CHAPTER - III

AZIMUTHAL RADIO FREQUENCY CONDUCTIVITY MEASUREMENT IN AN ARC PLASMA BY STUDYING THE EDDY CURRENT EFFECT.

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INTRODUCTION

Measurement of radio frequency conductivity in a plasma using an inductor having the discharge tube as a core material has been proposed by various authors (Ciampi and Talini, 1967; Heald and Wharton, 1965; Mikoshiba and Smy, 1969; Donskoi et al, 1963; Tanaka and Hagi, 1964; Akimov and Konenko, 1966). The measurement of radio frequency conductivity of a low density plasma such as is produced in a glow discharge has been carried out in this laboratory with the plasma acting as a lossy dielectric within the tuning condenser in the secondary circuit (Sen and Ghosh, 1966; Sen and Gupta, 1969). Donskoi et al (1963), Tanaka and Hagi (1964), Akimov and Konenko (1966) proposed methods for measuring plasma conductivity based on the action of a plasma on a radio frequency oscillator circuit. In some of the above methods the plasma, enclosed in a non-conducting container, was inserted into the inductance coil of the oscillator circuit. This produced either the change in the resonant frequency or the Q-factor. The circuit used by Donskoi et al was calibrated with electrolytes with known conductivities placed in cylindrical vessels with an internal diameter equal to the diameter of the plasma stream, thus making it possible to obtain calibration curves $\Delta Q = \Delta Q(\sigma)$. Akimov and Konenko discussed the validity of the above method and tried to explore various other possibilities. They obtained the conductivity of the plasma from probe measurements (the frequency and the gas pressure of the discharge was so chosen that r.f. and d.c. conductivity could be assumed to be the same) and obtained the frequency shift, and compared the frequency shift for electrolytes with known conductivities. They arrived at an important conclusion that plasma and its simulation electrolytes do not always have the same effect on measurement circuit. The authors attributed the discrepancy between the plasma conductivity averaged over the cross-sections and the calibrating curves to the radial non-uniformity of the plasma. It may, however, be mentioned that the depth of penetration played a very important role in the above experiment for their choice of the frequency range. Experiment of Tanaka and Hagi was intended for a different attitude. They have chosen this type of radio frequency method for conductivity measurement to avoid the inherent capacitance effect of the plasma when applied frequency and collision frequencies are comparable. The negative frequency shift was put as an open question by them since in their measurement the effect of coil plasma capacitance was ignored.

In all the above experiments, the plasma was inserted directly inside the oscillator coil, and which evidently might load the oscillation. Some of them did not however ignore the loading effect and tried to minimise it by choosing the coil diameter very large in comparison to the plasma radius. This, however, reduced the sensitivity of the measurement. Sugawara and Ieiri (1974) have also studied the reduction in the radio frequency Q-factor of a coil due to the presence of a lossy glow discharge plasma within it but the non-linearity and the appearance of maxima in the increase of band-width versus axial conductivity curves as represented in their paper cannot properly be explained in terms of the equivalent circuit proposed therein.

Here all the difficulties of the above methods have been tried to be removed by exciting the working coil which forms a part of a tank circuit, by a r.f. oscillator coil through weak coupling. The theory has been developed in such a way so that no calibration with electrolyte is necessary. When a conductor is placed inside a coil carrying a radio frequency current a portion of the radio frequency power is lost due to (a) the stray capacitative bypass of r.f. current and (b) the eddy current heating of the plasma. The later effect is very small in the radio frequency range in the case of glow discharge plasma. In the case of an arc plasma where the percentage of ionization is very high and conductivity is comparatively much higher, power loss is essentially due to the eddy current heating of the plasma.

Based on these two assumed mechanisms of loss, a generalized theory is presented here showing the quantitative variation of loss factor for a plasma with small conductivity such as glow discharge to a plasma with high conductivity as in the case of arc discharge. The theory developed in conjunction with the experimental observation enables us to obtain the azimuthal radio frequency conductivity of the arc plasma.

THEORETICAL CONSIDERATION

As mentioned earlier, the loss of r.f. power of the resonant circuit due to the presence of a plasma column within a coil is affected by two factors :-

(i) Eddy current loss -

A plasma column can be assumed to be a cylindrical conductor. The alternating magnetic field associated with the r.f. current induces an r.f. electric current within the plasma, the amount of which is proportional to the azimuthal conductivity of the plasma. The plasma column itself can be considered to act like a secondary coil. The reflected resistance can easily be expressed in terms of the eddy loss and hence in terms of the azimuthal conductivity, if it is assumed that the plasma forms almost a short circuited secondary of turn number unity.

(ii) Capacitative by-pass -

The plasma column forms a capacitance with the coil wound around the discharge tube. A portion of the r.f. current by-passes this capacitor to ground through a resistance which is proportional to the axial value of the resistance of the plasma column.

