ROGERS MAJESTIC ELECTRONICS LTD.
Electronic Tube Division
11-19 Brentcliffe Road
LEASIDE (Toronto 17) ONTARIO

TECHNICAL DATA SHEET FOR TYPE 6047

PHYSICAL CHARACTERISTICS

Bulb:	T6½
Base:	Small button 9-pin
Overall Length:	2.50" maximum
Seated Height:	2.25" maximum
Diameter:	0.88" maximum

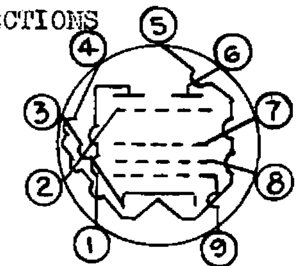
DIRECT INTER-ELECTRODE CAPACITIES
(No external shield)

Input Capacity	5.0 uuf
Output Capacity	10.0 uuf
Capacity a1 to a2	1.0 uuf
Capacity g1,1 or g1,2 or g1,3 to a1 or a2	0.5 uuf

ELECTRICAL RATINGS

Heater Voltage	6.3V ± 10%
Sum Collector Voltage	330 maximum
Carry Collector Voltage	330 maximum

BASE CONNECTIONS



Pin	1	a2
"	2	g2
"	3	k
"	4	h
"	5	h
Pin	6	a1
"	7	g1,1
"	8	g1,2
"	9	g1,3

DESIGN DATA

	1 Without Interstage Cathode Follower	2 With Interstage Cathode Follower
Ef	6.3V	6.3V
If	150 mA	150 mA
Ebb	250 Vdc	250 Vdc
Ec2	125 Vdc	125 Vdc
Ek	27.5 Vdc	14 Vdc
Ecc1	75 Vdc	75 Vdc
*Ra1	63,000 ohms	47,000 ohms
*Ra2	63,000 ohms	47,000 ohms
*Rg1,1, Rg1,2, Rg1,3	63,000 ohms	0
*Rk	0	6,300 ohms
Ib1	1.3 mA min.	1.6 mA min.
Ib2	1.2 mA min.	1.6 mA min.
CR1	2.5 min.	3.5 min.
CR2	15 min.	30 min.

* These are equivalent resistance values.

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TYPE 6047*

The Rogers' Additron 6047 is an electrostatically focussed radial double beam tube, designed primarily for use as a binary adder tube in high speed digital computing devices.

The internal construction of the tube is shown diagrammatically in Figures 1-3. Twelve control elements, placed symmetrically on a circle around the cathode are connected internally to form the three control electrodes (G1,1, g1,2 and g1,3, collectively referred to as g1**). Twelve collector elements, alternate ones connected internally to form two collector electrodes (a1 and a2, collectively referred to as a), are placed on a circle and opposite the gaps between the control elements. The collector elements are shielded from each other by the screen (g2).

If one of the eight possible combinations of a zero voltage and a positive voltage is applied to the three control electrodes of the Additron, the electrostatic field set up in conjunction with the self-bias of the tube directs the electron beams to either a sum (a1) or a carry (a2) collector element, to neither or to both according to Table I. This corresponds to the function table for binary addition where $E_{c1,1}$*** is the augend input, $E_{c1,2}$ the addend input, $E_{c1,3}$ the carry input (from the preceding stage). I_{b1} is the sum output and I_{b2} the carry output (to the following stage), whether the positive voltage represents a 1-digit and the zero voltage a 0-digit, or vice-versa.

TABLE I

$E_{c1,1}$	$E_{c1,2}$	$E_{c1,3}$	I_{b1}	I_{b2}
0	0	0	0	0
+	0	0	+	0
0	+	0	+	0
0	0	+	+	0
+	+	0	0	+
+	0	+	0	+
0	+	+	0	+
+	+	+	+	+

* R.M.A. Type Designation
** All symbols according to JAN specifications unless otherwise noted.
*** All voltages referred to ground, not to the cathode.

Design Notes

Figures of merit for an additron are:-

(a) Time factor

This is the ratio $\frac{E_{c1} \times (C_{in} + C_{out})}{I_b}$ (sec.)

For directly coupled tubes, $C_{in} + C_{out}$ is 15 uuf* and either collector current for E_{c1} = 100V. is 1.6 milliamperes (Table II), giving for the time factor a value of about 1 microsecond.

For cathode follower coupling, neglecting the effect of the cathode follower input capacity, C_{in} is zero, and C_{out} is 10 uuf. The current is 2.3 milliamperes (Table IV). The time factor is thus about 0.5 microsecond.

These values determine the ultimate speed with which the tubes can be satisfactorily operated.

(b) Control ratios CR_1 and CR_2

For each collector, the control ratio is defined as the ratio of the lowest desirable current to highest undesirable current and is a measure of the effectiveness with which that collector distinguishes between a 1- and a 0-digit.

The control electrodes, when positive, draw currents which are functions of the input voltage combinations and for which allowance must be made in the design of a circuit. These currents can be used to equalize the input potentials approximately, when two or three grids are positive, by placing resistance in the input circuits. The way in which equalization occurs can be deduced from the curves in Figure 4, which shows that when the potential of one positive grid changes slightly, the grid currents change so as to drive the potentials of the other positive grids in the same direction. This tendency toward equalization is more evident in Figure 5.

Figure 4 also shows that the tube will tolerate inequalities of 10% in nominally equal input potentials.

