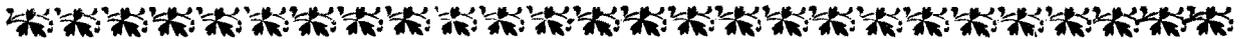




CHAPTER IV

ELECTROLUMINESCENCE



**Paper based on the text of this Chapter is :
ELECTROLUMINESCENCE OF S_r SO_4 : Dy PHOSPHORS.
Indian Journal of pure and Applied Physics (In Press)**

4.1 Introduction :

Electroluminescence (EL) is a process in which the electrical energy is directly transformed into the optical energy through luminescent material. The light emission resulting from the direct action of an electric field on semiconductors was observed as early as 1920 by Gudden and Pohl¹, during the study on photoconductivity of ZnS. However, the phenomenon of electroluminescence was first reported by Lossev in 1923², and further it was extensively studied after the pioneering work of Destriau³ in 1936. Since then, studies on EL behaviour of various phosphors have been a subject of interest in many fields of light engineering^{4.5}. The electroluminescence has opened the new areas of research not only in solid state physics but also in electronics⁶. One of the aims of EL studies is to prepare an efficient electroluminophor, by controlling its preparative parameters; so that it can be successfully employed as one of the means for the direct conversion of electrical energy into light without any intermediate steps. Moreover, innumerable modern applications of electroluminescence demand the improvisation of efficiency of electroluminophores.

The survey of literature shows that EL studies of oxygen dominated lattices have received less attention although they exhibit other luminescence properties such

as photo and thermoluminescence. The lack of literature on EL studies of strontium Sulphate Phosphor might be probably its large band gap. Most of the studies on electroluminescence in oxygen dominated lattices have been made with dry powder, pressed between the conducting plates^{7,8}. The powder phosphor system after the application of high A.C. field emits light which can be seen through one of the transparent conducting plates.

Recently, Pawar et al.⁹ have studied the phenomenon of electroluminescence in high Tc Ceramic superconductors (Y-Ba-Cu-Zr-O) of different compositions, for the first time. Very interestingly they have noted that the samples which showed superconductivity exhibit electroluminescence, suggesting the possible importance of copper and oxygen stoichiometry in both the phenomena. Pawar et al.¹⁰ have also reported the electroluminescence in bismuth based high Tc superconductors and found that the brightness of EL is higher for higher Tc samples. They have pointed that there exists some relation between the mechanism of EL and superconductivity of these materials. The EL of sulphate phosphors activated with rare-earth impurity has been reported in the literature^{11,12}. However, there is no data on EL studies of strontium sulphate phosphors activated with Dy and Tb in powder form.

In the present investigation an attempt has been made to study the effect of voltage, frequency and activator concentration on EL brightness with the view to understand the mechanism of electroluminescence in $\text{SrSO}_4:\text{Dy}$, Tb phosphors. Further, an attempt has been made to explain the role of Na_2SO_4 in EL behaviour of these phosphors. Owing to the complexity of the microscopic properties that can affect EL, the assessment of the results made in this chapter, is purely qualitative in nature.

4.2 Theoretical Background :

The processes involved in the phenomenon of EL have been discussed in detail by Piper and Williams¹³, Gurie^{14,15} and Henisch¹⁶. It involves mainly five stages which are described below.

The first and the most essential important stage involved in the EL process is the EXCITATION OF CHARGE CARRIERS. It may occur by -

- 1) field ionisation of valance electrons
- 2) field ionisation of impurity ion electrons and
- 3) injection of minority carriers.

In the first two processes mentioned above excitation by electric field rises electrons from valance band or from luminescence centre into the conduction band of the crystal. Franz¹⁷ calculated for large-band-gap material,

the probability per unit time, P_i , for ionisation from the valance band in the field V ,

$$P_i = \left(\frac{ea}{h}\right) V \exp \left\{ \frac{-(2m^*)^{\frac{1}{2}} E_g}{4 \hbar e V} \right\} \dots 4.1$$

Where, E_g is the band gap, 'a' is the lattice parameter and e , h , \hbar and m^* have their usual meaning. This process requires field in excess of those for dielectric breakdown.

The probability, P_i , for the field ionisation of an impurity ion electron is given by⁸.

$$P_i = 17 \times 10^{12} (m^*/m) (V/\epsilon')^{\frac{5}{4}} \exp \left\{ \frac{-7 \times 10^7 (m^*/m)}{V} E_n^{3/2} \right\} \dots 4.2$$

Where, E_n is the depth of the impurity level from the bottom of the conduction band, E is the dielectric constant. The injection of minority charge carriers is observed in p-n junction, and in schottky barriers. A schottky barrier usually occurs at the surface of a semiconductor in contact with a metal. Such a barrier can act as p-n junction.

The second stage involved in the EL process is the ACCELERATION OF CHARGE CARRIERS. In this stage excited charge carriers (electrons or holes) are accelerated by the action of electric field localised in

a narrow region. The charge carriers created in the crystal bands by any of the above processes are accelerated to high kinetic energies by the applied field. To achieve this, electron or hole must receive energy in the applied field than it losses by the interactions with phonons. According to Piper and Williams¹⁸, the necessary field strength to accelerate the charge carriers to optical energies is of the order of 10^6 volts/cm which is too high when compaired with the applied voltage. This has made it necessary to assume that the potential applied across the phosphor does not exist throughout the interior of the crystal but is localised in a small region. Such a configuration exists in the Mott-Schottky type barrier¹⁹. Even with the moderate electric field, the field strength produced in such a barrier is sufficient to accelerate the charge carriers to optical energies.

The third stage involved in the EL. process is to TRANSFER OF ENERGY TO RADIATING SITES. The charge carriers accelerated to optical energies in the second stage have to transport the energy to the radiating sites which would eventually lead to radiative transition. This may be achieved either by an excited electron-hole pair called excitation or by the moment of accelerated charge carriers.

The fourth stage involved in the EL process is TRANSFER OF ENERGY TO RADIATING CENTRES. This is achieved by three different processes namely -

- a. Collision process.
- b. Capture of charge carriers and
- c. Exciton excitation.

The most important stage involved in the EL process is the EMISSION OF LIGHT. In this final stage (5th Stage), the emitting system which is raised from ground state to excited state, by the absorption of electrical energy, returns to the ground state with the emission of light. In this process there is transition of electron from an upper to a lower energy level. These levels can be either intrinsic band stages or impurity levels. The transitions may be from 1) band to band transition (interband); 2) from one state to another in the same band (interband); 3) band to impurity level; 4) impurity state to band and; 5) impurity state to impurity state. The above successive five stages involved in the phenomenon of electroluminescence process give the broad idea regarding act of emission of light from EL Phosphors.

4.3 Experimental set-up for Electroluminescence :

In the present study EL measurements of polycrystalline SrSO_4 phosphors were made under the action of sinusoidal voltage. The photograph of the experimental set-up designed and fabricated in our laboratory is shown in fig. 4.2. The EL set-up consists mainly of electroluminescent cell, electronic excitation source and the brightness measuring system. This is shown schematically in fig. 4.3

The experimental set-up consists of three parts as detailed below :-

I. Electronic Excitation Source

The electronic excitation source consists of mainly audio frequency generator and wide band amplifier. An audio frequency generator (Systronics - 1052) with a frequency range 0.1 C/S to 100 KC/S and having maximum output voltage 20 volts was used as an excitation source. As this voltage is not sufficient to excite the phosphor, its output is coupled to a wide-band amplifier which is capable to deliver 2.5 K.V. at various frequencies. The circuit diagram of the wide-band amplifier is shown in fig. 4.4. It is designed to give 2.5 KV r.m.s in the frequency range 50 C/S to 5 KC/S.

In order to achieve the higher voltages, generally a transformer is used at the output stage of the electronic circuit. The usefulness of the transformer lies in the fact that electrical energy can be transferred from one circuit to another circuit without direct connection and at any desired voltage level. Many transformers are available in market which works on 50 C/S (either step-up or step-down) and output transformers for amplifiers, radios and different electronic circuits²⁰. However, the output transformer which can deliver the voltage upto 2.5 KV r.m.s. in the

frequency range 50 C/S to 5 KC/S when coupled to electronic circuit, is not readily available in the market. In the present investigation the transformer used in the output stage of the wide band amplifier is wound in the laboratory and discussed below in detail.

A former, on which the wire is wound, is made up of insulating material. The details of the former designed from the insulating paper having thickness 0.25 mm is shown in fig. 4.4.(b). In the present investigation secondary coil is wound into two parts as shown in fig. 4.4.(b) with the help of winding machine. The splitting of secondary into two parts is necessary to avoid the possibility of sparking and to increase the life of the transformer. The turns of the primary are wound at the central portion of the former. The total number of turns of secondary are 12000 and primary are 300. The insulated copper wire of 48 S.W.G. and 40 S.W.G. are used for secondary and primary windings respectively. A thin sheet of treated paper acting as the insulation was interposed between two layers.

EI laminated cores of the grain oriented steel are used (specifications are shown in fig. 4.4(a)). Before using the laminations the coating of the shellac was applied in order to insulate laminations from each other. This insulation helps to reduce the eddy - current losses. The vacuum impregnation by varnish was carried

out to this wound transformer. In the vacuum impregnation all air inside the winding is replaced by varnish, which automatically increases the strength of the insulation of coil and protects the damage of the transformer during working with high voltages because of air moisture.

The vacuum impregnated transformer is embedded into wax, inside a bakelite box. The primary of the transformer is connected in the circuit as shown in Fig. 4.5 .

II. Electroluminescent cell

The efficiency of EL cell depends upon its geometry and hence its design aspect is equally important factor in EL studies. The literature^{21,23}, describing the design aspects of EL cell gives variety of modifications in its construction. It is usually made in the form of a parallel plate capacitor, of which at least one of the conducting plate is transparent. The EL cell suitable in the present studies was fabricated in the laboratory and its main features are described below.

The sectional side view of EL-cell and its top view are shown in fig. 4.6. The aluminium plate (D) was fixed in a bakelite frame (C) and was used as one electrode. A thin phosphor layer (E) was mounted on the aluminium plate. The phosphor was then covered with a

uniform transparent mica sheet (F) of thickness 0.01 cm. having high dielectric constant and sufficient breakdown strength. A conducting glass plate (G) having Resistance 100 ohm/cm^2 was used as a second electrode. It was fixed in a cavity grooved on lower surface of bakelite frame (H) which has a small window (I) of size 1.7 cm x 1.2 cm in the middle of the top surface. The inter electrode distance and pressure can be adjusted with the help of screw (A) with spring (B).