The composite equivalent circuit adopted, considering the above two factors, is depicted in Fig.(3.1). The effective resistive impedance of the coil can be written as

$$R' = R_0 + \frac{R_2 C^2}{(C_0 + C)^2 + \omega^2 R_2^2 C^2 C_0^2} + \frac{\omega^2 M^2}{R_1^2 + \omega^2 L_1^2} R_1 \qquad .. \quad (3.1)$$

where R_0 = coil resistance (ohm); C_0 = value of the tuning capacitor (farad); C = stray capacitance (farad) formed between the coil and the plasma column; R_2 = axial plasma resistance (ohm); R_1 = azimuthal plasma resistance (ohm); ω = angular frequency (radian); L_1 = eddy secondary inductance (Henry); L = coil inductance (Henry); M = mutual inductance (Henry) of L and L_1; The last term of the expression (3.1) is the reflected resistance in the primary due to the eddy current flowing through the plasma.

The value of C can be estimated by observing the amount of change of capacitance of the tuning capacitor required to restore the tuning when the plasma is on. For a quantitative analysis, if it is assumed that $R_1 \simeq R_2$, then $(R^1 - R_o)$ can be plotted in terms of the plasma conductance $(^1/_{R_1})$ knowing the actual values of all other terms of equation (3.1). M and L can be estimated by assuming the plasma inductance to be a secondary with turn unity and having an average cross-section equal to half the inner cross-section of the tube (Simpsom, 1960). The nature of the variation of $(R^1 - R_o)$ with $(\log {}^1/_{R_1})$ is shown in Fig. (3.2). For the lower values of conductivity, as in the case of ordinary glow discharge, the third term is very small in comparison to the second term and $(R^1 - R_o)$ i.e., the change in band-width increases with the increase in conductivity, attaining a maximum when $R_2 \simeq (C_o + C)/\omega CC_o$; with further increase in the conductivity when $(C_o + C)^2 > \omega^2 R_2{}^2 C^2 C_o{}^2$, $(R^1 - R_o)$ decreases. For some higher values of conductivity (designated by the glow-arc transition region in Fig. (3.2) both the second and third terms of equation (3.1) are significant and $(R^1 - R_o)$ reaches a minimum. Finally in the arc region the reflected resistance term only becomes predominant and the band-width rises linearly until $R_1{}^2$ and $\omega^2 L_1{}^2$ are comparable. When $R_1{}^2 = \omega^2 L_1{}^2$ the curve shows another maximum. In the present experiment

$\omega^2 L_1^2 \ll R_1^2$ and equation (3.1) can be written for the arc region as

$$R^1 = R_o + \frac{\omega^2 M^2}{R_1} \quad .. \quad (3.2)$$

If i_o and i be the tuned radio frequency currents through the coil before and during the discharge respectively the azimuthal conductance is given by

$$\sigma = \frac{R_o (\alpha - 1)}{\omega^2 M^2} \quad \text{where } \alpha = i_o / i$$

To determine the azimuthal conductivity σ_s from the measurement of azimuthal conductance, it is necessary to understand the current path. Neglecting the effect of skin depth (between 2 cm. and 8 cm.), the total conductance is approximately the conductance of the current path of cross section $r \times \ell$ and average length πr, where r and ℓ are the radius of the discharge column and length of the coil respectively. Thus σ_s is given by

$$\sigma_s = \frac{\pi}{\ell} \cdot \frac{\alpha - 1}{\omega^2 M^2} \cdot R_o \quad .. \quad (3.3)$$

Thus knowing $(\alpha - 1)$, σ_s can be calculated for different discharge currents.

EXPERIMENTAL PROCEDURE AND RESULTS

The schematic diagram of the experimental arrangement is shown in Fig. (3.3). Measurements were made for a mercury arc plasma formed within the arc tube of length 30 cm. and diameter 1.9 cm. (anode-cathode spacing 20 cm.). The oscillator coil was placed near the work coil (A) (dimensions: diameter 1.9 cm., length 6 cm., wire diameter 2 mm., turns 50) and the induced r.f. voltage was tuned with a variable condenser B. The tuned currents were measured with a radio frequency milliammeter. The discharge current could be varied with the help of rheostats connected in series with the d.c. supply. Any change in the tuned r.f. current should be an indication of the change of resistive impedance of the resonant circuit.

Several measurements of the tuned radio frequency current, both in the presence and in the absence of plasma, were taken for different discharge currents and exciting frequencies. The dependence of $(\alpha - 1)$ on discharge currents at three different frequencies, namely 2.56 MHz., 4.1 MHz., and 5.1 MHz. is depicted in Fig. (3.4). The dependence of azimuthal conductivity (mhos/cm) on the discharge current can be found by multiplying the ordinate values of Fig. (3.4) by the factor $\pi R_0 / (\ell \omega^2 M^2)$ which was close to 15.51 f^{-2}, if f is the frequency (MHz). The resistance R_0 of the circuit was determined by measuring the Q-factors at different frequencies.