When the output of one additron directly drives the input of another additron, the equivalent input resistance of the second tube is equal to the equivalent output resistance of the first one, provided the coupling is effected by a low impedance device such as a neon light or a condenser (Figure 6).

Where direct coupling is used, it is recommended that the cathode resistor be zero and that the cathode potential be between 35% and 42% of the input potential. The equivalent load resistance should be 63,000 ohms or greater. The equivalent circuit and typical operating conditions for direct coupling are shown in Figure 7 and Table II respectively.

* For capacitances etc., see Technical Data Sheet, which is attached.

TABLE II

Ebb (volts)	Ec2 (volts)	Ecc1 (volts)	Ek (volts)	Ra (ohms)	Rg1 (ohms)	Rk (ohms)	Ib1 (mA)	Ib2 (mA)	CR1	CR2
300	125	100	35	63,000	63,000	0	1.6	1.6	3.0	15
250	125	75	27.5	68,000	68,000	0	1.2	1.2	2.5	15
250	125	50	20	72,000	72,000	0	0.7	0.7	2.5	30

If the additrons are coupled by cathode followers (Figure 8), the currents to positive control electrodes are of less importance in designing the circuit, but it may still be advisable to retain some resistance in the input circuits for equalization of the control electrode voltages as explained above. The equivalent circuit for cathode follower coupling is shown in Figure 7, where Rgl in this case will have a small value. In Table III are shown typical operating conditions for the case where the input resistance to the additron is zero and Table IV shows an intermediate case where the values of R_k and Rgl are between the values for the cases shown in Table II and Table III.

TABLE III

Ebb (volts)	Ec2 (volts)	Ecc1 (volts)	Ek (volts)	Ra (ohms)	Rg1 (ohms)	Rk (ohms)	Ib1 (mA)	Ib2 (mA)	CR1	CR2
300	125	100	18	42,000	0	5,600	2.5	2.5	4.0	30
250	125	75	14	47,000	0	6,300	1.7	1.7	3.5	30
250	125	50	10	56,000	0	6,800	1.1	1.1	3.0	35

TABLE IV

Ebb (volts)	Ec2 (volts)	Ecc1 (volts)	Ek (volts)	Ra (ohms)	Rg1 (ohms)	Rk (ohms)	Ib1 (mA)	Ib2 (mA)	CR1	CR2
300	125	100	27	47,000	7,500	4,200	2.3	2.3	3.5	30
250	125	75	20	56,000	10,000	4,700	1.4	1.4	3.0	30
250	125	50	14	63,000	12,000	5,600	0.9	0.9	2.5	40

The values of the control ratios depend on the values of Ecc1, Rg1, E_k and R_k. In Figure 9 the variation of $I_{c1,1}$ with $E_{c1,1}$ is shown for the case where $E_{c1,1} = E_{c1,2}$ and $E_{c1,3} = 0$. The slope of this curve increases rapidly as the grid potential approaches the screen potential. For this reason, the screen voltage should be held at the maximum of the grid swing or above. The difference between collector and screen supply voltages must be at least equal to the desired signal output.

The bleeder circuit (see Figure 6 and Figure 8) may be so designed that the coupling neon lights extinguish when the carry collector receives current. However, this method of equalization of negative inputs is not absolutely necessary, since the carry collector voltage swings between two levels, one determined by the screen potential, the other by the collector supply voltage. If the circuit is designed such that the neon lights are always conducting, a condenser should be placed in parallel with the neon lights.

The measurements of Table V were made on one additron under the conditions indicated and in the equivalent circuit (see Figure 7) to illustrate the manner in which the currents to the various electrodes depend on the combination of input potentials.

TABLE V

(a) Test Conditions:-

E_{bb} = +250V; E_{c2} = +125V; E_k = +27.5V.

R_a = 63,000 ohms; R_{g1} = 63,000 ohms; R_k = 0.

$E_{cc1,1}$ (volts)	$E_{cc1,2}$ (volts)	$E_{cc1,3}$ (volts)	I_{b1} (mA)	I_{b2} (mA)	$I_{c1,1}$ (uA)	$I_{c1,2}$ (uA)	$I_{c1,3}$ (uA)	I_{c2} (uA)
0	0	0	0	0	0	0	0	0
75	0	0	1.5	0.03	60	0	0	400
0	75	0	1.7	0.05	0	50	0	500
0	0	75	1.5	0.04	0	0	100	460
75	75	0	0.3	1.2	490	500	0	80
75	0	75	0.3	1.2	480	0	500	90
0	75	75	0.2	1.2	0	520	510	100
75	75	75	1.6	1.4	630	640	630	210

$$CR_1 = \frac{1.5}{0.3} = 5.0$$

$$CR_2 = \frac{1.2}{0.05} = 24$$

(b) Test Conditions:-

E_{bb} = +250V; E_{c2} = +125V; E_k = +14V.

R_a = 47,000 ohms; R_{g1} = 0; R_k = 6,300 ohms.