Different dielectric media such as castor oil, polystyrene, chlorinated rubber etc. proposed in the literature have been tried. But with these media, in the present study, EL intensity was found to be less. As a result, phosphor layer without any binder was found to be suitable. Although, it was found difficult to obtain phosphor layer of uniform thickness, the reproducibility of EL-cell was found satisfactory. The intensity of EL emission could be reproduced within 10% by constructing the cell with the same phosphor at different times.

III. Brightness measuring system

It includes IP-21 photomultiplier tube, power supply and nano-ammeter (Aplab FET, model - 5006).

The alternating voltage applied to the phosphor was varied upto 1000 volts r.m.s. keeping frequency constant. The electroluminescent emission was measured in

terms PM tube current in arbitrary units. The observations were taken at room temperature (300 K).

4.4 Results and Discussion :

In the present investigation, EL study has been carried out on series of $\text{SrSO}_4:\text{Dy}$ and $\text{SrSO}_4:\text{Tb}$ phosphors prepared, both with and without charge compensator. All the phosphors listed in table 2.1 were visually tested for EL brightness and it was observed that all of them give EL response. However, there is no noticeable colour change observed in the voltage and frequency range studied. Some brighter phosphors were selected from each series for further and detailed investigation of EL parameters like voltage and frequency. The results of EL measurements obtained in the present study are reported and are discussed at length in this section.

4.4.1 Voltage Dependence of Brightness

The valuable information regarding the mode of excitation of charge carriers, in the phenomenon of EL, can be obtained from the study of voltage dependence of brightness. When the sinusoidal voltage is applied across the phosphor in the EL-cell, it is observed to emit light, the intensity of which is a function of amplitude 'V' of applied voltage and frequency 'f'. The EL-output of SrSO_4 phosphors have been measured in the voltage range of 0 to 1000 Volts (r.m.s.) at different

frequencies. The graph of brightness (in arb. units) were plotted against the applied voltage. The nature of B - V curve is similar for almost all the phosphors studied and hence to avoid the repetition, the curves for typical phosphors $\text{SrSO}_4:\text{Tb}$ (SC_{17}) and $\text{SrSO}_4:\text{Dy}$ (SC_{06}) at different frequencies are shown in figures 4.7 and 4.8 respectively. It can be noted from the figures that, EL-brightness is increasing as a function of applied voltage and this increase is more rapid at higher frequencies. Further, the B-V curves show that, there exists a minimum voltage called threshold voltage V_{Th} , above which EL starts. The existence of threshold voltage for EL phosphor can be understood as follows. The voltage applied across the phosphor system excites the impurity ion electron, which in consequence, leads to the emission of light from EL phosphor. When the applied voltage is increased then more and more active regions are exposed to voltage gradient above the threshold level, giving increase in brightness.

Attempt has been made to understand the possible relationship existing between brightness (B) and applied voltage (V). There are several equations in the literature ^{27,31-35}, which explain the possible relationship between brightness and voltage at fixed frequency. In order to reveal the nature of B-V curves following graphs have been tried in the light of equations proposed.

1. The logarithm of (B/V) as a inverse function of V.
2. The logarithm of (B/V) as a inverse function of \sqrt{V} .
3. The logarithm of (B) as a inverse function of V.
4. The logarithm of (B) as a function of V and
5. The logarithm of (B) as a inverse function of \sqrt{V} .

These curves, however, show non linearity suggesting there by that the respective equations reported in the literature^{27,31-35} are not in a position to give the behaviour of brightness (B) with applied voltage (V).

The equation 4.1 (Section 4.2) gives the probability 'Pi' of transfer of electron from valance band to conduction band with the consequent emission of light via luminescence center. Since 'pi' is propartional to brightness (B) of EL, the euqation 4.1 can be written as

$$B = AV \exp. (-X/V) \quad \dots 4.3$$

Where

$$X = \frac{\pi (2m^*)^{\frac{1}{2}} E_g}{4 \hbar e}$$

and A is constant involving ea/\hbar . In the present investigation an attempt has been made to test the validity of the equation 4.3 for the phosphor system under consideration. The euqation 4.3 suggests that the graph of $\log B/V$ Versus $1/V$ is expected to be linear, if there exists the possibility of excitation of charge carriers by the field ionisation of valance electrons.

However, the non linearities were observed in the graph which rules out the possibility of excitation of charge carriers by the field ionisation of the valence electrons. Further, the other possibility of excitation of charge carriers is the transfer of electron from impurity ion to the conduction band. The equation 4.2 gives this probability. In the experimental arrangement the field strength applied across EL-cell is of the order of 10^4 volts/cm. Hence, the exponential term in equation 4.2. can be ignored. Therefore, equation 4.2 can be written as :

$$P_i = AV^n \quad \dots\dots 4.4$$

Where, $A = 17 \times 10^{12} (m^*/m)^{\frac{1}{2}}$ and 'n' is constant. Putting 'B' as proportional to 'P_i' equation 4.4 can be written as,

$$B = AV^n \quad \dots\dots 4.5$$

The equation 4.5 suggests that the graph of log B versus log V is linear, if the excitation of charge carriers by field ionisation of impurity ion electron is taking place in the present phosphor system. To see the validity of equation 4.5 the graph of logarithm of brightness was plotted against logarithm of voltage, From fig. 4.9 it can be seen that the graph is linear. The linearity of this plot was confirmed by calculating there correlation coefficient 'r' by using the equation³⁶.

$$r = \frac{n \sum XY - \sum X \sum Y}{\left[n \sum X^2 - (\sum X)^2 \right]^{1/2} \left[n \sum Y^2 - (\sum Y)^2 \right]^{1/2}}$$

Where, $X = \log V$, $Y = \log B$ and n is the number of observations. The values of 'r' calculated from the graph 4.9 are nearly equal to one, confirming the linearity of the graph of $\log B$ - $\log V$ plot. Similar results were obtained for all $\text{SrSO}_4:\text{Tb}$ and $\text{SrSO}_4:\text{Dy}$ phosphors suggesting the power law relation (eq.ⁿ 4.5) to be hold good for the phosphor system under investigation. This finding clearly indicates that the charge carriers are excited by the field ionisation of the impurity ion electron.

The $\log B$ - $\log V$ plots were obtained for all $\text{SrSO}_4:\text{Tb}$ and $\text{SrSO}_4:\text{Dy}$ Phosphors to find the values of the power 'n' by taking the slopes of respective plots. The values of 'n' so calculated are presented in Table 4.1. It can be noted that 'n' varies with the frequency of applied field and also with the activator concentration. However the variation is not systematic, and hence conclusion can not be drawn from it.

4.4.2 Frequency Dependence of Brightness

The EL brightness was measured as a function of frequency keeping voltage constant. The brightness was found to increase with frequency in a manner shown in figures 4.10 and 4.11 for typical $\text{SrSO}_4:\text{Tb}$ (SC_{17}) and $\text{SrSO}_4:\text{Dy}$ (SC_{06}) phosphors. An increase in EL brightness with the frequency has been reported by earlier

workers^{13,37,38,39,40} for microcrystalline, powder phosphors as well as for single crystal and for thin films. The increase in EL brightness with the frequency may be understood as follows :

In A.C. electroluminescence, in one cycle the maximum peak value of the voltage is applied twice to the phosphor system. At this maximum peak value electron is excited from its ionised impurity state and combines with the luminescence center giving out the flash of light. Naturally, in every cycle of excitation two quanta of light are emitted. When the frequency of excitation increases, the number of quanta and hence there is increase in EL brightness with the frequency.

Various relations^{41,44} reported in the literature, have been tried to reveal the nature of B-F curves obtained in the present study. As reported earlier^{11,12}. $\log B$ versus $\log F$ plots were found to be linear for almost all the phosphors studied. This indicates that the brightness versus frequency curves have essentially exponential form. The plot obtained for a typical phosphor of $\text{SrSO}_4:\text{Tb}$ (SC_{17}) is presented in fig. 4.12. The linear nature of the plot can be fitted in mathematical relation of the form,

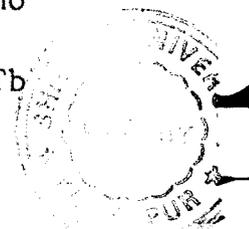
$$B = AF^b$$

Where A & b are constants depending on the phosphor system. The values of threshold voltage, V_{Th} , for

different frequencies and for various phosphors system are presented in table 4.2. It can be noted from table that ' V_{th} ' decreases with the increase of frequency of applied voltage for almost all the phosphors studied. This may be explained with the fact that, in A.C. electroluminescence in one cycle the maximum peak value of the voltage is applied twice to the phosphor system. When the frequency of applied sinusoidal voltage is increased the impurity ion might receive energy at rapid rate, as a result it gets excited at comparatively smaller field. This explains the decrease of V_{Th} with the increase in frequency of the applied field for all the phosphors studied.

4.4.3 Role of Activators & Concentration Quenching in Electroluminescence :

The close observation of the figures 4.7, 4.8, 4.10 and 4.11 show that the nature of voltage and frequency dependence of EL brightness is almost the same for all $SrSO_4:Tb$ and $SrSO_4:Dy$ phosphors, studied in the present investigation. This appears to indicate that the nature of B-V and B-F curves is not significantly influenced by the activators Dy or Tb. It is interesting to note from table 4.2 that, for same concentration of activator, ' V_{Th} ' for Dy activated phosphor is slightly greater than for Tb activated phosphor and there is no appreciable change in, V_{Th} , for same concentration of Tb



or Dy in SrSO_4 phosphor. This observation is as per expectation, because the first ionisation potential⁴⁵ for Dy atom is 6.82 eV and for Tb it is 6.74 eV, which are nearly equal.

