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8. "General Electric Transistor Manual", General Electric Company, Liverpool, N.Y. 1965

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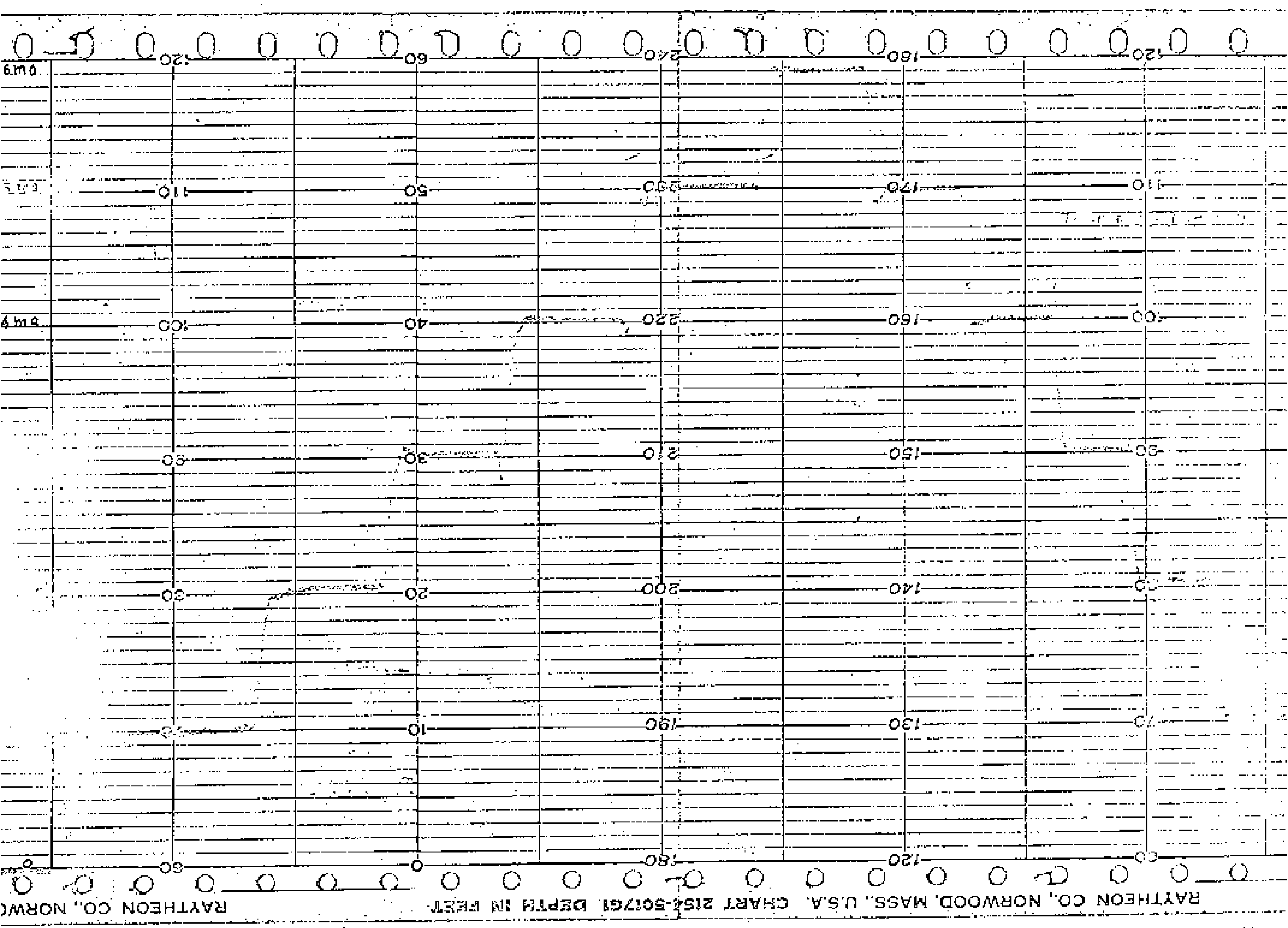


Fig. R4 Y axis linearity test (tested on 12AU7)