$E_{cc1,1}$ (volts)	$E_{cc1,2}$ (volts)	$E_{cc1,3}$ (volts)	I_{b1} (mA)	I_{b2} (mA)	$I_{c1,1}$ (uA)	$I_{c1,2}$ (uA)	$I_{c1,3}$ (uA)	I_{c2} (uA)
0	0	0	0	0	0	0	0	0
75	0	0	2.3	0.05	130	0	0	80
0	75	0	2.2	0.04	0	170	0	170
0	0	75	2.2	0.06	0	0	100	90
75	75	0	0.4	2.2	1050	1200	0	370
75	0	75	0.4	2.2	990	0	1200	500
0	75	75	0.3	2.2	0	1150	1100	520
75	75	75	2.2	2.0	1010	1090	1050	680

$$CR_1 = \frac{2.2}{0.4} = 5.5$$

$$CR_2 = \frac{2.0}{0.06} = 33$$

TABLE V (Cont'd.)

(c) Test Conditions:-

E_{bb} = +250V; E_{c2} = +125V; E_k = +20V.

R_a = 56,000 ohms; R_{g1} = 10,000 ohms; R_k = 4,700 ohms.

$E_{cc1,1}$	$E_{cc1,2}$ (volts)	$E_{cc1,3}$	I_{b1} (mA)	I_{b2} (mA)	$I_{c1,1}$ (uA)	$I_{c1,2}$ (uA)	$I_{c1,3}$ (uA)	I_{c2} (uA)
0	0	0	0	0	0	0	0	0
75	0	0	1.8	0.04	70	0	0	110
0	75	0	1.8	0.04	0	50	0	150
0	0	75	1.8	0.05	0	0	120	180
75	75	0	0.4	1.9	900	930	0	310
75	0	75	0.3	1.9	820	0	1000	430
0	75	75	0.3	1.9	0	960	980	420
75	75	75	1.9	1.8	970	1000	1000	710

$$CR_1 = \frac{1.8}{0.4} = 4.5$$

$$CR_2 = \frac{1.8}{0.05} = 36$$

The process of addition usually involves two discrete steps. First, the numbers to be added are applied to the control electrodes of the tube. Second, the addition is carried out. Usually it is desirable to have the tube operative only during the second step. If the cathode is the gating element, its potential is normally above the highest of the input potentials and a negative pulse to the cathode permits the addition to take place.

The screen may also be used for gating. Currents to the output elements are effectively cut off when the screen is at cathode potential. In this case the positive control electrodes will draw current. The use of the screen as a gating element is also facilitated by the small screen currents (approximately half the output currents).

Function tables other than that for binary addition may also be obtained. If the cathode is returned to a voltage approximately 55% of the input voltage, the outputs of Table VI (a) are obtained, while if a large cathode resistor is returned to a voltage negative with respect to the lower grid swing, the outputs of Table VI (b) are obtained.

TABLE VI

$E_{c1,1}$	$E_{c1,2}$	$E_{c1,3}$	(a) I_{b1}	(a) I_{b2}	(b) I_{b1}	(b) I_{b2}
0	0	0	0	0	+	+
+	0	0	0	0	+	0
0	+	0	0	0	+	0
0	0	+	0	0	+	0
+	+	0	0	+	0	+
+	0	+	0	+	0	+
0	+	+	0	+	0	+
+	+	+	+	+	+	+

Queries and comments regarding type 6047, the operating conditions and circuitry, are invited.