Fig. 4.13 gives the variation of EL brightness as a function of activator concentration both for with and without Na_2SO_4 added phosphors. From the figure it can be noted that there is falling off in the EL output after optimum concentration which is about 0.01 gm wt% Tb for SrSO_4 phosphor. Similar curves are obtained for SrSO_4 :Dy phosphors but they are not presented here to avoid the repetition. The falling off in EL output after optimum concentration is considered in terms of well known concentration quenching effect. The mechanism of concentration quenching in the TL - output of RE doped CaSO_4 phosphor were reported in the literature^{46,47}. In the present investigation the concentration quenching observed, is due to energy transfer from one ion to a lower lying level of another ion by transitions that are matched in energy at optimum concentration level.

4.4.4 Role of Na_2SO_4 in Electroluminescence

As observed in structural, electric and magnetic characterisation described in chapter-III, Na^+ ion from Na_2SO_4 has played predominant role in EL process of SrSO_4 phosphors. In fig. 4.14, the brightness - voltage

curve are presented for the typical $\text{SrSO}_4:\text{Tb}$ phosphor (SC_{44}^* and SC_{17}) prepared both with and without addition of Na_2SO_4 . It can be noted from figure that the nature of B-V curves has remained nearly the same and they are not significantly influenced by Na^+ ion. However, it is interesting to note from fig. 4.14 that the curves for phosphors prepared with and without addition of Na_2SO_4 cross each other at a particular voltage, say V_c . Below V_c the brightness of Na_2SO_4 added phosphor is smaller than that for without Na_2SO_4 added phosphor. This can be explained as follows : The Na^+ ion in $\text{SrSO}_4:\text{Tb}$ phosphor (SC_{44}^*) may give rise to acceptor levels which are deeper when the voltage is less than V_c . The acceptor levels are believed to be inactive and hence do not contribute to the process of emission of light. But when the voltage exceeds V_c , these acceptor levels become active and show affinity for the charge carriers, which play a vital role in the process of emission of light. This explains why the brightness, for Na_2SO_4 added phosphors, decreases when the applied voltage is below V_c .

The situation, however, reverses when applied voltage is greater than V_c i.e. brightness of Na_2SO_4 added phosphor is greater than that for without Na_2SO_4 added phosphors. Fig. 4.13, which shows the variation of brightness as a function of activator concentration, also speaks of the similar result. The increase of EL brightness for Na_2SO_4 added phosphors can be explained on

the basis of charge compensation theory. The entry of activator ion (Dy or Tb), along with Na^+ ion, from Na_2SO_4 , makes it possible to incorporate a large no. of luminescence centres in the host lattice of SrSO_4 giving more emission of light for Na_2SO_4 added phosphor. Similar results have been obtained by Sabnis and Pawar⁴⁶ and by Mulla and Pawar⁴⁷ for RE activated CaSO_4 phosphors, in the TL, EL and fluorescence phenomena.

4.4.5 Possible Mechanism of Electroluminescence in SrSO_4 phosphors activated with Dy or Tb

In this section an attempt has been made to reveal the possible mechanism of electroluminescence by taking into account results reported in the present investigation. There are different steps involved in the phenomenon of electroluminescence and they are portrayed in fig. 4.1. It is well known that the act of emission of light takes place by transition from one state to another state. This transition may be within the same band (Intraband), band to band (Interband), from one band to an impurity state and vice versa, or from impurity state to impurity state.

It is well known that the SrSO_4 is a high band gap material. Naturally interband transitions would fall in the UV-region. However in the present study the EL emission lies in the visible region (Greenish red) which rules out the possibility of interband transitions. In

case of intraband transition, and band to impurity state transition (or vice versa), one expects a band spectrum and not the line spectrum. It has been reported that EL spectrum is a characteristic of activator i.e. Tb^{3+} or Dy^{3+} . The characteristic emission due to Tb^{3+} or Dy^{3+} rules out the possibility of intraband or from one band to impurity state and vice versa transitions. This appears to suggest that, in the present phosphor system, the radiative transition of excited impurity from higher level to lower level leads to the EL emission from $SrSO_4$ phosphors.

It has been reported (in section 3.3.3), that the phosphor material is of P-type, hence carrier injection mechanism will not correspond to the actual act of emission of light. It is worth noting from table 4.2 that the V_{Th} , depends upon the type of activator used in $SrSO_4$ phosphor. In case of field ionisation of valance electrons, V_{Th} is expected to be independent of activator used. However, in the present study, V_{Th} depends upon the type of activator used which rules out the possibility of field ionisation of valance electrons. The data, obtained from Voltage dependence study (section 4.4.1) indicates that radiative system is likely to be excited by the field ionisation of impurity ion electron.

The excited impurity ion electron is then further accelerated by the action of field localised in a

narrow region⁴⁸. and transports the energy to the radiating sites. This transfer of energy to radiating sites may take place either by (1) exciton excitation, (2) collision process or (3) capture of charge carriers. The study of I - V characteristics in section 3.3.1 for these phosphors indicates that the possibility of exciton excitation formation is improvable. Further EL study of these phosphors shows that these phosphors exhibits EL decay, therefore the possibility of transfer of energy to radiating sites by collision process is also unlikely. This takes one to conclude that radiating centres receive energy by the capture of charge carriers, and get excited, which on returning back to the ground state there is emission of light.

Frequency (c/s) →	200	500	1000	2000	5000
Phosphors ↓					
SC ₀₅	6.2	6.51	6.3	-	-
SC ₀₃	2.18	3.0	2.22	-	-
SC ₀₆	1.8	2.3	2.5	2.0	2.2
SC ₀₉	3.4	3.2	2.8	3.7	1.5
SC ₁₀	2.0	2.3	2.8	2.3	-
SC ₀₁	-	-	2.5	3.0	3.1
SC ₃₂ *	7.3	7.2	7.1	-	-
SC ₃₀ *	3.0	2.5	3.3	2.7	-
SC ₃₃ *	4.29	4.3	4.2	4.5	4.1
SC ₃₆ *	4.71	4.29	4.3	4.52	4.7
SC ₃₇ *	3.2	2.5	4.0	3.5	-
SC ₀₂ *	-	-	3.1	3.4	3.2
SC ₁₁	4.12	4.25	4.3	4.1	-
SC ₁₅	3.1	3.2	2.5	2.7	-
SC ₁₄	3.0	2.84	2.89	2.90	-
SC ₁₇	4.5	4.0	4.75	5.25	5.0
SC ₁₆	3.8	3.3	3.9	3.7	-
SC ₃₈ *	3.37	3.9	3.4	3.57	-
SC ₄₂ *	2.46	2.5	2.9	2.7	-
SC ₄₁ *	3.2	3.1	3.5	3.4	-
SC ₄₄ *	5.3	5.9	5.47	6.88	-
SC ₄₃ *	3.9	3.4	3.42	3.4	-

TABLE NO 4.1

The Variation of n (Slope of $\log B - \log V$ plot) with frequency of a.c. field for SrSO_4 phosphors of various activator concentration.

Phosphors ↓	Frequency (c/s) → 200	500	1000	2000	5000
SC ₀₅	570	550	500	-	-
SC ₀₃	650	560	525	-	-
SC ₀₆	540	505	475	455	430
SC ₀₉	570	550	530	510	475
SC ₁₀	580	550	500	490	-
SC ₀₁	-	-	610	575	490
* SC _{*32}	585	560	515	-	-
SC _{*30}	690	575	530	475	-
SC _{*33}	545	515	500	475	445
SC _{*36}	590	555	540	515	485
SC _{*37}	585	575	515	500	-
SC ₀₂	-	-	615	580	495
SC ₁₁	490	480	560	450	-
SC ₁₅	650	535	500	475	-
SC ₁₄	575	525	500	450	-
SC ₁₇	565	535	525	475	435
SC ₁₅	640	575	525	450	-
* SC _{*38}	505	490	575	465	-
SC _{*42}	670	540	505	455	-
SC _{*41}	580	530	510	465	-
SC _{*44}	575	560	550	510	-
SC ₄₃	655	580	535	465	-

TABLE NO. 4.2

Threshold voltage V_{Th} in volts as a function of activator concentration for different frequencies.

FIGURE CAPTIONS

Figure	Title
4.1	Chart showing the processes involved in the mechanism of electroluminescence.
4.2	Photograph of experimental set-up used for studying variation of brightness with frequency and voltage.
4.3	Schematic block diagram of experimental arrangement used for studying variation of brightness with frequency and voltage.
4.4	a) Details of EI laminations. b) Details of designing of former A & C space for secondary winding. B - space for Primary winding.
4.5	Circuit diagram of the wide band amplifier.
4.6	Sectional side view and top view of EL. cell.
4.7	Plot of B against V for phosphor SC ₁₇ .
4.8	Plot of B against V for phosphor SC ₀₆ .
4.9	Plot of logB against logV for phosphor SC ₁₇ .
4.10	Plot of Brightness versus frequency at different voltages for SC ₁₇ phosphor.
4.11	Plot of Brightness versus frequency at different voltages for SC ₀₆ Phosphor.
4.12	Plot of logB against logF for phosphor SC ₁₇ .

4.13 Plot of EL brightness versus log of Tb concentration.

(Constant $V = 800$ volts and $F = 500$ c/s) for $\text{SrSO}_4:\text{Tb}$ phosphors.

