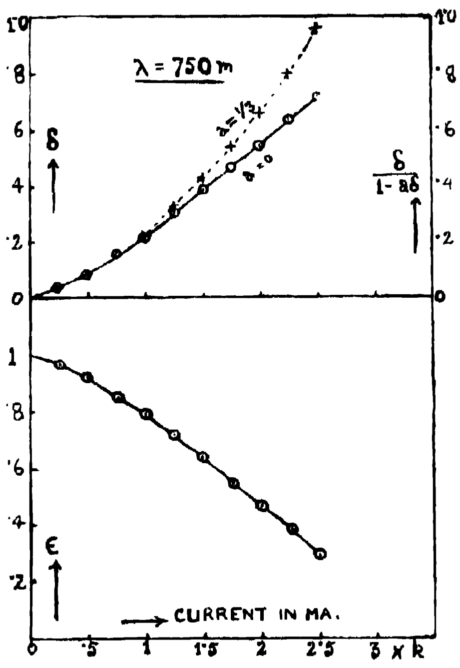

FIGURE 3

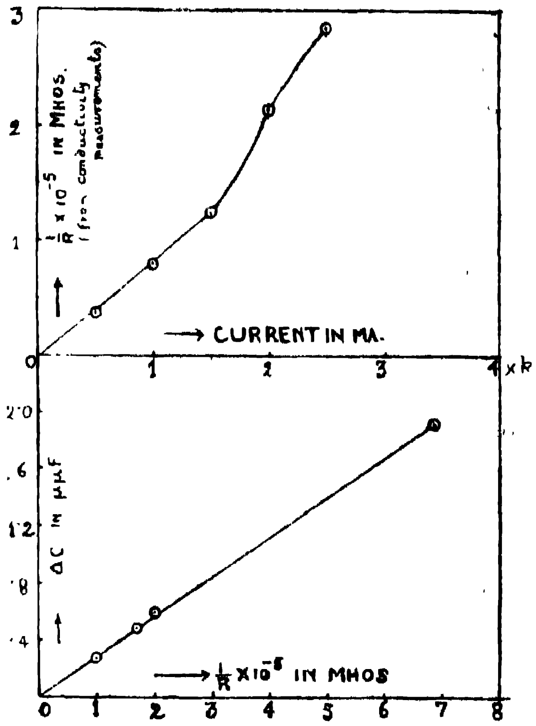

FIGURE 3(a)

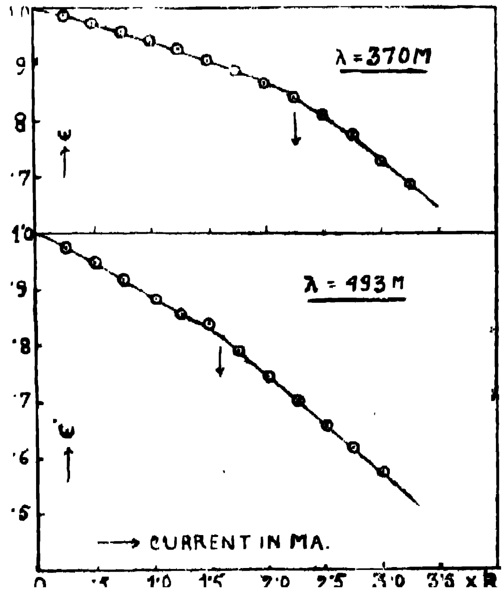

FIGURE 4

$\lambda = 750$ m. (freq : 399.9 kc.) of the measuring field ('a' being the Lorentz term). The calibration graphs from which the conductivity corrections were made for this set are shown in fig. 3(a).

It can be seen from fig. 3 that for $\lambda = 750$ metres, a linear relation holds between the dielectric constant of the electronic medium and the thermionic current, except for very small values of the latter. The linear relation also seems to hold for the other two wavelengths except for a sudden discontinuity in each case at a certain value of the thermionic current. The discontinuity in each diagram of fig. 4 is indicated by an arrow mark.