Table 3.1

Probe fre- quency f in MHz.	Arc cur- rent in amp.	r.f. current i in mA (discharge on)	r.f. current i in mA (dis- charge off)	$\alpha = i_0/i$	$\alpha - 1$	σ_s mhos/cm
	2	66	118	1.7879	.7879	.4701
	3	53	118	2.2264	1.2264	.7318
5.1	4	46.5	118	2.5934	1.5834	.9508
	5	39.5	118	2.9873	1.9873	1.1858
	2	78.5	116	1.4777	.4777	.4410
	3	67.0	116	1.7313	.~~0~~7313	.6751
4.1	4.	57.5	116	2.0174	1.0174	.9393
	5	52.0	116	2.2308	1.2308	1.1363
	2	98	118	1.2041	0.2041	.4872
	3	91	118	1.2967	0.2967	.7082
2.55	4	84.5	118	1.3964	0.3964	.9962
	5	78.5	118	1.5032	0.5032	1.2011

DISCUSSION

The first portion of the graph depicted in Fig.(3.2), where capacitative by-pass loss is predominant, closely resembles the curve obtained by Sugawara and Ieiri (1974). It is possible to obtain the value of the stray capacitance (C) from the position of the maxima depicted therein. Taking the following values as given by Sugawara and Ieiri,

$$\omega = 2\pi \times 10^6 \ Hz \ ; \quad l = 66 \ cm \ ; \quad d = 3.1 \ cm \ ;$$
$$C << C_0 \ ; \quad \sigma = 2 \times 10^{-1} \ mhos/m$$

the value of C, the stray capacity, is found to be 30 pF in agreement with values found in the present experiment. This is expected since the geometry of the coil and the plasma column in the experiment of Sugawara and Ieiri do not differ much from that in the present experiment. Thus azimuthal conductivity in this method is difficult to obtain in the case of glow discharge plasma because of the unavoidable stray capacitance effect discussed earlier, but in the case of arc plasma where the effect of eddy current loss becomes dominant it is possible to obtain the value of azimuthal conductivity, and the values obtained here by this method [see Fig.(3.3) and Fig.(3.4) and Table (3.1)] are found to be quite in agreement with the axial conductivity values measured using the relation

$$\sigma_z = I_z / \pi r^2 E_z$$

where E_z is the field in the positive column, which has been measured with a double probe; the typical value of E_z is found to be 1.14 volts/cm. The dependence of azimuthal conductivity on the axial conductivity σ_z (mho/cm.) can be found from Fig. (3.4) by multiplying the abscissa value by the factor 0.435.

From equation (3.3) it is noted that $\sigma_s = K(\alpha-1)/\omega^2$ if it is assumed that the change of radio frequency resistance R_θ is small within the range of frequencies investigated here. This is found to be nearly true from Fig.(3.4) with $(\alpha-1)$ proportional to $\omega^{1.9}$.

SUMMARY

It is thus seen that the azimuthal conductivity in an arc plasma can be measured by a method which was suggested earlier but not used in the case of an arc plasma. Early measurements on glow discharge are subject to error, due to the stray capacitance effect which is important in the case of glow discharge. It has, however, been shown in the present theory that the capacitative loss is not at all important in the case of arc plasma and the present method is suitable for azimuthal conductivity measurement in an arc plasma. Further, it is observed that the generalized theory presented here can explain not only our experimental results but also the results reported earlier in the case of glow discharge by Sugawara and Ieiri. The method could be advantageously used for some anisotropic plasmas as well.

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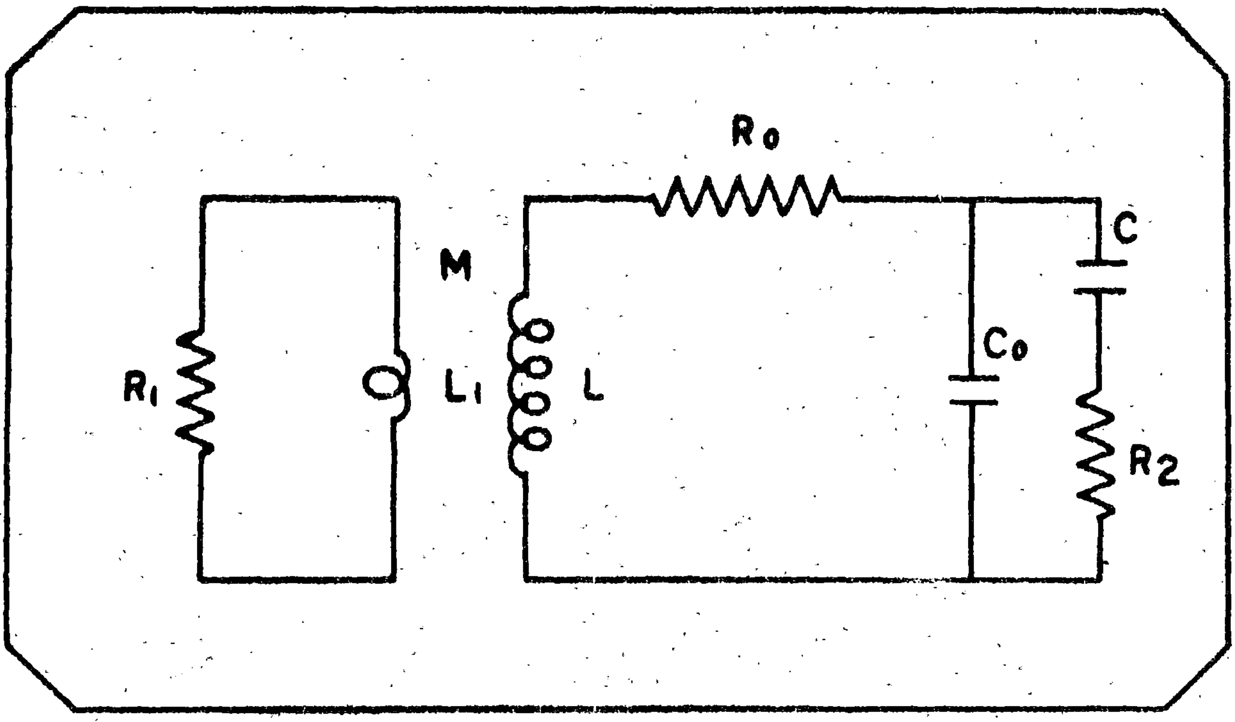