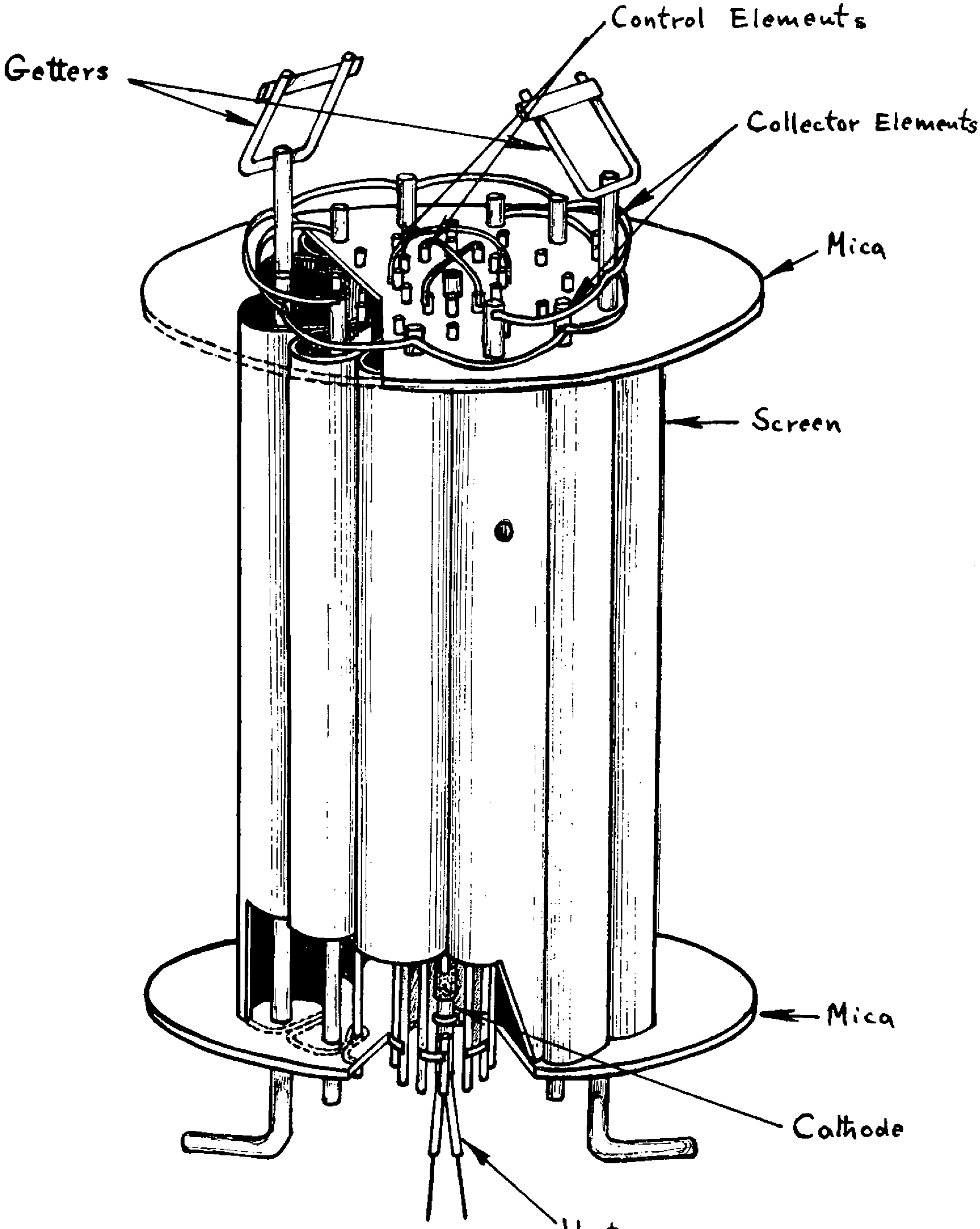

Control Elements
Getters
Collector Elements
Mica
Screen
Mica
Cathode
Heater

FIG. 1.

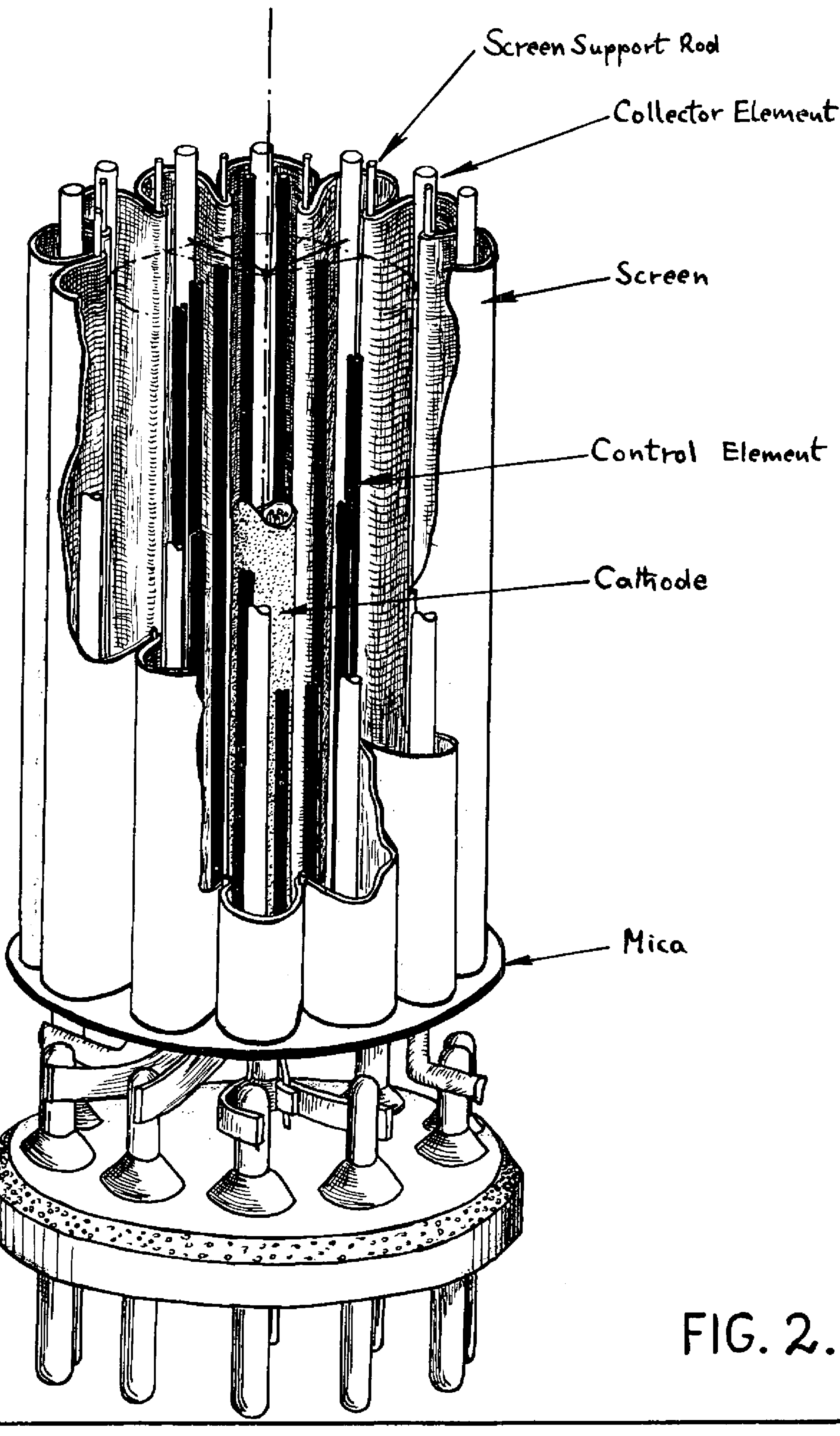

Screen Support Rod
Collector Element
Screen
Control Element
Cathode
Mica

FIG. 2.