DEDUCTIONS FROM THE ABOVE EXPERIMENTS

Accepting Lorentz's expression for the dielectric constant of a frictionless electronic medium and introducing a multiplying factor μ to obtain the effect of the finite time of stay of the electrons in the inter-electrode space, we have

$$\epsilon = n^2 - \frac{c^2 k^2}{\omega^2} = 1 - \frac{4\pi N \mu e^2}{m\omega^2 + a(4\pi N \mu e} \qquad (1)$$

where ϵ = dielectric constant, μ = a multiplying factor,
k = absorption index, n = refractive index,
ω = angular frequency of the measuring field, c = velocity of light,
N = elctron concentration, a = Lorentz term,
e = charge on an electron, m = mass of an electron.

Putting $\delta = 1 - \epsilon$ we obtain

$$\frac{\delta}{1 - a\delta} = \frac{4\pi e^2 (N\mu)}{m\omega^2} \qquad \ldots \quad (2)$$

When $a = 0$
$$\delta = \frac{4\pi e^2}{m\omega^2}(N\mu).$$

If the anode and the screen-grid voltages are kept fixed throughout a set of measurements it is evident that the velocity of the electrons would remain constant so that the electron concentration could be normally taken as proportional to the thermionic current* through the anode = screen-grid space. Again, since the time of stay of the electrons in the inter-electrode space and the frequency are usually kept fixed in one set of observations, the multiplying factor could be regarded as constant so that for the Lorentz formula to hold, $\frac{\delta}{1 - a\delta}$ should vary directly as the thermionic current. In fig. 3, both δ and $\frac{\delta}{1 - a\delta}$

are plotted against the thermionic current for one set of observations (freq. 399.9 kc./sec., λ =750 m.). The variation of ϵ is also shown in the same diagram. It will be seen from fig. 3 that δ or ϵ was found to vary proportionately with the thermionic current except when the latter was very small. The law of direct proportionality, however, fails when the values of $\frac{\delta}{1-a\delta}$ are plotted for the different values of the thermionic current. The conclusion that can be drawn under the circumstances is that either the Lorentz term $a=0$ or alternatively for some unknown reason the electron density increased with the increase of the thermionic current at a rate more than the proportionate rate of increase The latter could perhaps be expected if the secondary electrons were emitted at the anode and the screen-grid surfaces.

Variation of the effective dielectric constant of the electronic medium with the wavelength (or frequency) of the measuring field for a definite electron concentration of the medium

The experimental data for the evaluation of the dielectric constant of the electronic medium are collected in table II. The observed shift ΔC, the con ductivity correction $(\Delta C)_\sigma$ and the corrected shift $(\Delta C)_\epsilon$ due to the dielectric constant change alone are all entered in separate columns.

TABLE II

Thermionic current = 1.5 m.a. × k. Inter-electrode capacity = 8$\mu\mu f$.

Wavelength (Metres)	λ^2 Sq.cm.	ΔC $\mu\mu f$	Conductivity Correction $(\Delta C)_\sigma$ $\mu\mu f$	$(\Delta C)_\epsilon$	ϵ	δ	$\frac{\delta}{1-a\delta}$ $a=\frac{1}{3}$
350	1.225 × 10^9	.35	.30	.65	.92	.08	.082
400	1.600 ,,	.40	50	.90	.89	.11	.114
450	2.025 ,,	.55	.65	1.20	.85	.15	.16
500	2.05 ,,	.65	.78	1.43	.82	.18	.19
550	3.025 ,,	.80	.83	1.63	.80	.203	.22
600	3.60 ,,	1.2	.83	2.03	.75	.253	.28
650	4.225 ,,	1.6	.78	2.38	.70	.30	.33
700	4.9 ,,	2.1	.6	2.70	.66	.34	.38
750	5.69 ,,	2.75	.34	3.09	.61	.39	.45