FIG. 3'1. THE EQUIVALENT CIRCUIT

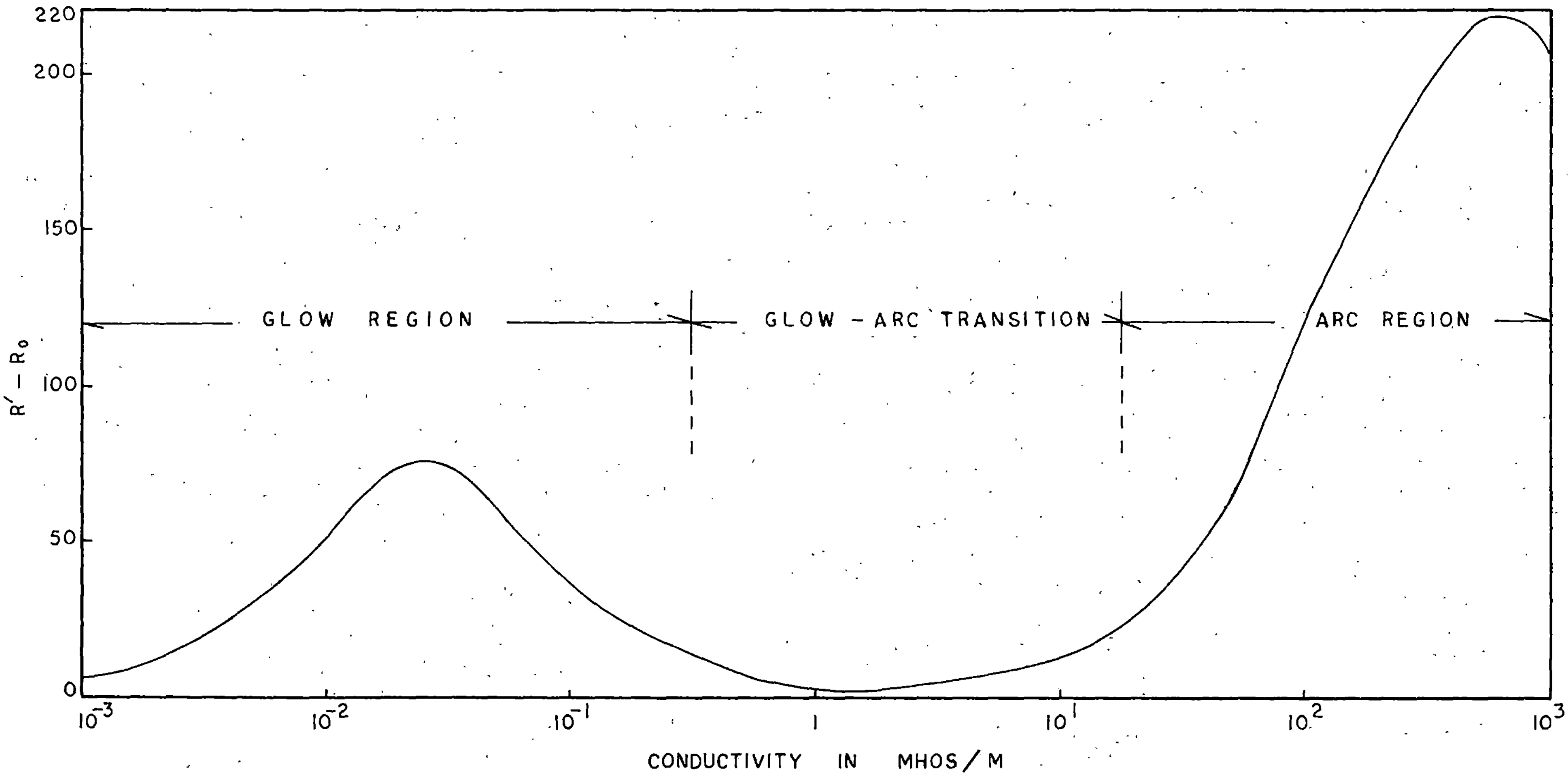

FIG. 3·2 . THEORETICAL NATURE OF VARIATION OF $(R' - R_0)$ WITH $(\text{Log } 1/R_1)$. [THEORETICAL CALCULATIONS EQN. (3·1)]. $C = 10$ PF, $C_0 = 45$ PF, $M = 0{\cdot}359\ \mu H$, $L = 18\ \mu H$, $\omega = 2\pi \times 5{\cdot}1$ MH$_3$, $R_0 = 10\ \Omega$, $L_1 = 7{\cdot}2 \times 10^{-3}\ \mu H$.