4.14 Plot 'B' against V for with & without charge compensator SrSO_4 phosphors.

PROCESSES INVOLVED IN THE MECHANISM OF EL

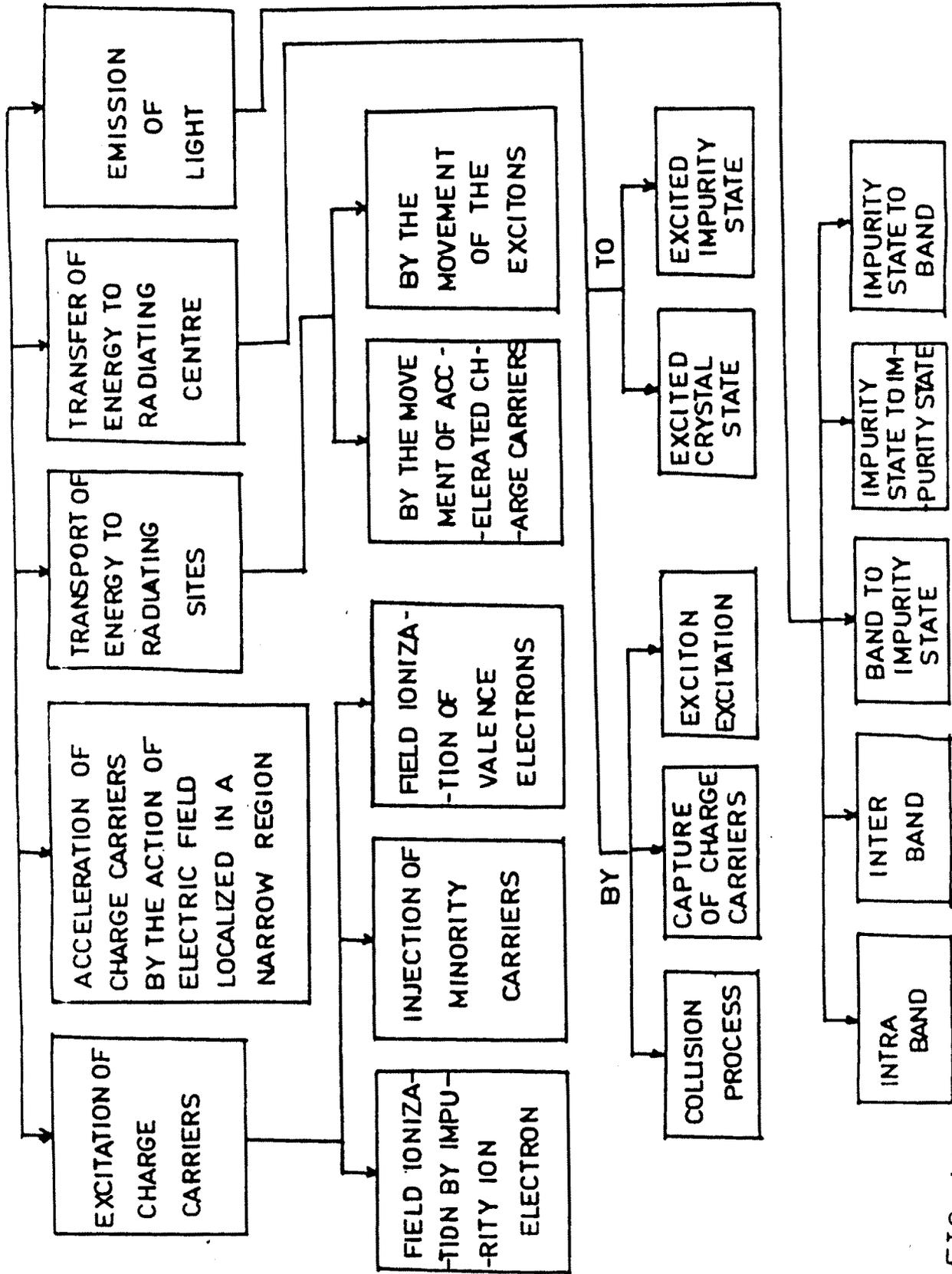


FIG : 4.1



FIG NO. 4.2

- 1 - Stabilizer
- 2 - Audio frequency generator.
- 3 - Wide band amplifier.
- 4 - V.T.V.M.
- 5 - P.M. tube housing.
- 6 - Dark current minimisation Circuit
- 7 - Nano-ammeter.
- 8 - Dimmerstat
- 9 - Power supply for P.M. tube.
- 10 - Voltmeter to measure the voltage applied to P.M. tube.
- 11 - Switch board.
- 12 - EL cell.

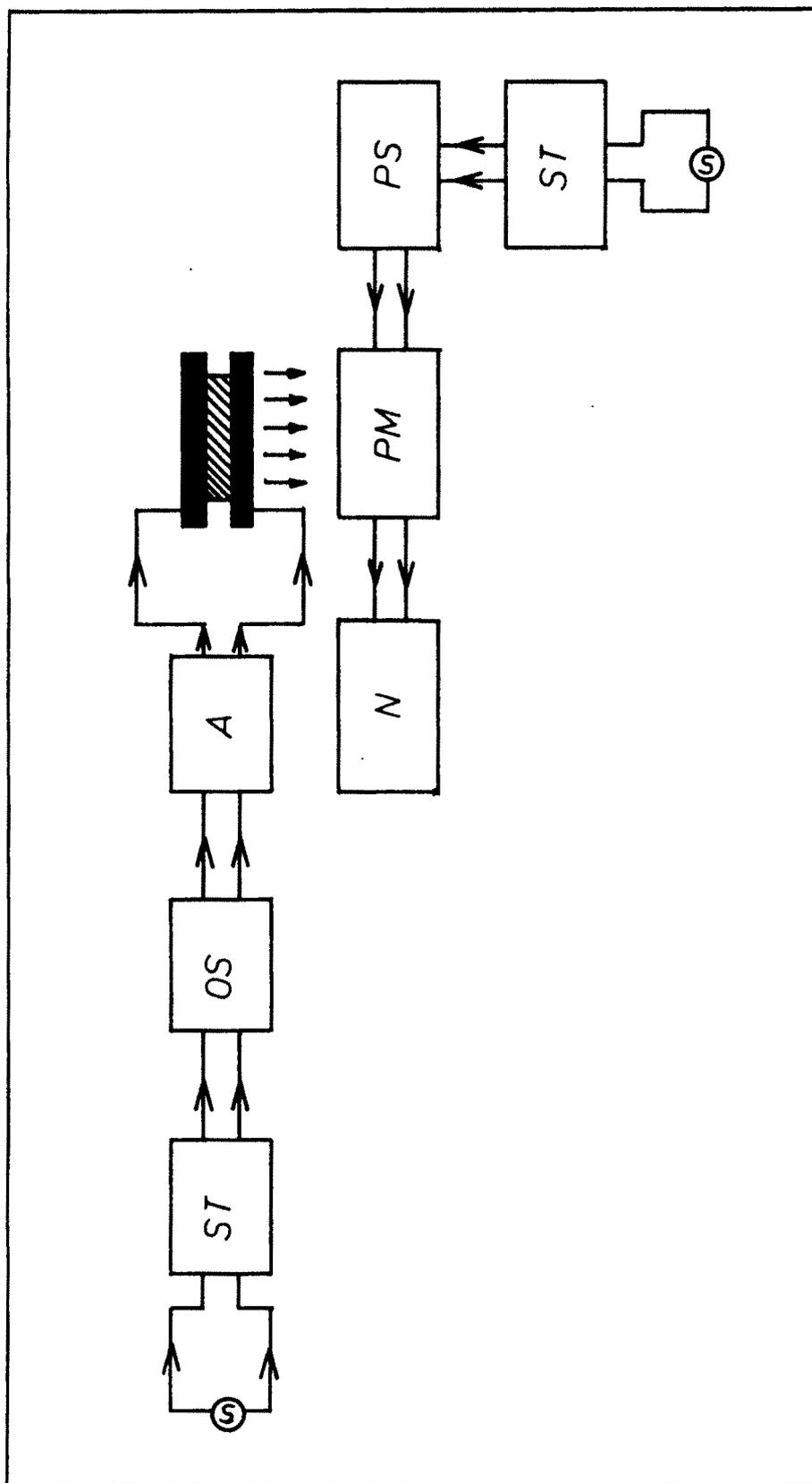


Fig. 4.3

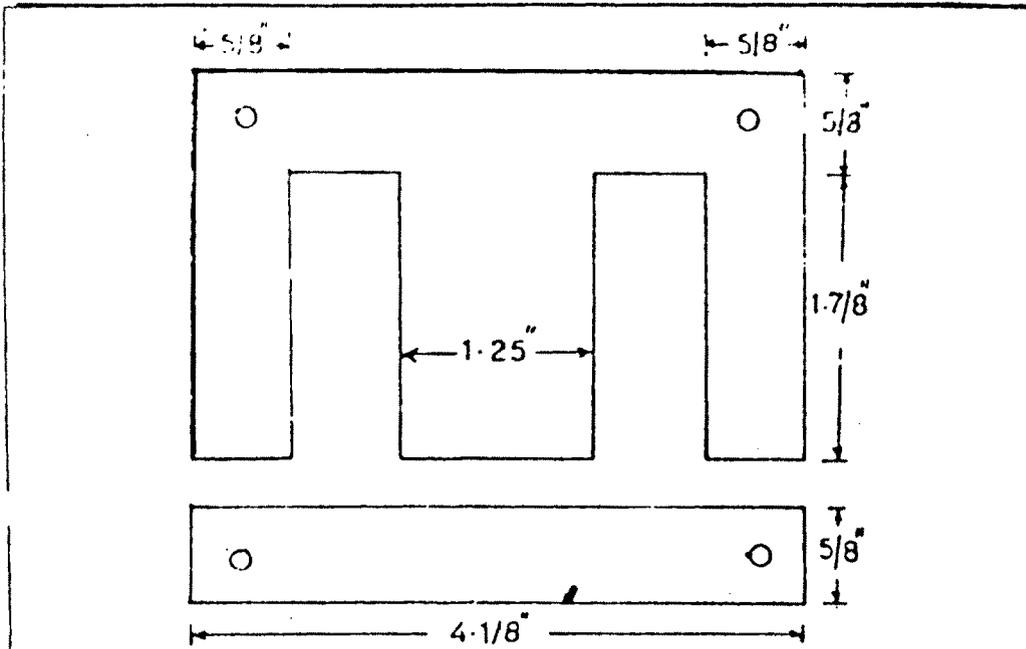


FIG. 4.4(a)