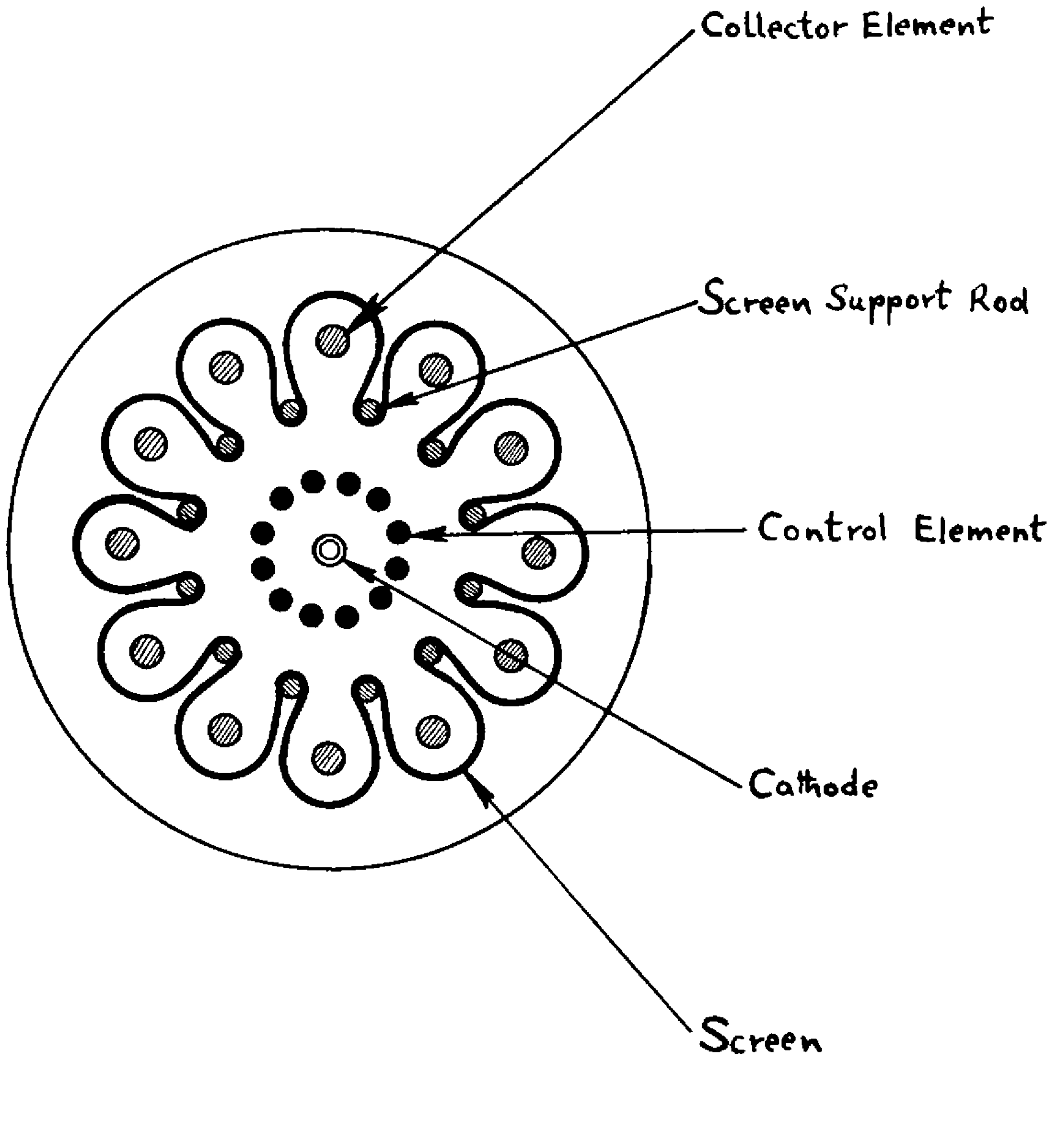

Collector Element
Screen Support Rod
Control Element
Cathode
Screen

FIG. 3.