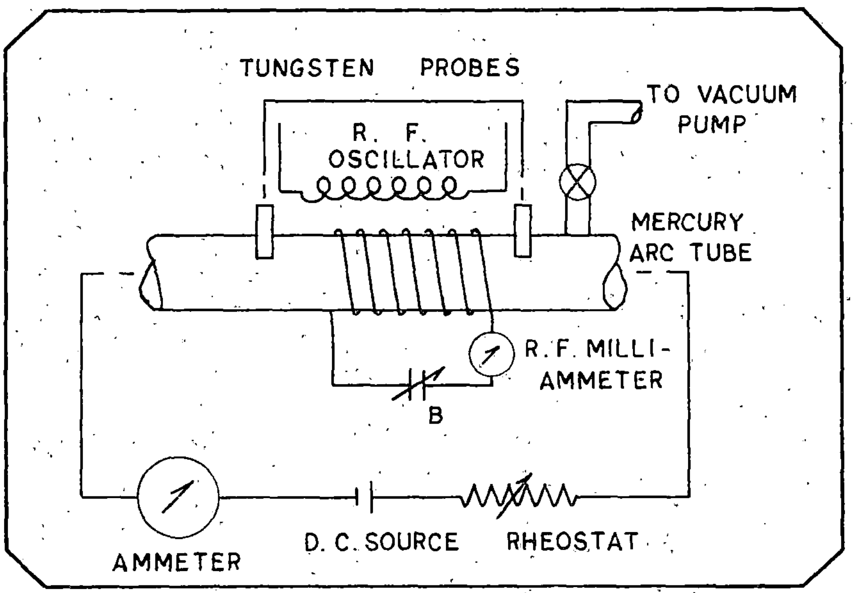

FIG. 3·3. SCHEMATIC EXPERIMENTAL ARRANGEMENT FOR THE DETERMINATION OF AZIMUTHAL RADIO – FREQUENCY CONDUCTIVITY & RADIAL DISTRIBUTION FUNCTION.

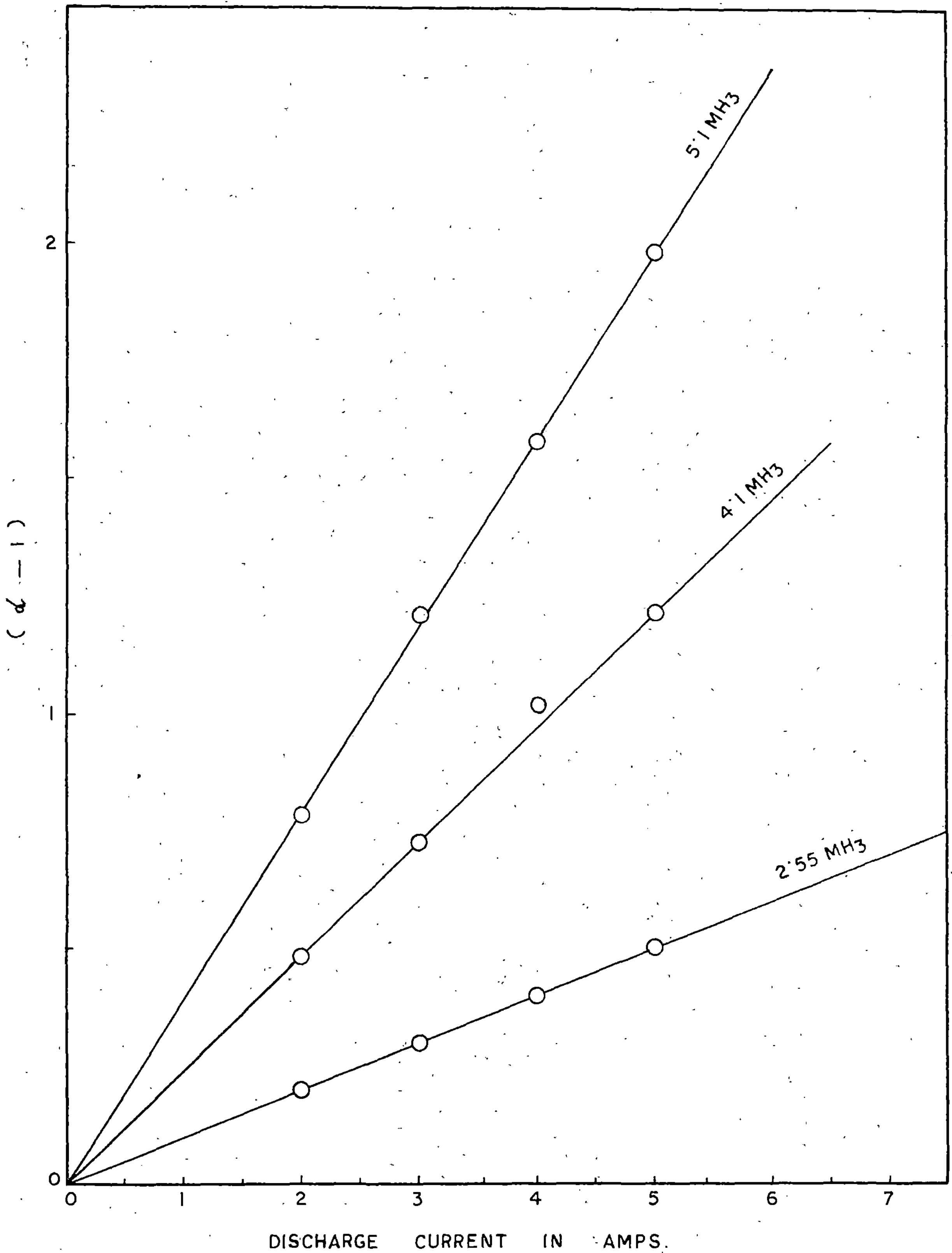

FIG. 3·4. VARIATION OF $(\alpha - 1)$ WITH ARC CURRENT FOR DIFFERENT FREQUENCIES. σ_s (MHOS/CM) = $K(\alpha - 1)$, WHERE K = 0·5967, 0·9232 AND 2·387 FOR FREQUENCIES f (MH3) = 5·1, 4·1 AND 2·55 RESPECTIVELY FROM ABOVE DOWNWARDS.