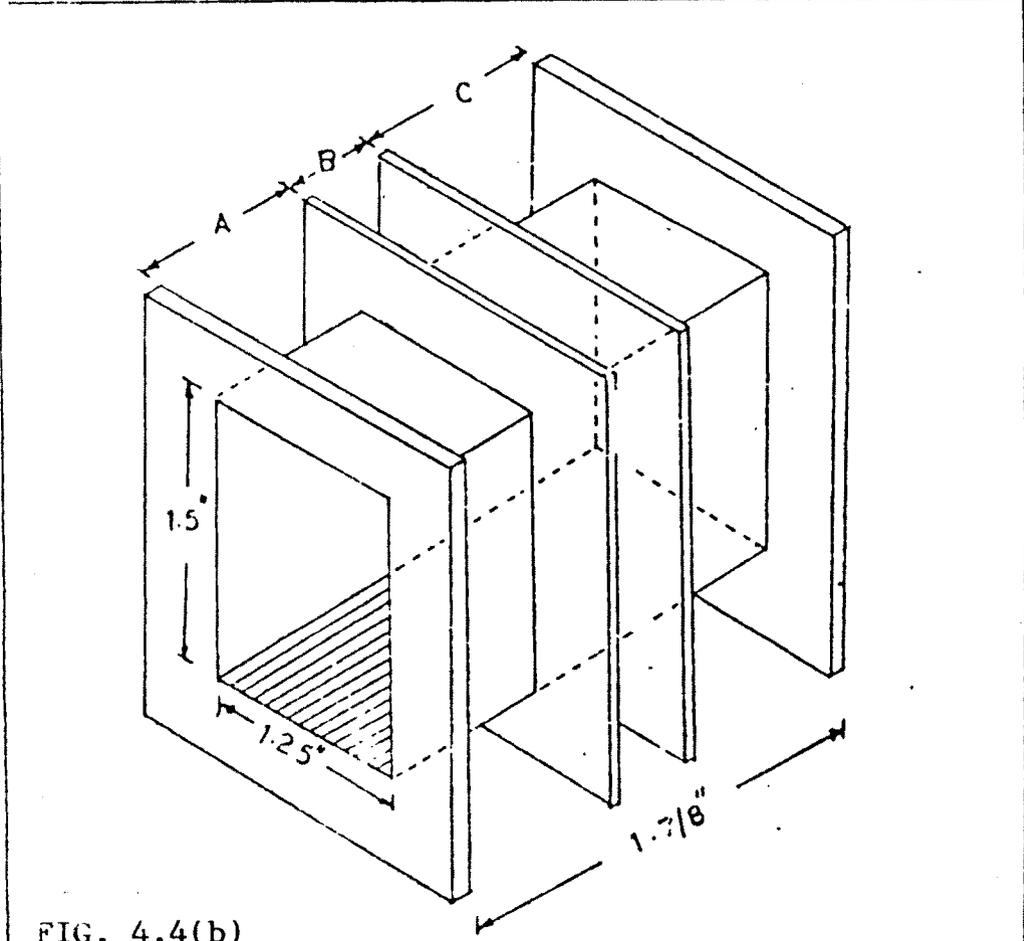


FIG. 4.4(b)

Fig. 4.4 (a) Details of EI laminations
 (b) Details of designing of former.
 A-C-space for secondary winding, B-space for primary winding.

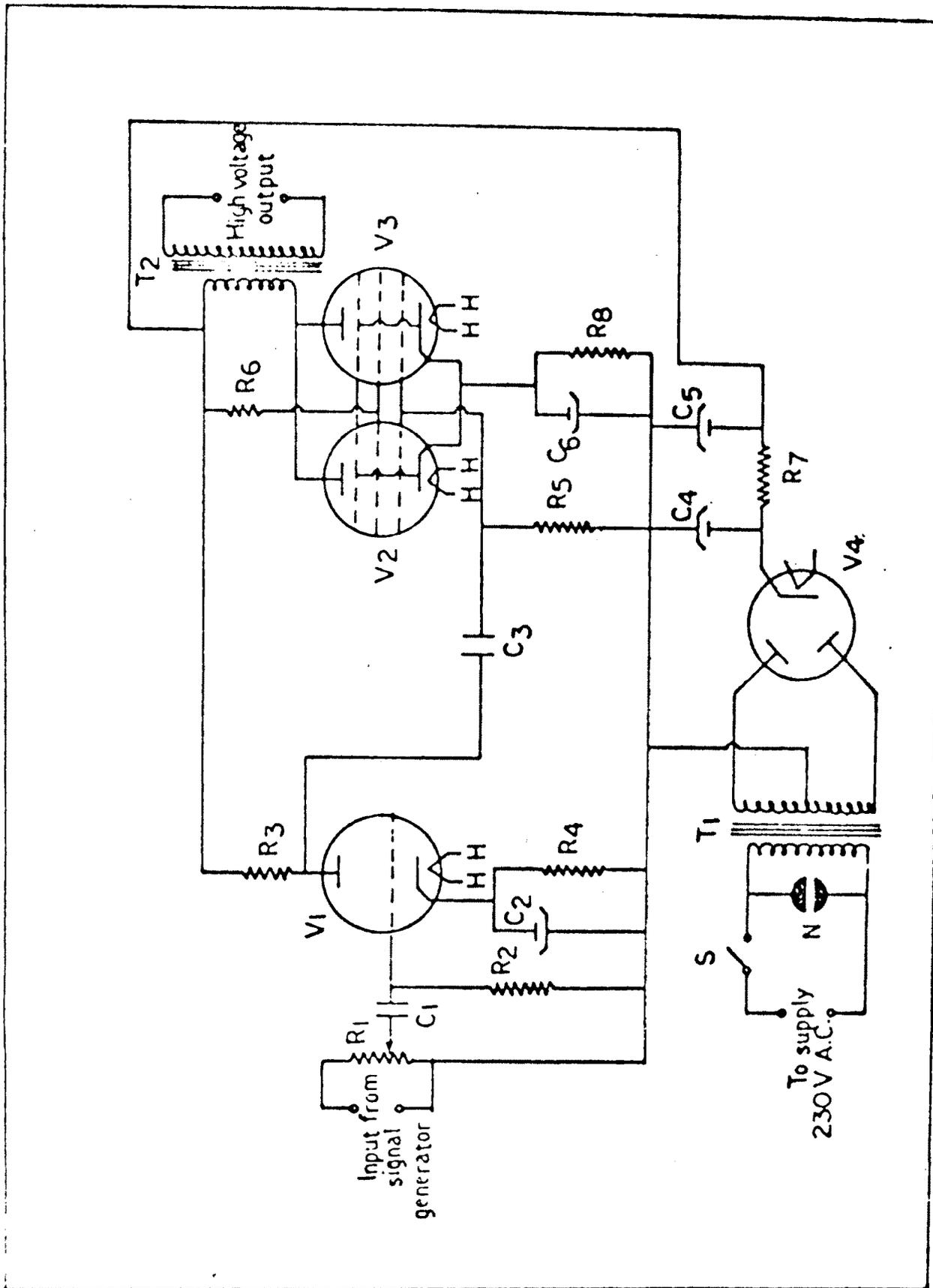


FIG. 4-5 Circuit diagram of the wide band amplifier.