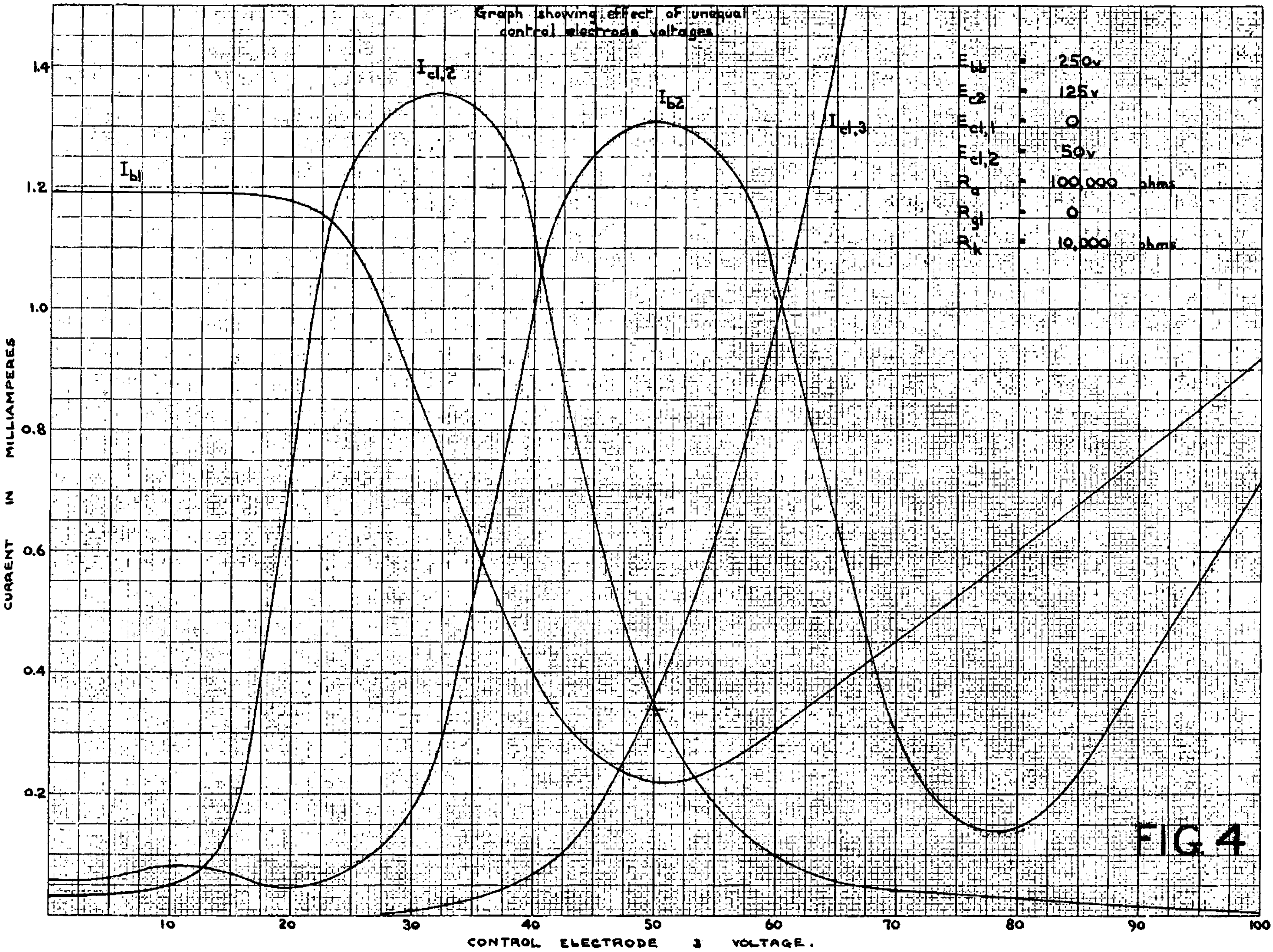

Graph showing effect of unequal control electrode voltages
E bb = 250v
E c2 = 125v
E cl,1 = 0
E cl,2 = 50v
R a = 100,000 ohms
R g1 = 0
R k = 10,000 ohms
I b1
I cl,2
I b2
I cl,3
1.4
1.2
1.0
0.8
0.6
0.4
0.2
10
20
30
40
50
60
70
80
90
100
CURRENT IN MILLIAMPERES
CONTROL ELECTRODE 3 VOLTAGE.