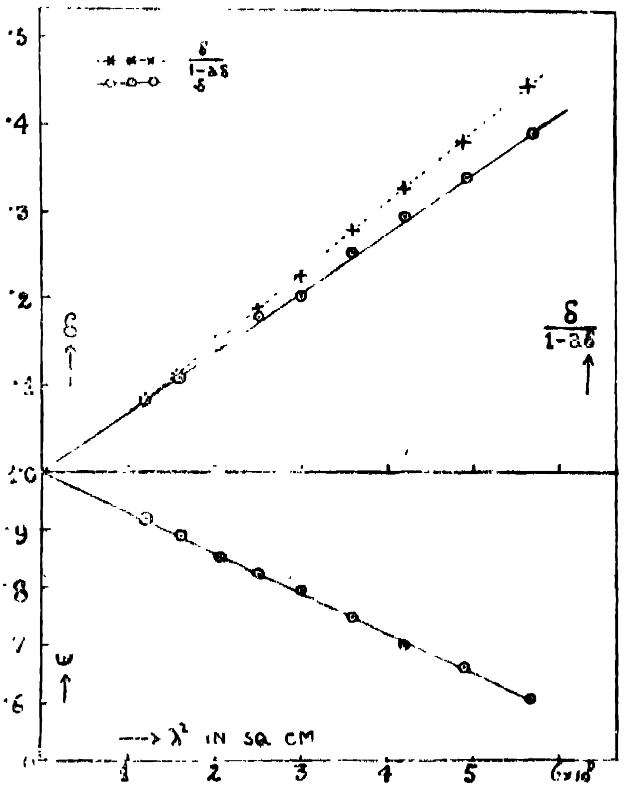

FIGURE 5

The results are graphically shown in fig. 5. In the diagram the values of ϵ, δ and $\frac{\delta}{1-a\delta}$ are plotted against the squares of wavelengths employed. It is interesting to find that all the curves are practically straight lines.

DEDUCTIONS FROM THE ABOVE EXPERIMENTAL RESULTS

The multiplying factor μ introduced in the Lorentz expression for the dielectric constant of a frictionless electronic medium can be expressed in the form

$$\mu = \frac{A}{\lambda} \cdot f(t), \qquad \cdots \quad (3)$$

where t is the transit-time of the electrons, λ the wavelength of the measuring field and A a constant. From the expression given in (2) we therefore get

$$\frac{\delta}{1-a\delta} = \frac{\lambda^2 e^2 N}{\pi m c^2}\left(\frac{A}{\lambda}\right). f(t).$$

On neglecting Lorentz term we have

$$\delta = \frac{\lambda^2 e^2 N}{\pi m c^2}\left(\frac{A}{\lambda}\right). f(t).$$

In the experiments the results of which are recorded in the last section, t = const. and N = const. We have also seen from fig. 5 that both δ or ϵ and $\frac{\delta}{1-a\delta}$ when plotted against λ^2 gave straight lines, so that it can be said that $\frac{A}{\lambda}$ = const. In other words it can be concluded that the constant A in the multiplying factor is proportional to the wavelength λ.

DEPENDENCE OF THE DIELECTRIC CONSTANT OF THE ELECTRONIC MEDIUM ON THE TRANSIT-TIME OF THE ELECTRONS

Keeping the thermionic current through the inter-electrode capacity fixed at a certain value and working with a fixed frequency of the measuring field, the effect of varying the time of stay of the electrons on the dielectric constant of the electronic medium was studied. The time of stay was varied by varying the anode or the screen-grid voltage, but the thermionic current through the anode-screen-grid space was kept constant by adjusting the filament current. The higher the voltage V, the smaller is the transit-time t of the electrons. In fact, we can write $t \propto \frac{1}{\sqrt{V}}$, so that when N = const., ω = const., it can be seen that

$$\frac{\delta}{1-a\delta} \propto f(t) \propto f\left(\frac{1}{\sqrt{V}}\right),$$

since $\qquad \frac{A}{\lambda}$ = const. or approximately $\Delta C \propto f\left(\frac{1}{\sqrt{V}}\right)$,

where ΔC is the observed change of inter-electrode capacity when the inter-electrode space is filled with electrons. In fig. 6 are shown two curves for two different frequencies of the measuring field. The values of ΔC are plotted against $\frac{1}{\sqrt{V}}$ in this figure.

It is evident that ΔC increased steadily with the diminution of the voltage, *i.e.*, with the increase of the transit-time t.