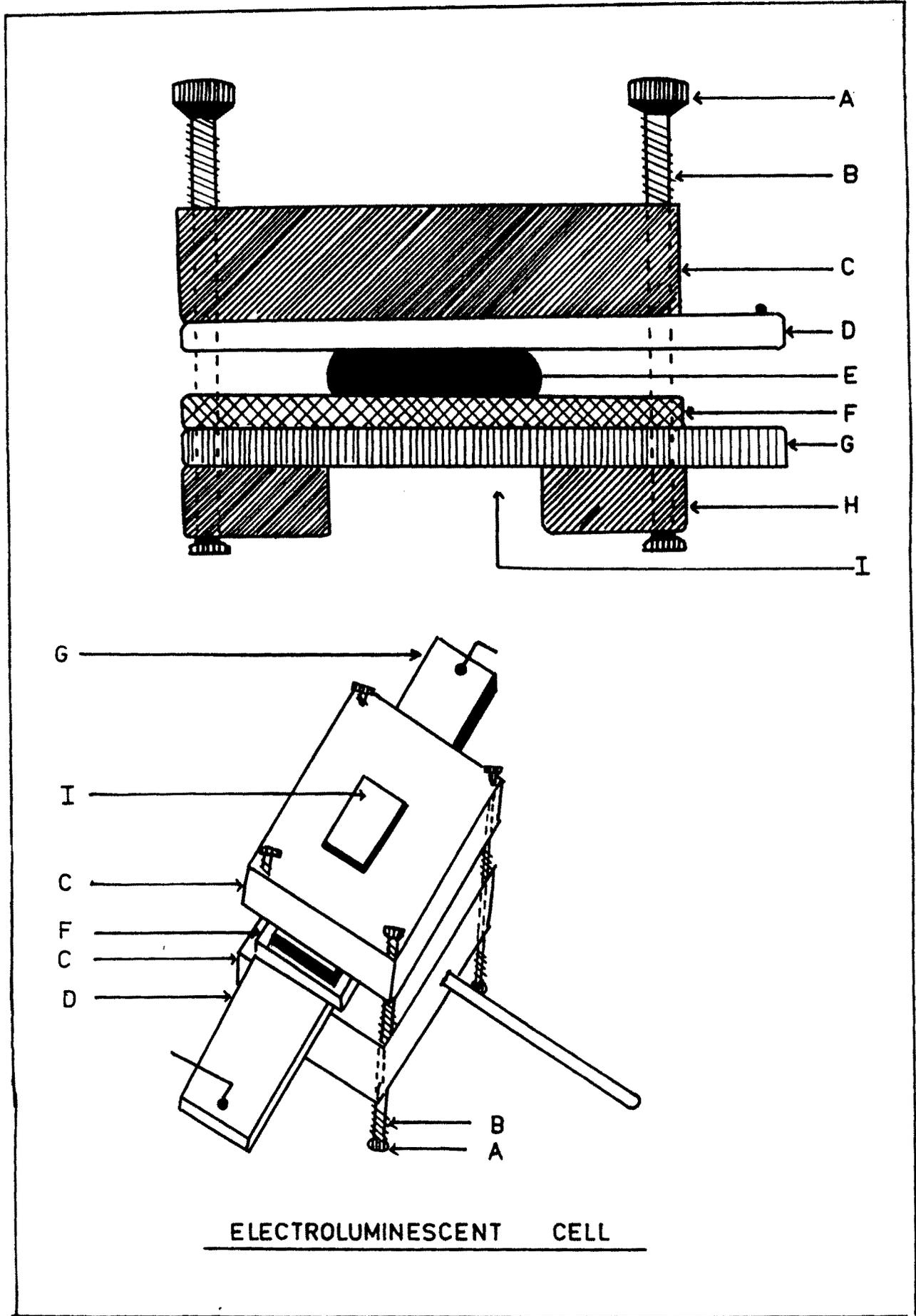


FIG. 4-6

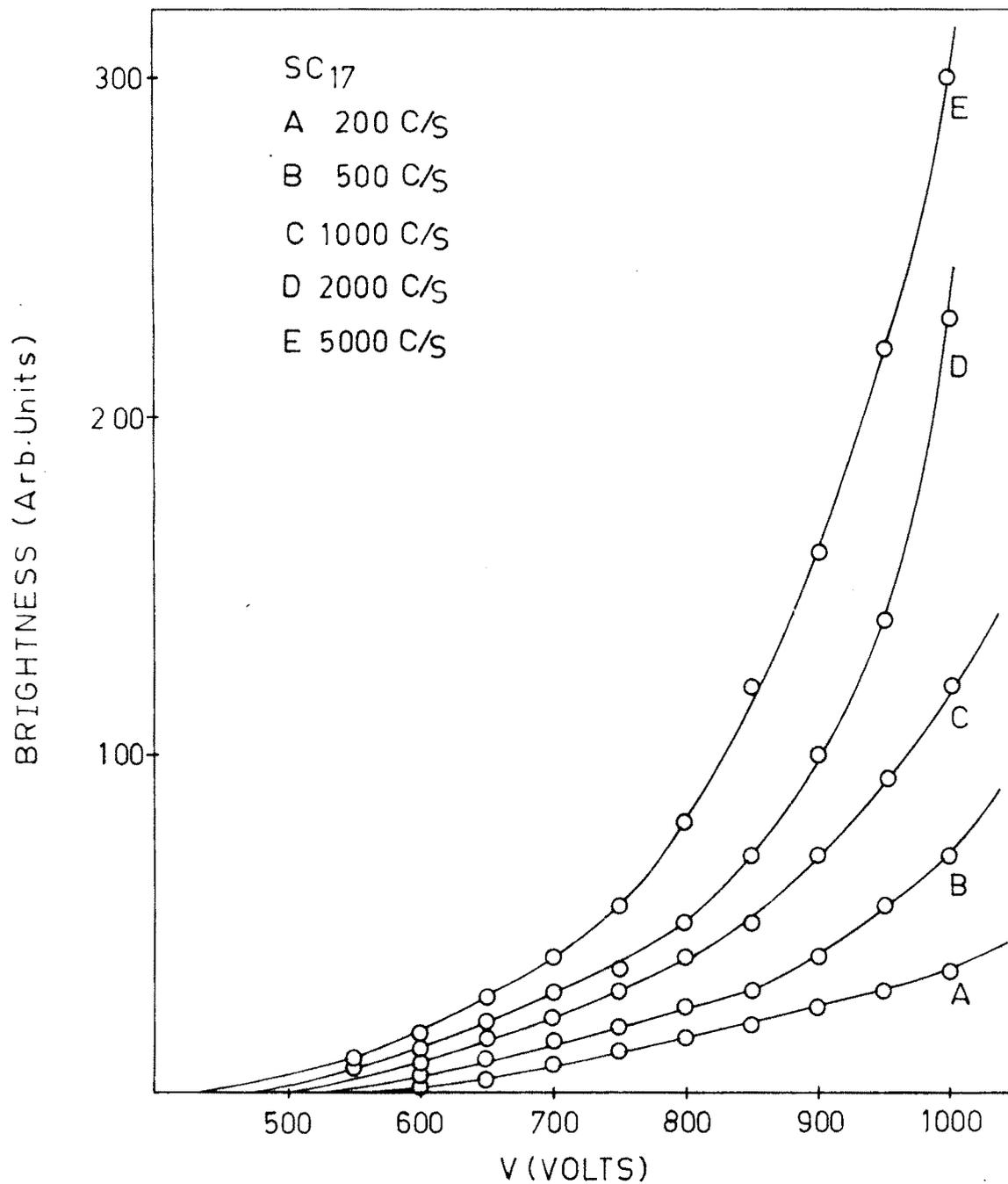


FIG:4-7



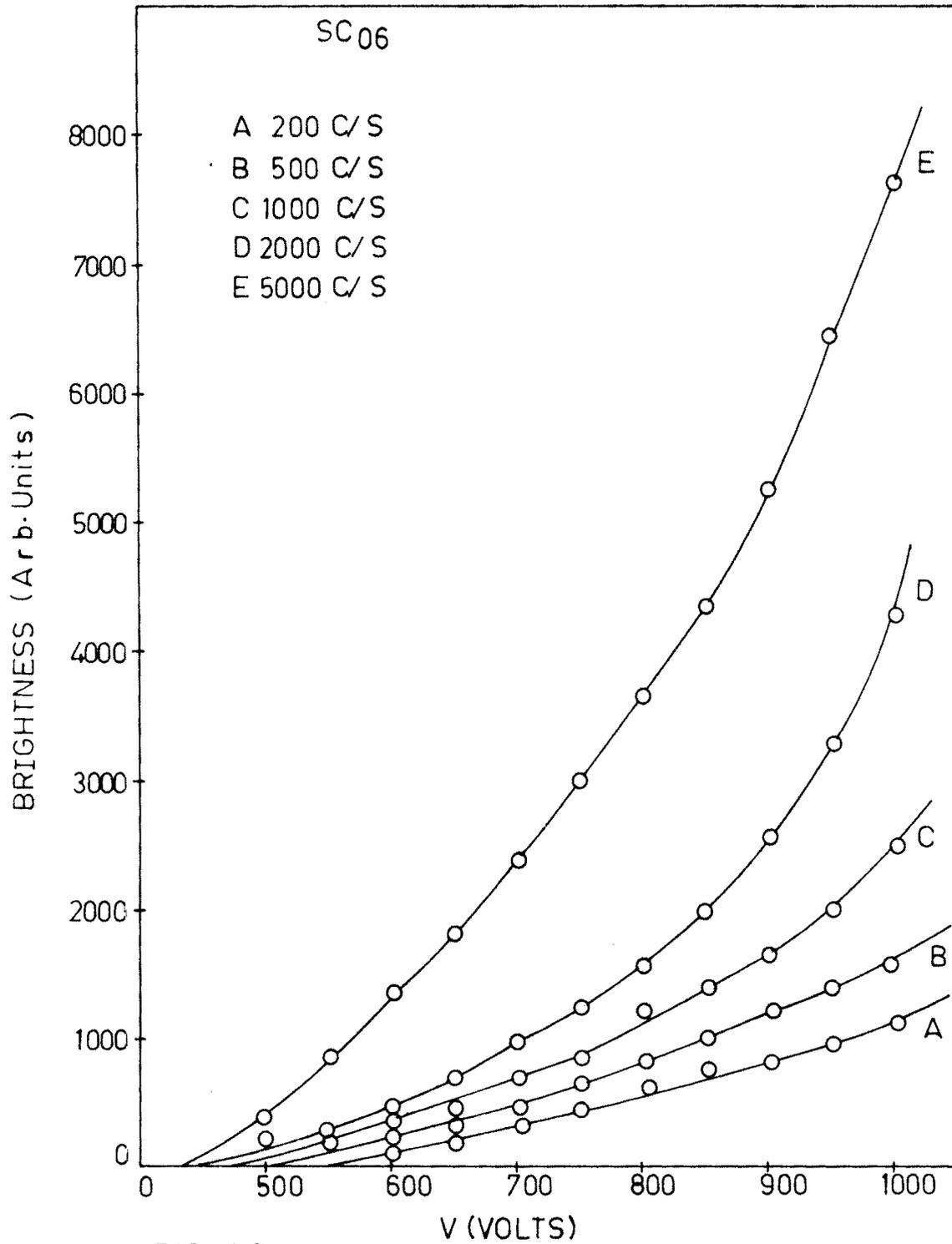


FIG: 4.8