FIG. 4

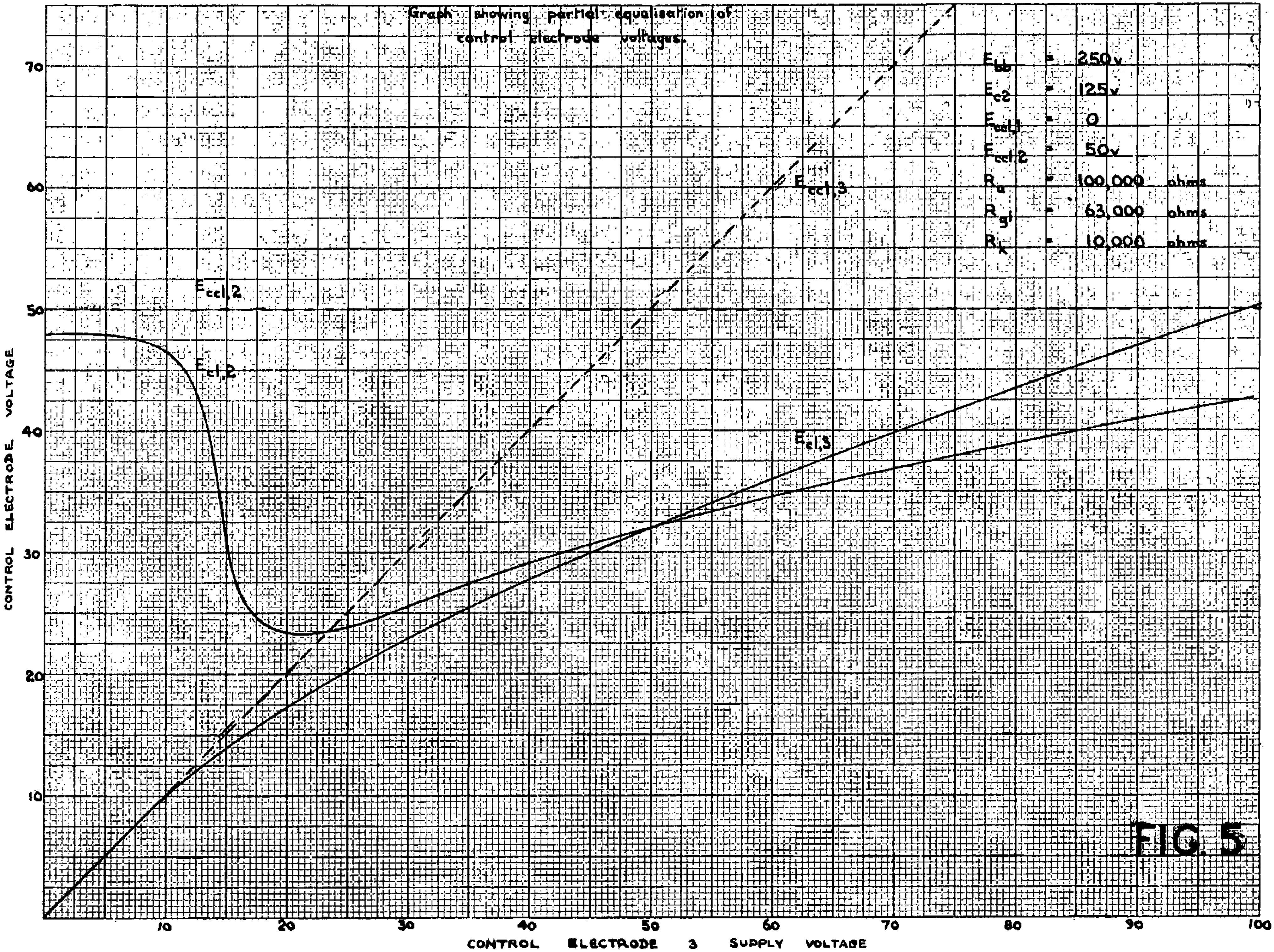
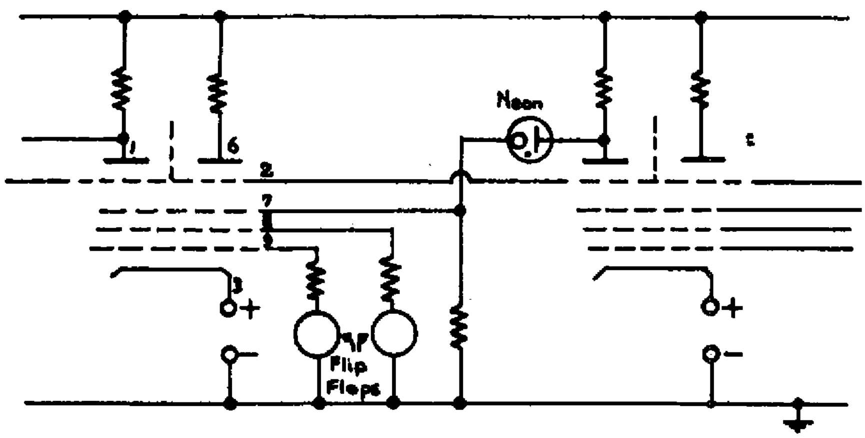
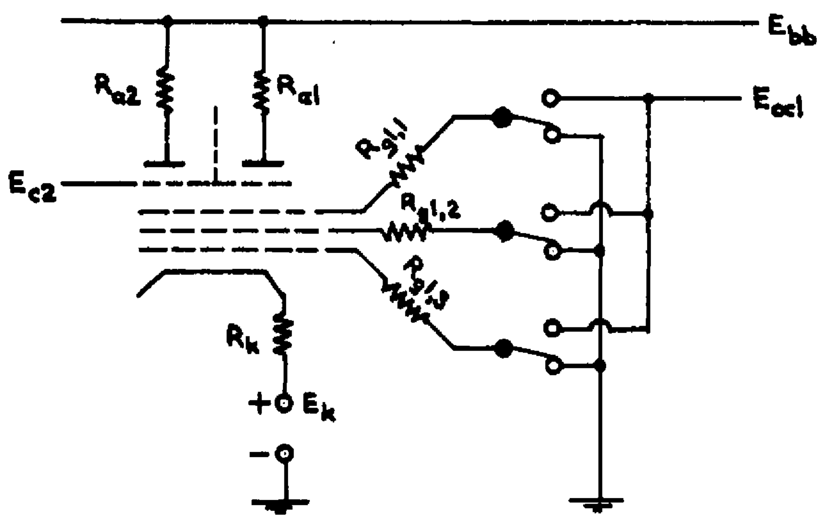

Graph showing partial equalisation of control electrode voltages.
E bb = 250v
E c2 = 125v
E cc1,1 = 0
E cc1,2 = 50v
R a = 100,000 ohms
R g1 = 63,000 ohms
R k = 10,000 ohms
E cc1,2
E c1,2
E cc1,3
E c1,3
10
20
30
40
50
60
70
80
90
100
CONTROL ELECTRODE 3 SUPPLY VOLTAGE
CONTROL ELECTRODE VOLTAGE