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Azimuthal radiofrequency conductivity measurement in an arc plasma by studying the eddy current effect

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Azimuthal radiofrequency conductivity of an arc plasma has been estimated by measuring the reflected resistance of a primary coil wound around a mercury arc tube. A linear relationship between the azimuthal conductivity and the discharge current has been obtained. The non-linearity and the existence of maxima observed by previous authors in the change in band-width versus axial conductivity curve have been explained theoretically by considering a generalized equivalent circuit. It has also been pointed out that the azimuthal conductivity measurement by this method is possible only when the conductivity of the plasma is fairly high.

1. Introduction

Measurement of radiofrequency conductivity in a plasma using an inductor having the discharge tube as a core material has been proposed by various authors (Ciampi and Talini 1967, Heald and Wharton 1965, Mikoshiba and Smy 1969). The measurement of the azimuthal radiofrequency conductivity of a low density plasma such as produced in a glow discharge has been carried out in this laboratory with the plasma acting as a lossy dielectric within the tuning condenser in the secondary circuit (Sen and Ghosh 1966, Sen and Gupta 1969). Sugawara and Ieiri (1974) have studied the reduction in the radiofrequency Q-factor of a coil due to the presence of a lossy glow discharge plasma within it. The non-linearity and the appearance of maxima in the increase of band-width versus axial conductivity curves as represented in their paper cannot properly be explained in terms of the equivalent circuit proposed therein.

When a conductor is placed inside a coil carrying a radiofrequency current a portion of the radiofrequency power is lost, due to (*a*) the stray capacitance by-pass of r.f. current and (*b*) the eddy current heating of the plasma. The latter effect is very small in the radiofrequency range in the case of a glow discharge plasma. In the case of an arc plasma where the percentage of ionization, and hence the conductivity, is much higher, power loss is essentially due to the eddy current heating of the plasma.

Based on these two assumed mechanisms of loss, a generalized theory is presented here showing the quantitative variation of loss factor from a plasma with small conductivity such as a glow discharge to a plasma with high conductivity as in an arc discharge. The theory developed in conjunction with the experimental observations enables us to obtain the azimuthal radiofrequency conductivity of the arc plasma.

2. Theoretical consideration

As mentioned earlier, the loss of r.f. power of the resonant circuit due to the presence of a plasma column within a coil is affected by two factors :

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(i) *Eddy current loss*

A plasma column can be assumed to be a cylindrical conductor. The alternating magnetic field associated with the r.f. current induces an r.f. electric current within the plasma, the amount of which is proportional to the azimuthal conductivity of the plasma. The plasma column itself can be considered to act like a secondary coil. The reflected resistance can easily be expressed in terms of the eddy loss and hence in terms of the azimuthal conductivity if it is assumed that the plasma forms almost a short circuited secondary of turn number unity.

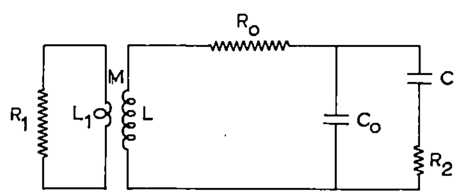

Figure 1. The equivalent circuit.

(ii) *Capacitative by-pass*

The plasma column forms a capacitance with the coil wound around the discharge tube. A portion of the r.f. current by-passes this capacitor to ground through a resistance which is proportional to the axial value of the resistance of the plasma column.

The composite equivalent circuit adopted, considering the above two factors, is depicted in Fig. 1. The effective resistive impedance of the coil can be written as

$$R' = R_0 + \frac{R_2 C^2}{(C_0 + C)^2 + \omega^2 R_2{}^2 C^2 C_0{}^2} + \frac{\omega^2 M^2}{R_1{}^2 + \omega^2 L_1{}^2} R_1 \tag{1}$$

where R_0 = coil resistance (ohm) ; C_0 = value of the tuning capacitor (farad) ; C = stray capacitance (farad) formed between the coil and the plasma column ; R_2 = axial plasma resistance (ohm) ; R_1 = aximuthal plasma resistance (ohm) ; ω = angular frequency (radian) ; L_1 = eddy secondary inductance (Henry) ; L = coil inductance (Henry) ; M = mutual inductance (Henry) of L and L_1. The last term of the expression (1) is the reflected resistance in the primary due to the eddy current flowing through the plasma.