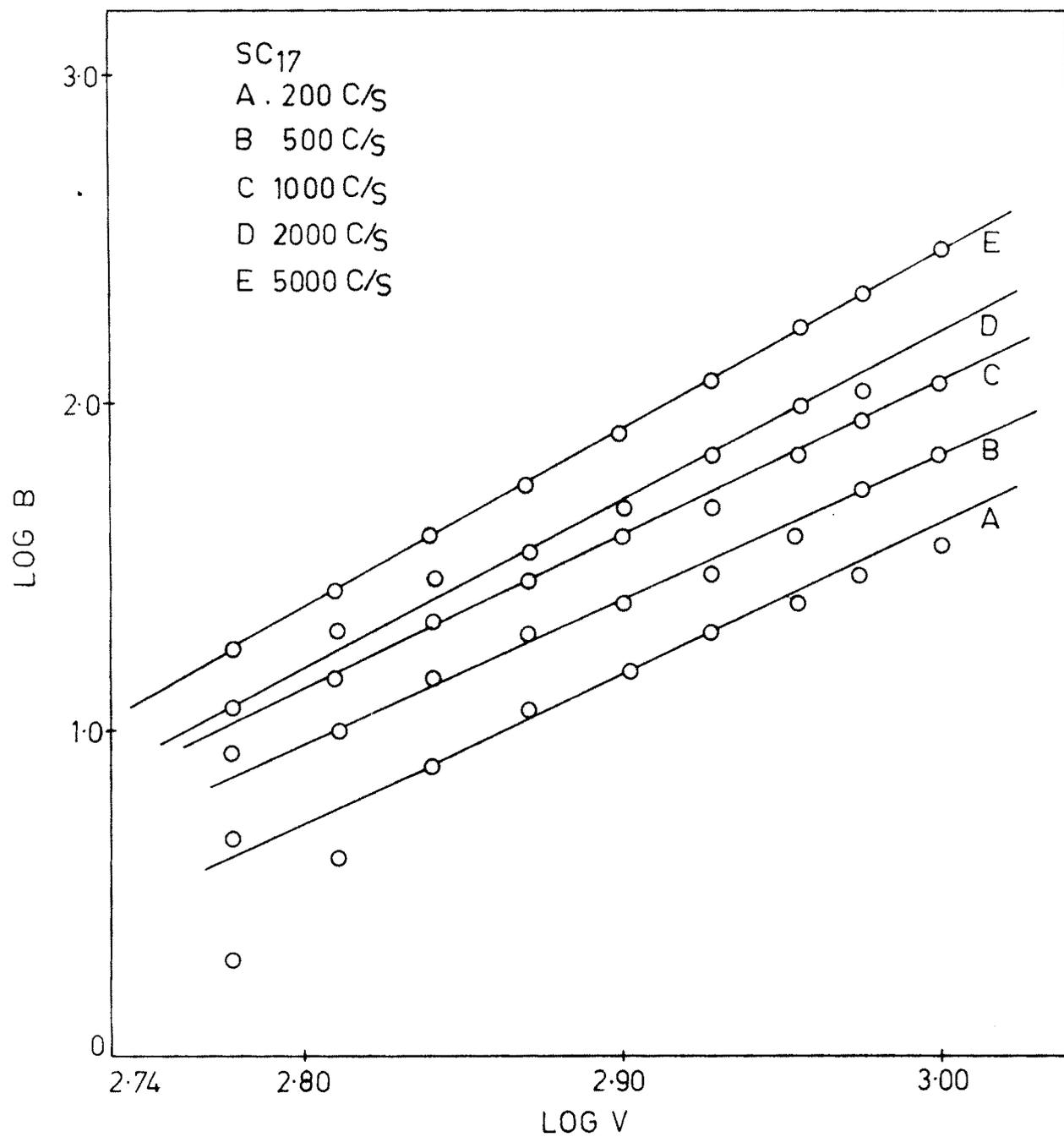


FIG:4.9

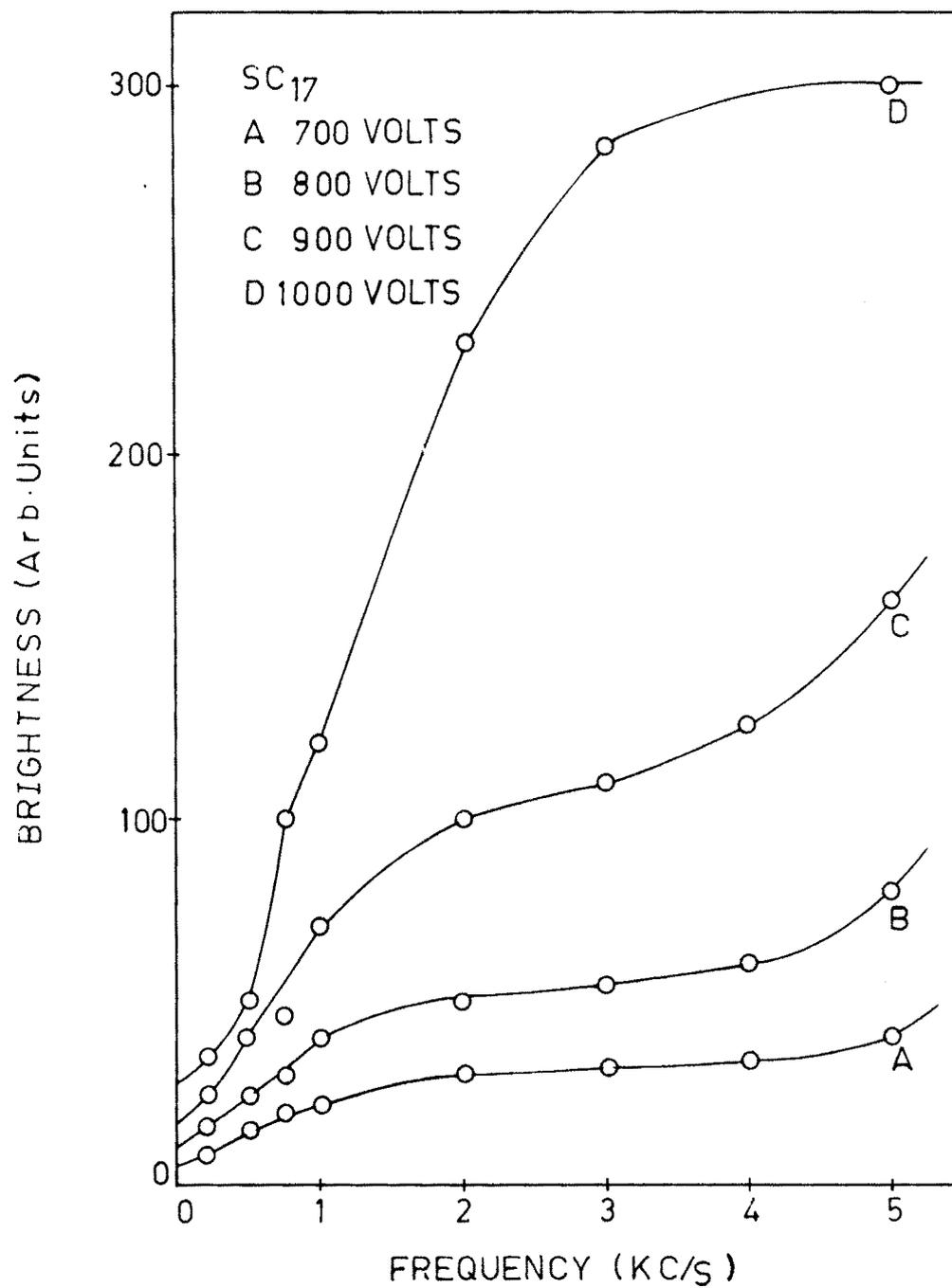


FIG: 4.10

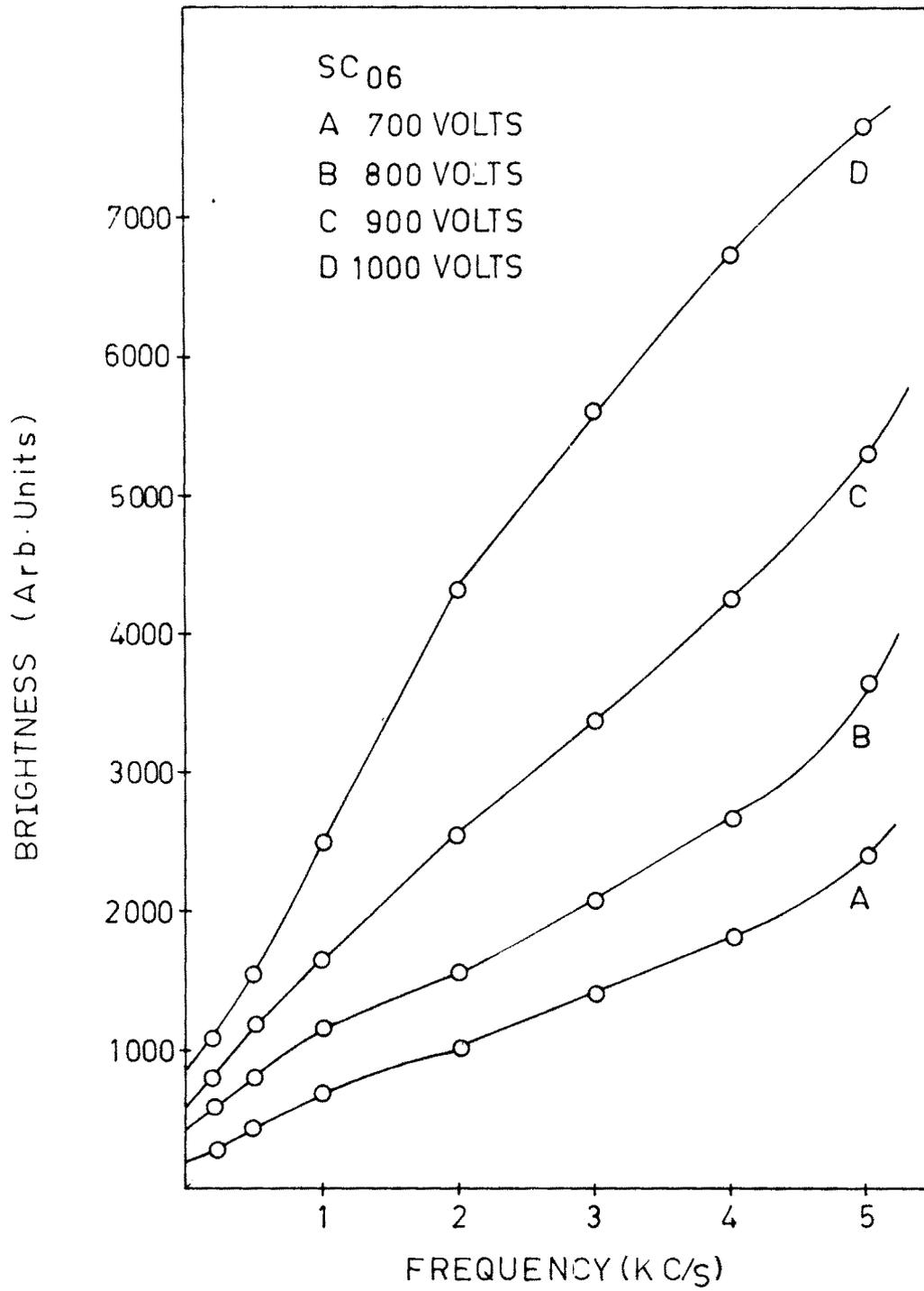


FIG:4.11

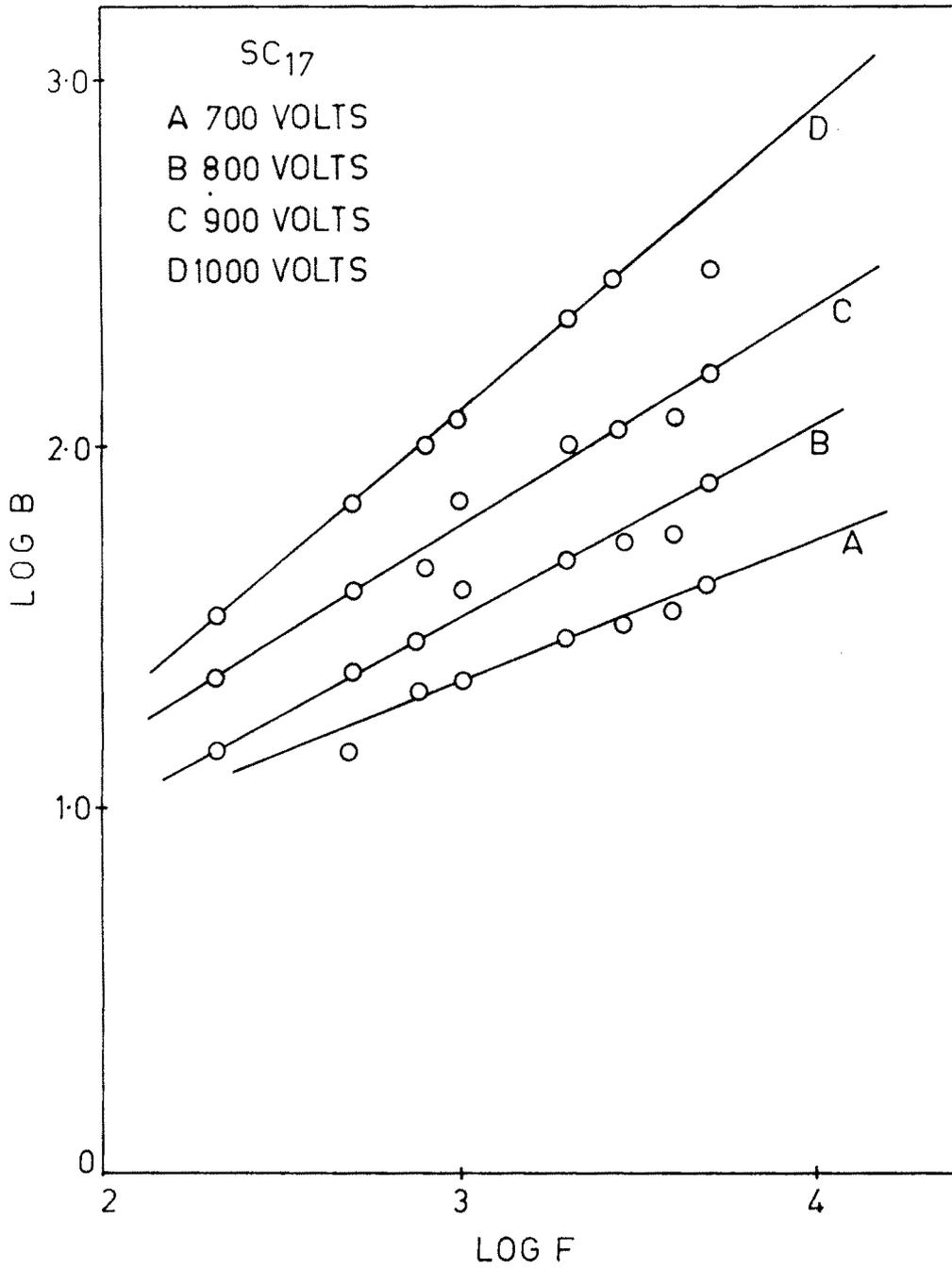