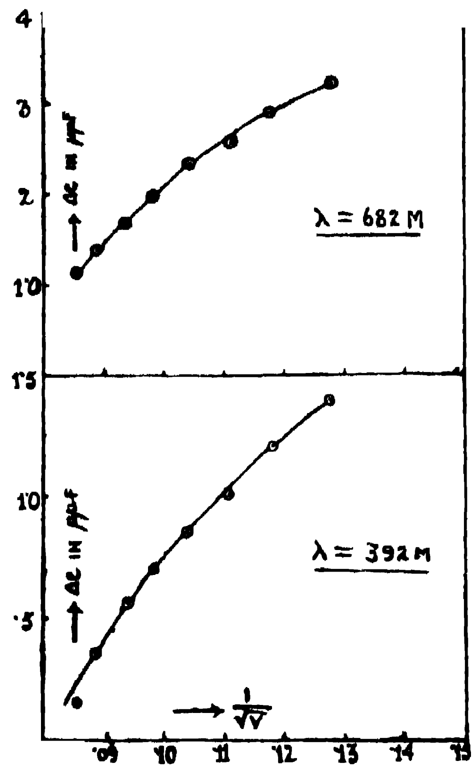

FIGURE 6

DEPENDENCE OF THE DIELECTRIC CONSTANT OF THE ELECTRONIC MEDIUM ON THE MAGNITUDE OF THE MEASURING FIELD

Prasad and Verma[8] reported a parabolic variation in the value of the dielectric constant of the medium with the variation of the magnitude of the measuring field. With ultra-high frequencies the results of some experiments in this laboratory definitely showed that the dielectric constant was independent of the magnitude. It has, however, been recently shown[9] that since in Prasad and Verma's experiments, the adjustment of the balancing condenser (to make up for the change of the inter-electrode capacity) was made till a fixed number of beats were heard per second, the distortion in the receiving set arising out of the non-linear performance of the detector unit was likely to give rise to such an apparent dependence. To test such dependence, if there is really any, the adjustment of the balancing condenser should be made for no-beat. When there is no beat, the complication arising from non-linear distortion is eliminated. Some experiments were therefore performed to examine whether the variation of the magnitude of the measuring field would affect the value of the dielectric constant by following the no-beat technique. The magnitude of the measuring field was varied in these experiments by varying the plate voltage of the valve-oscillator. To obtain an estimate of the voltage of the H. F. field across the inter-electrode capacity, the current in the balancing condenser branch was measured. This current when multiplied by the reactance of this branch would give the desired H. F. voltage. Since the capacity of the balancing condenser was changed only to a small extent, the voltage could be approximately measured in terms of this current. The thermionic current through the anode = screen-grid space was kept fixed during the test.