FIG. 5



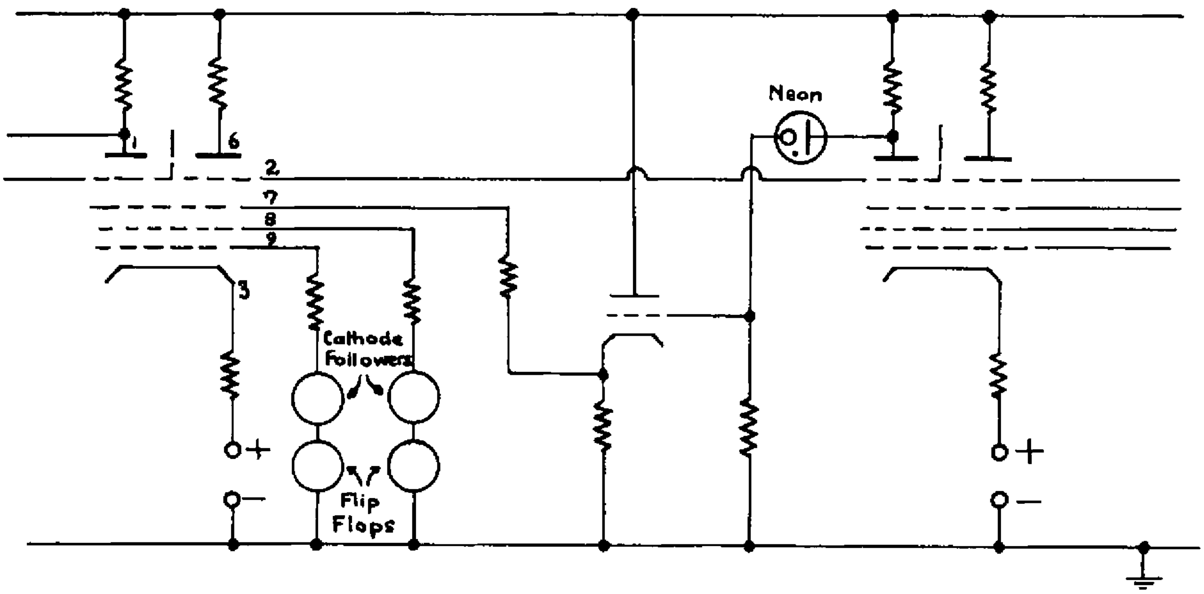
Circuit for direct coupling

FIG. 6



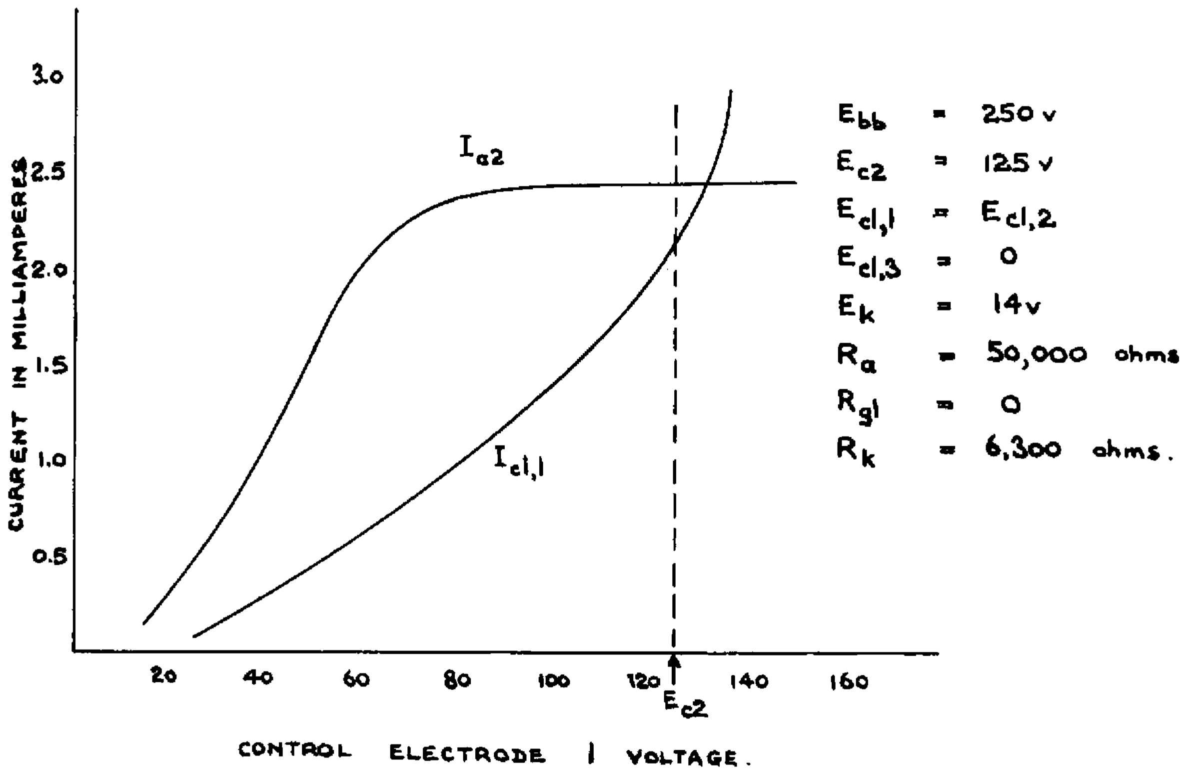
Equivalent circuit for an additron.

FIG. 7



Circuit for cathode follower coupling

FIG. 8



Graph of $I_{cl,1}$ against $E_{cl,1}$

FIG. 9