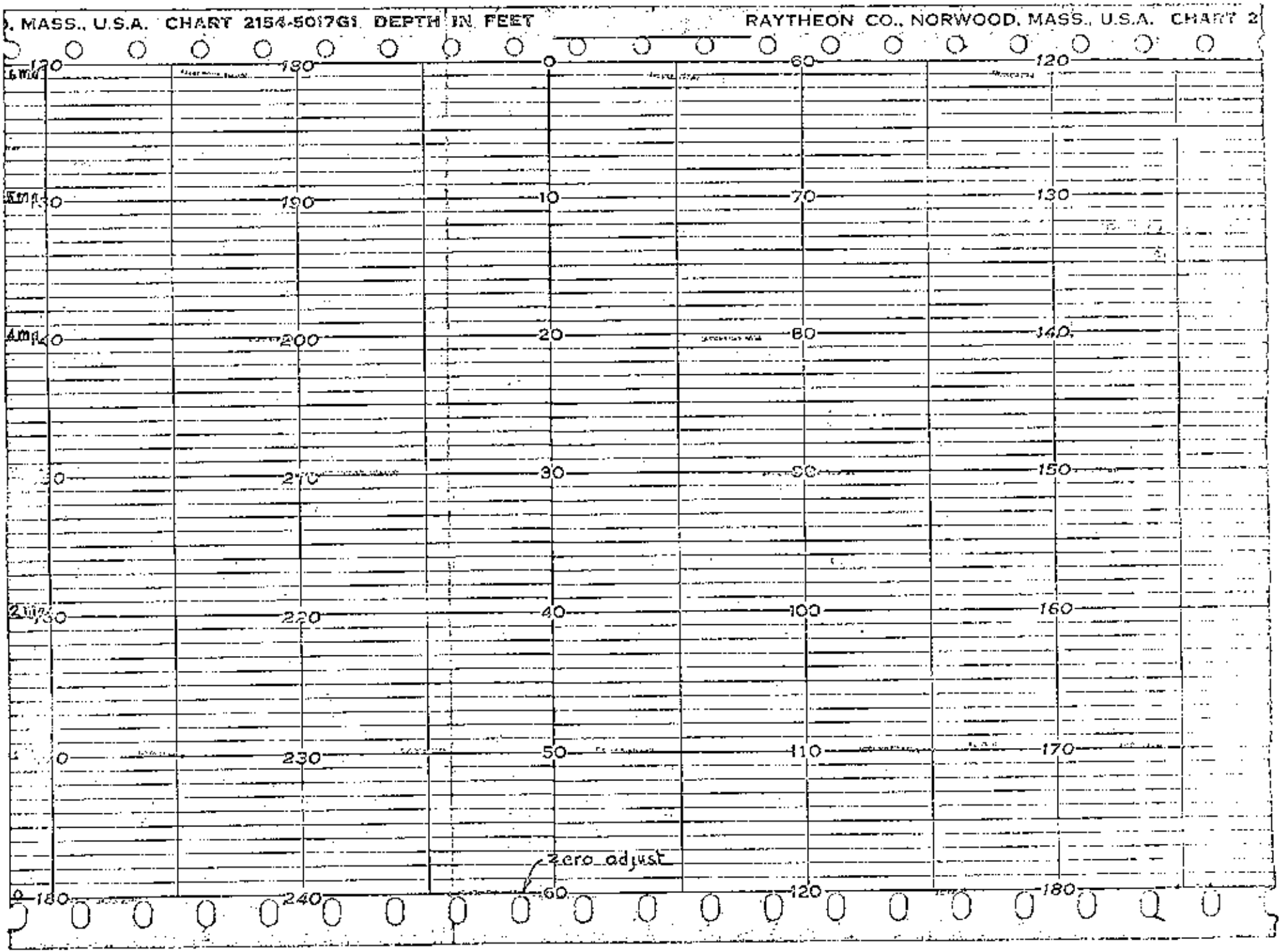


Fig. R2 Y axis linearity test. (tested on 12AU7)