The value of C can be estimated by observing the amount of change of capacitance of the tuning capacitor required to restore the tuning when the plasma is on. For a quantitative analysis, if it is assumed that $R_1 \approx R_2$, then $(R'-R_0)$ can be plotted in terms of the plasma conductance $(1/R_1)$ knowing the actual values of all other terms of eqn. (1). M and L can be estimated by assuming the plasma inductance to be a secondary with turn unity and having an average cross section equal to half the inner cross section of the tube (Simpson 1960). The nature of the variation of $(R'-R_0)$ with $(\log 1/R_1)$ is shown in Fig. 2. For the lower values of conductivity, as in the case of ordinary glow discharge, the third term is very small in comparison to the second term and $(R'-R_0)$, i.e. the change in band-width increases with the increase in conductivity, attaining a maximum when $R_2 \simeq C_0 + C/\omega CC_0$; with further increase in the conductivity when $(C_0+C)^2 > \omega^2 R_2{}^2 C^2 C_0{}^2$, $(R'-R_0)$ decreases.

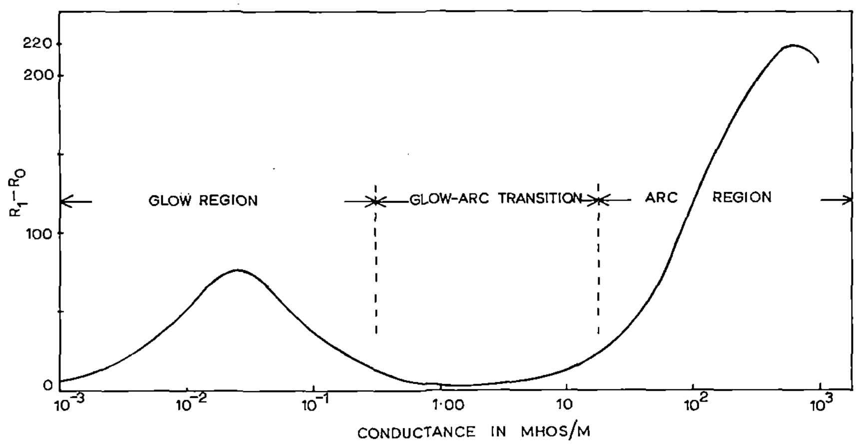

Figure 2. Variation of (R_1-R_0) with conductance. (Theoretical calculations eqn. (1).) $C=10$ pF ; $C_0=45$ pF ; $M=0{\cdot}359$ μH ; $L=18$ μH ; $\omega=2\pi\times5{\cdot}1$ MHz ; $R_0=10$ Ω.

For some higher values of conductivity (designated by the glow-arc transition region in Fig. 2) both the second and third terms of eqn. (1) are significant and $(R'-R_0)$ reaches a minimum. Finally in the arc region the reflected resistance term only becomes predominant and the band-width rises linearly until $R_1{}^2$ and $\omega^2 L_1{}^2$ are comparable. When $R_1{}^2 = \omega^2 L_1{}^2$ the curve shows another maximum. In the present experiment $\omega^2 L_1{}^2 \ll R_1{}^2$ and eqn. (1) can be written for the arc region as

$$R' = R_0 + \frac{\omega^2 M^2}{R_1} \tag{2}$$

If i_0 and i_1 be the tuned radiofrequency currents through the coil before and during the discharge respectively the azimuthal conductance is given by

$$\sigma_1 = \frac{R_0[\alpha-1]}{\omega^2 M^2} \quad \text{where} \quad \alpha = \frac{i_0}{i_1}$$

To determine the azimuthal conductivity σ_s from the measurement of azimuthal conductance, it is necessary to understand the current path. Neglecting the effect of skin depth (between 2 cm and 8 cm), the total conductance is approximately the conductance of the current path of cross section $r \times l$ and average length πr, where r and l are the radius of the discharge column and length of the coil respectively. Thus σ_s is given by

$$\sigma_s = \frac{\pi}{l} \frac{(\alpha - 1)}{\omega^2 M^2} R_0 \tag{3}$$

Thus, knowing $(\alpha - 1)$, σ_s can be calculated for different discharge currents.

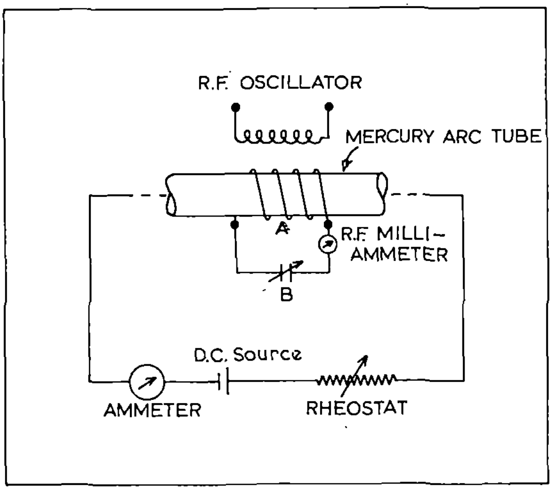

Figure 3. The experimental arrangement.

3. Experimental procedure and results

The schematic diagram of the experimental arrangement is shown in Fig. 3. Measurements were made for a mercury arc plasma formed within the arc tube of length 30 cm and diameter 1·9 cm (anode–cathode spacing 20 cm). The oscillator coil was placed near the work coil (A) (dimensions : diameter 1·9 cm, length 6 cm, wire diameter 2 mm, turns 50) and the induced r.f. voltage was tuned with a variable condenser B. The tuned currents were measured with a radiofrequency milliammeter. The discharge current could be varied with the help of rheostats connected in series with the d.c. supply. Any change in the tuned r.f. current should be an indication of the change of resistive impedance of the resonant circuit.