FIG:4.12

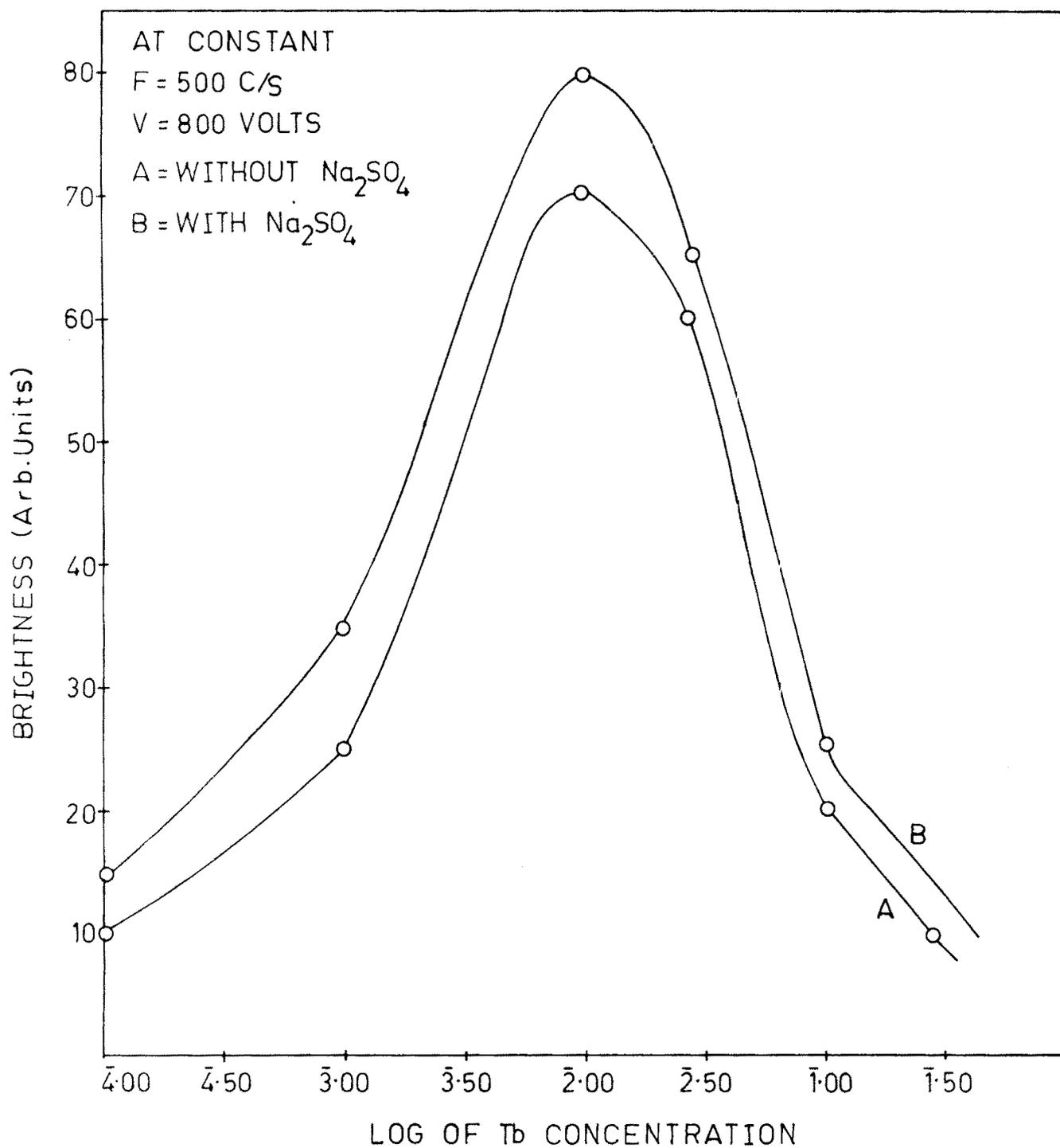


FIG:4.13

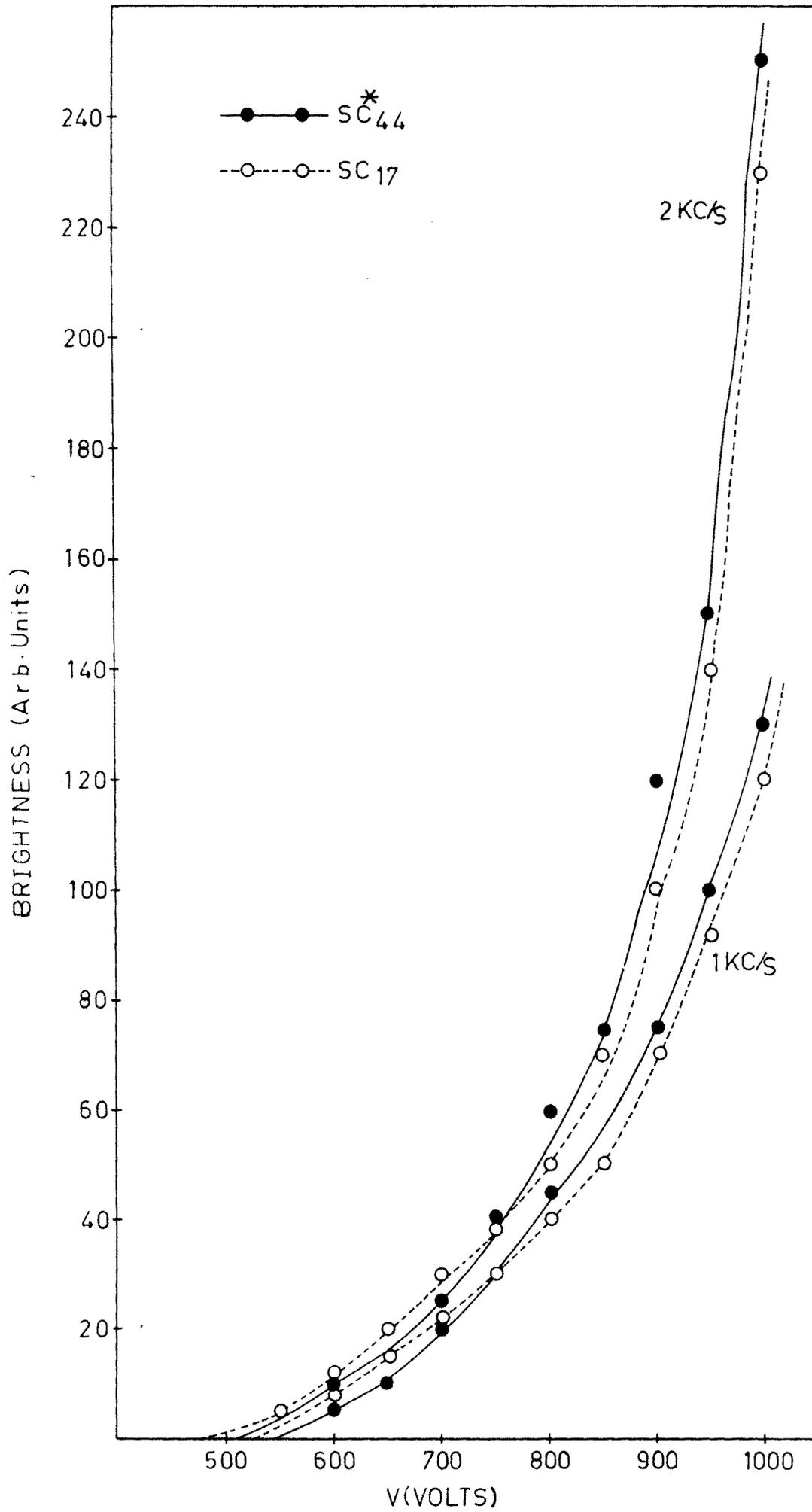


FIG: 4-14

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