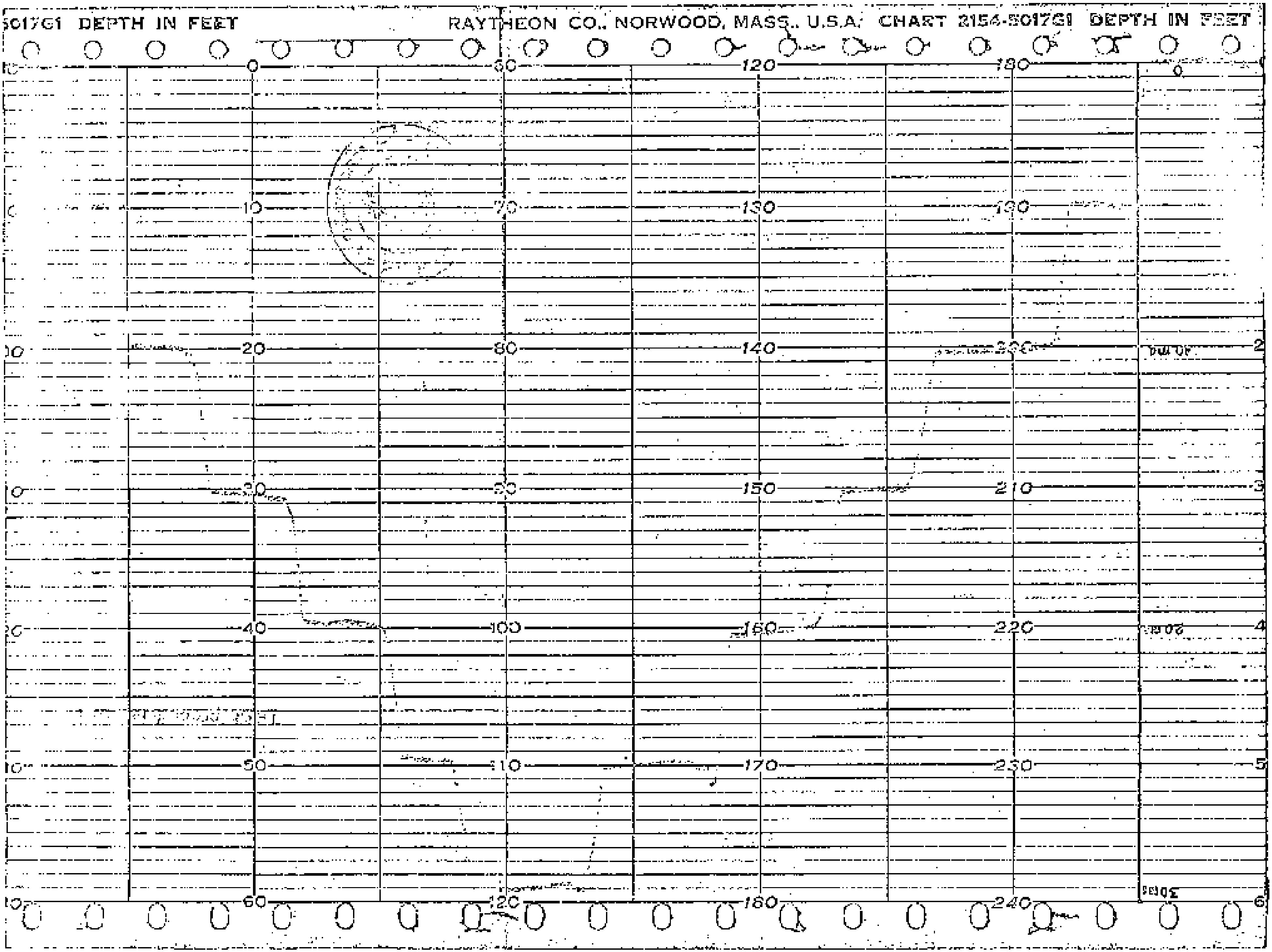


Fig. R3 Y axis linearity test, (tested on 12 AU7)