Several measurements of the tuned radiofrequency current, both in the presence and in the absence of plasma, were taken for different discharge currents and exciting frequencies. The dependence of $(\alpha - 1)$ on discharge current at three different frequencies, namely 2·55 MHz, 4·1 MHz and 5·1 MHz is depicted in Fig. 4. The dependence of azimuthal conductivity σ_s (mhos/cm) on the discharge current can be found by multiplying the ordinate value of Fig. 4 by the factor $\pi R_0/(l\omega^2 M^2)$, which was close to 15·51 f^{-2}, if f is the frequency (MHz). The resistance R_0 of the circuit was determined by measuring the Q-factors at different frequencies.

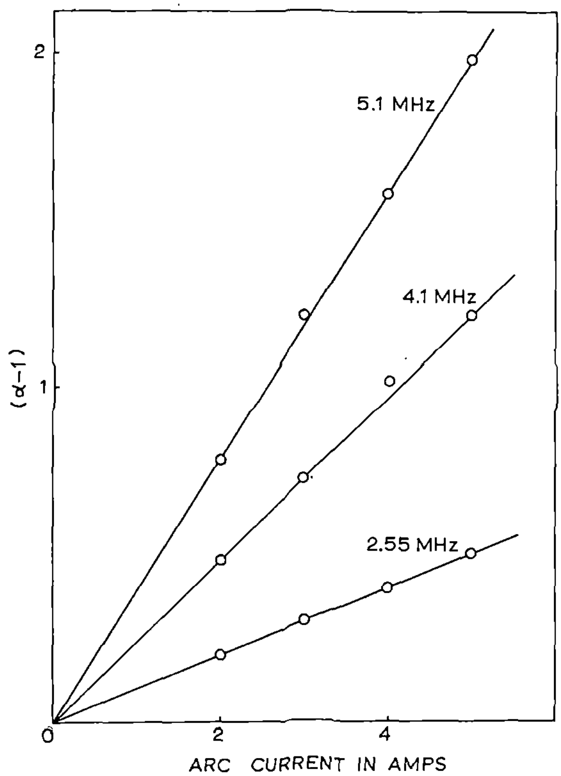

Figure 4. Dependence of $(\alpha-1)$ on I_z. σ_s (Mhos/cm) $= K(\alpha-1)$, where $K = 0{\cdot}5967$, $0{\cdot}9232$ *and* $2{\cdot}387$ *for frequencies* f (MHz) $= 5{\cdot}1$, $4{\cdot}1$ *and* $2{\cdot}55$ *respectively, from* above downwards.

4. Discussion

The first portion of the graph depicted in Fig. 2, where capacitative by-pass loss is predominant, closely resembles the curve obtained by Sugawara and Ieiri (1974). It is possible to obtain the value of the stray capacitance (C) from the position of the maxima depicted therein. Taking the following values as given by Sugawara and Ieiri,

$$\omega = 2\pi \times 10^6 \text{ Hz} \; ; \quad l = 66 \text{ cm} \; ; \quad d = 3{\cdot}1 \text{ cm} \; ;$$

$$C \ll C_0 \; ; \quad \sigma = 2 \times 10^{-1} \text{ mhos/m}$$

the value of C, the stray capacity, is found to be 30 pF in agreement with values found in the present experiment. This is expected since the geometry of the coil and the plasma column in the experiment of Sugawara and Ieiri do not differ much from that in the present experiment. Thus azimuthal conductivity in this method is difficult to obtain in the case of glow discharge plasma because of the unavoidable stray capacitance effect discussed earlier, but in the case of arc plasma where the effect of eddy current loss becomes dominant it is possible to obtain the value of azimuthal conductivity, and the values obtained here by this method (see § 3 and Fig. 4) are found to be quite in agreement with the axial conductivity values measured using the relation

$$\sigma_z = \frac{I_z}{\pi r^2 E_z}$$

where E_z is the field in the positive column, which has been measured with a double probe; the typical value of E_z is found to be 1·14 volts/cm. The dependence of azimuthal conductivity on the axial conductivity σ_z (mhos/cm) can be found from Fig. 4 by multiplying the abscissa value by the factor 0·435.

From eqn. (3) it is noted that $\sigma_s = K(\alpha - 1)/\omega^2$ if it is assumed that the change of radiofrequency resistance R_0 is small within the range of frequencies investigated here. This is found to be nearly true from Fig. 4 with $(\alpha - 1)$ proportional to $\omega^{1 \cdot 9}$.

5. Summary

It is thus seen that the azimuthal conductivity in an arc plasma can be measured by a method which was suggested earlier but not used in the case of an arc plasma. Early measurements on glow discharge are subject to error, due to the stray capacitance effect which is important in the case of glow discharge. It has however been shown in the present theory that the capacitative loss is not at all important in the case of arc plasma and the present method is suitable for azimuthal conductivity measurement in an arc plasma. Further, it is observed that the generalized theory presented here can explain not only our experimental results but also the results reported earlier in the case of glow discharge by Sugawara and Ieiri. The method could be advantageously used for some anisotropic plasmas.

Acknowledgments

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