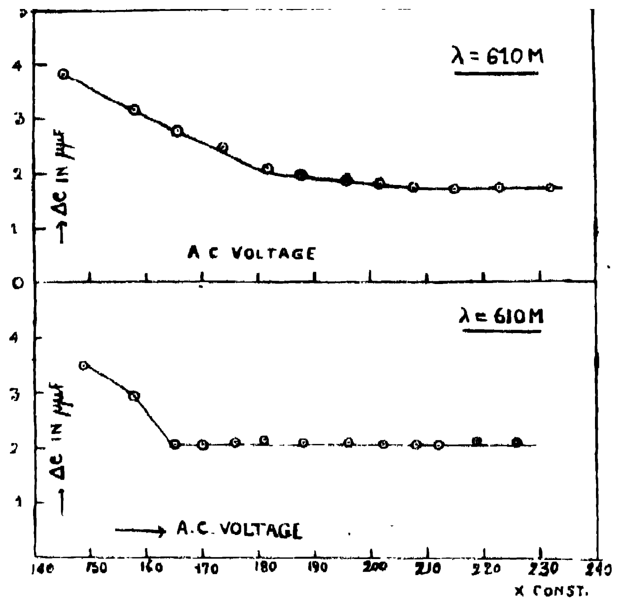

FIGURE 7

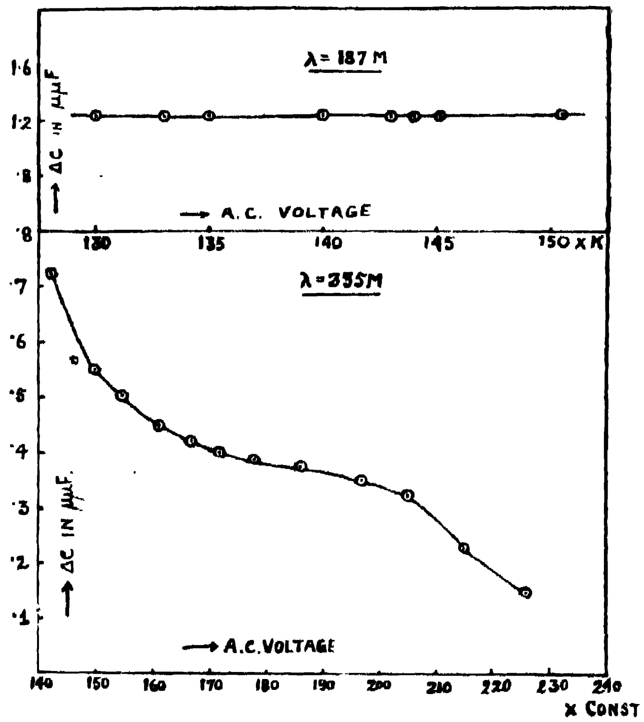

FIGURE 8

In fig. 7 are shown the results of two sets of experiments for $\lambda = 610$ m.

It can be seen that for small H. F. voltages of the measuring field, ΔC diminished with the increase of voltage but ultimately it steadied down to a constant value. Similar experiments were performed with higher frequencies. These results are graphically shown in fig. 8.

It is significant that for $\lambda = 187$ m. ΔC remained constant throughout the range of H. F. voltages of the measuring field. For $\lambda = 335$ m. the diminution persisted even for the higher voltages. The experiments with wavelengths in the neighbourhood of 300 m. were performed many times—but the results were all similar.

The amplitude of the electrons moving under the action of an alternating field is given by $\frac{eF_m}{\omega^2 m}$, where F_m is the peak value of the applied field. As F_m is increased, the amplitude is increased. For the smaller values of F_m the electrons may not be able to reach the anode surface. So long the anode is not reached the conductivity of the space must be small, *i.e.*, the equivalent shunt resistance across it rather higher. This resistance would gradually fall with the increasing value of F_m. Ultimately when the anode is reached by the electrons, this resistance would fall to a constant value. In other words, the conductivity correction $(\Delta C)_\sigma$ for the smaller voltages should be small ; it would gradually increase and attain a constant value for the higher voltages. Since the observed ΔC is equal to $(\Delta C)_\epsilon - (\Delta C)_\sigma$, the observed diminution of ΔC and the ultimate constancy of ΔC with the increasing voltage of the measuring field could be explained. In the case when the diminution of ΔC persisted with the increasing voltage it can perhaps be said that the amplitude of the electrons did not extend sufficiently to reach the anode surface.

SUMMARY AND CONCLUSIONS

In this paper are recorded the results of an investigation on the variation of the effective dielectric constant of an electronic medium in the anode=screen-grid space of a Philips A442 valve under various conditions for medium rodio-frequencies. The measurements of the effective dielectric constant were made, by following the no-beat technique of a double heterodyne method. The corrections for the conductivity of the medium were made in estimating the dielectric constants. The procedure for carrying out these conductivity corrections are fully described.

The experimental results have been analysed following Lorentz's formula for the dielectric constant of a frictionless electronic medium. A multiplying factor μ has been introduced in the expression to obtain the effect of the time of stay of the electrons in the inter-electrode space. The factor has been expressed in the form $\mu = \frac{A}{\lambda} \cdot f(t)$, where A is a const., t the transit-time and λ the wavelength of the measuring field.

Working with a definite frequency and keeping the transit-time of the electrons fixed, the effective dielectric constant of the electronic medium was found on the whole to decrease almost proportionately with the increase of the thermionic current. This is what is expected from Lorentz's formula.

When the frequency was changed, keeping the thermionic current and the transit-time fixed, the effective dielectric constant of the medium was found to decrease strictly proportionately with the square of the wavelength of the measuring field. In order to fit in with the Lorentz's formula (after introducing the factor μ) it was concluded that the transit-time factor μ must be independent of the wavelength. The constant A should therefore vary directly as the wavelength.

Keeping the thermionic current through the anode=sceen-grid space constant and working with a fixed frequency it was found that the observed change of capacity on filling the inter-electrode space with electrons increased steadily with the increase of the transit-time of the electrons. This meant that the effective dielectric constant of the electronic medium in these experiments decreased steadily with the increase of the transit-time. It is therefore concluded that the multiplying factor μ depends only on the transit-time.

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