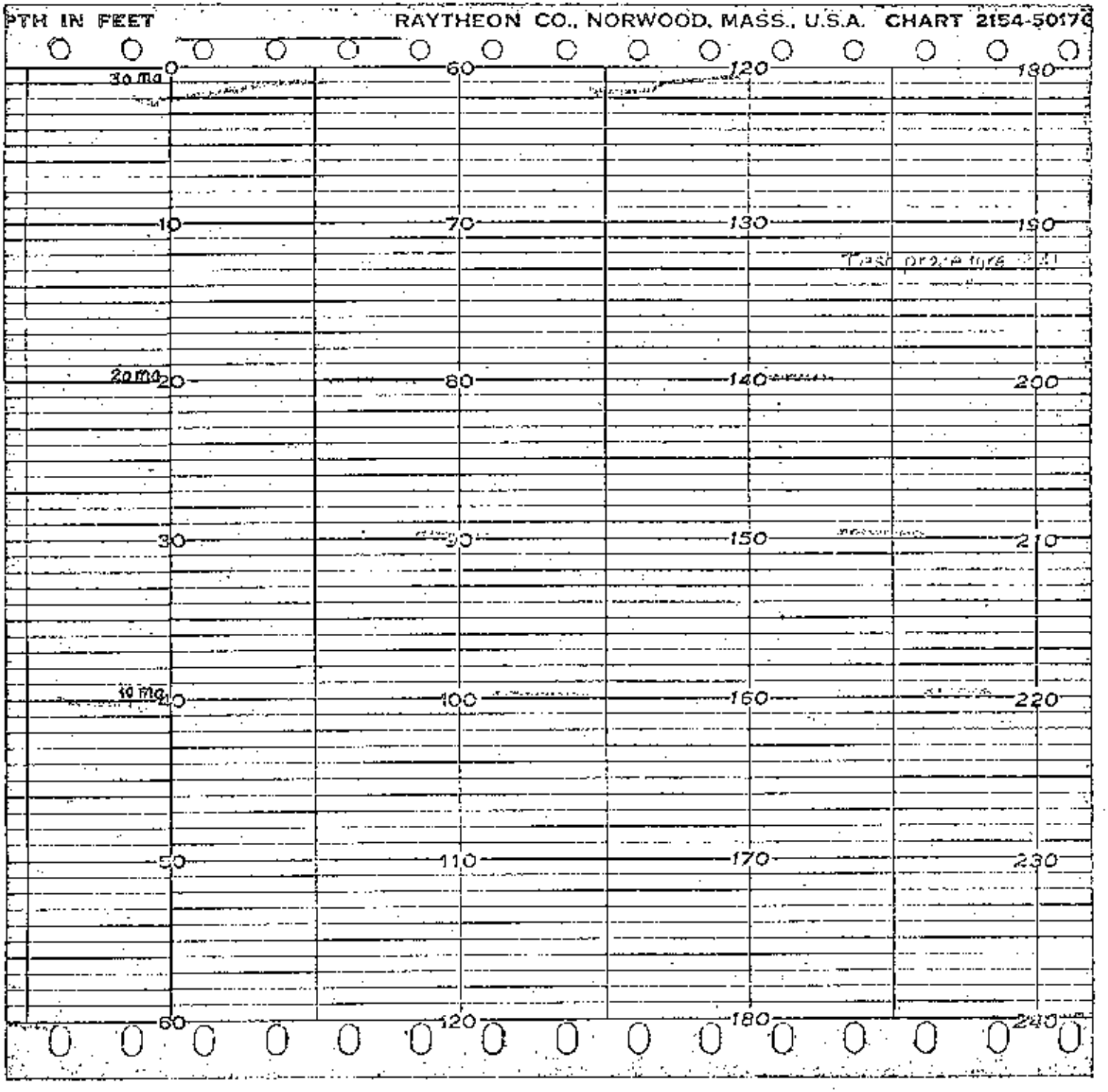


Fig. R4 Y axis linearity test, (tested on 12AU7)

Test data 2.42 b , The relation between voltage control potentiometer 1 and no load output voltage of the plate voltage supply unit.

Relative angular displacement	Measurement no.			Error from measure. no.			Expecting value
	1	2	3	1	2	3	
1	0	0	0	0	0	0	0
2	23	23	23	-1.0	-1.0	-1.0	24
3	46.8	48	47	-3.2	0	-1.0	48
4	72.3	72	73	+0.3	0	+1.0	72
5	98.1	98	98	+2.1	+2.0	+2.0	96
6	121.7	122	122	+1.7	+2.0	+2.0	120
7	144.0	145	145	0	+1.0	+1.0	144
8	169.3	169	169	+1.3	+1.0	+1.0	168
9	190.8	191	192	+1.2	-1.0	-0	192
10	213	213	213	-3.0	-3.0	-3.0	216
11	236	237	237	-4.0	-3.0	-3.0	240
12	260	260	260	-4.0	-4.0	-4.0	264
13	283	284	284	-5.0	-4.0	-4.0	288
14	305	305	305	-5.0	-5.0	-5.0	310

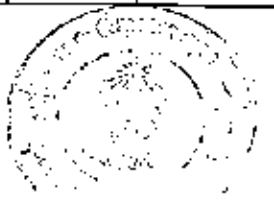
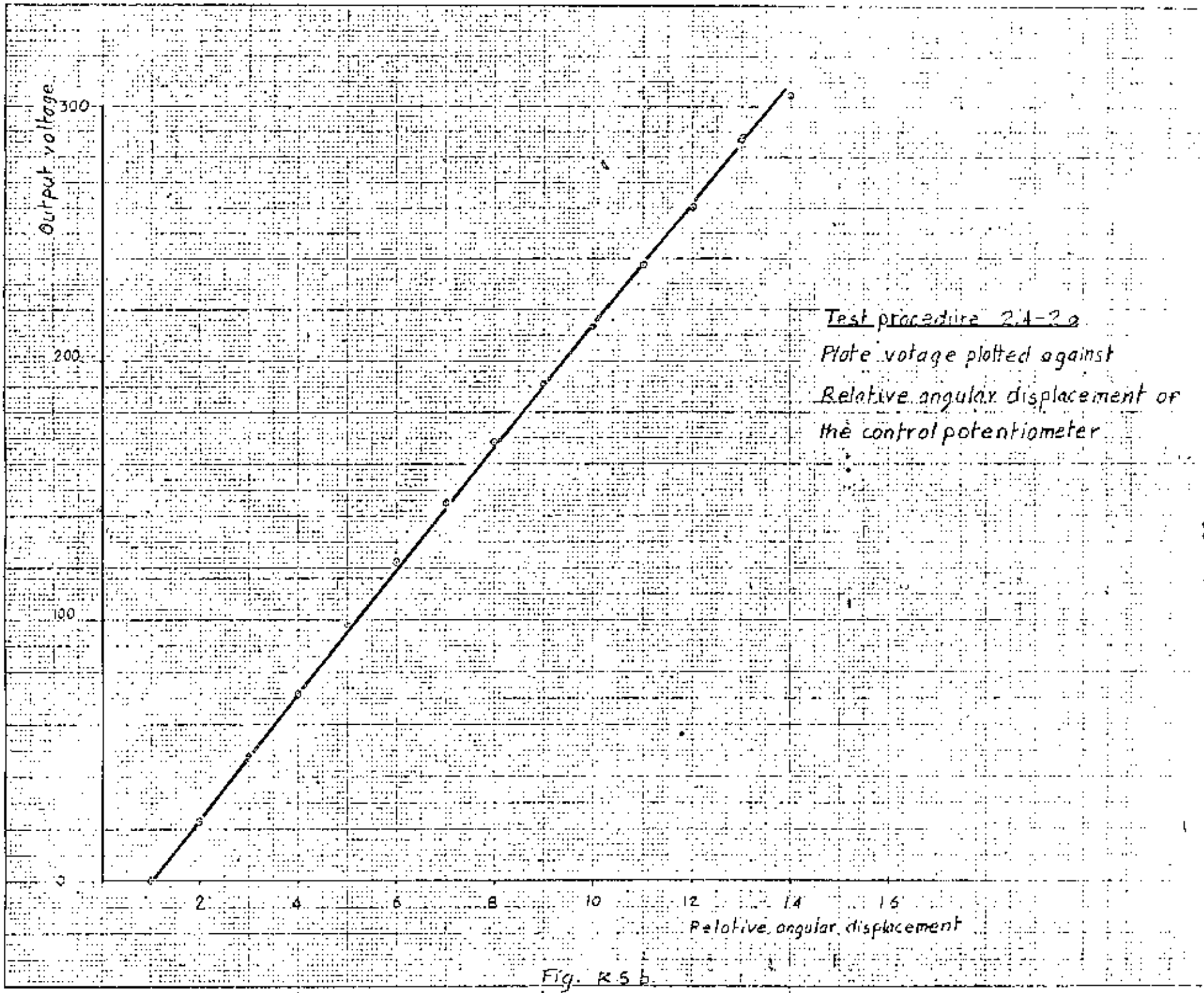


Fig. R 5 a.

Note Final output voltage range was set between 20 and 276 volts



Test procedure 2.4-2 a

Plate votage plotted against

Relative angular displacement of

the control potentiometer

Fig. R 5 b.

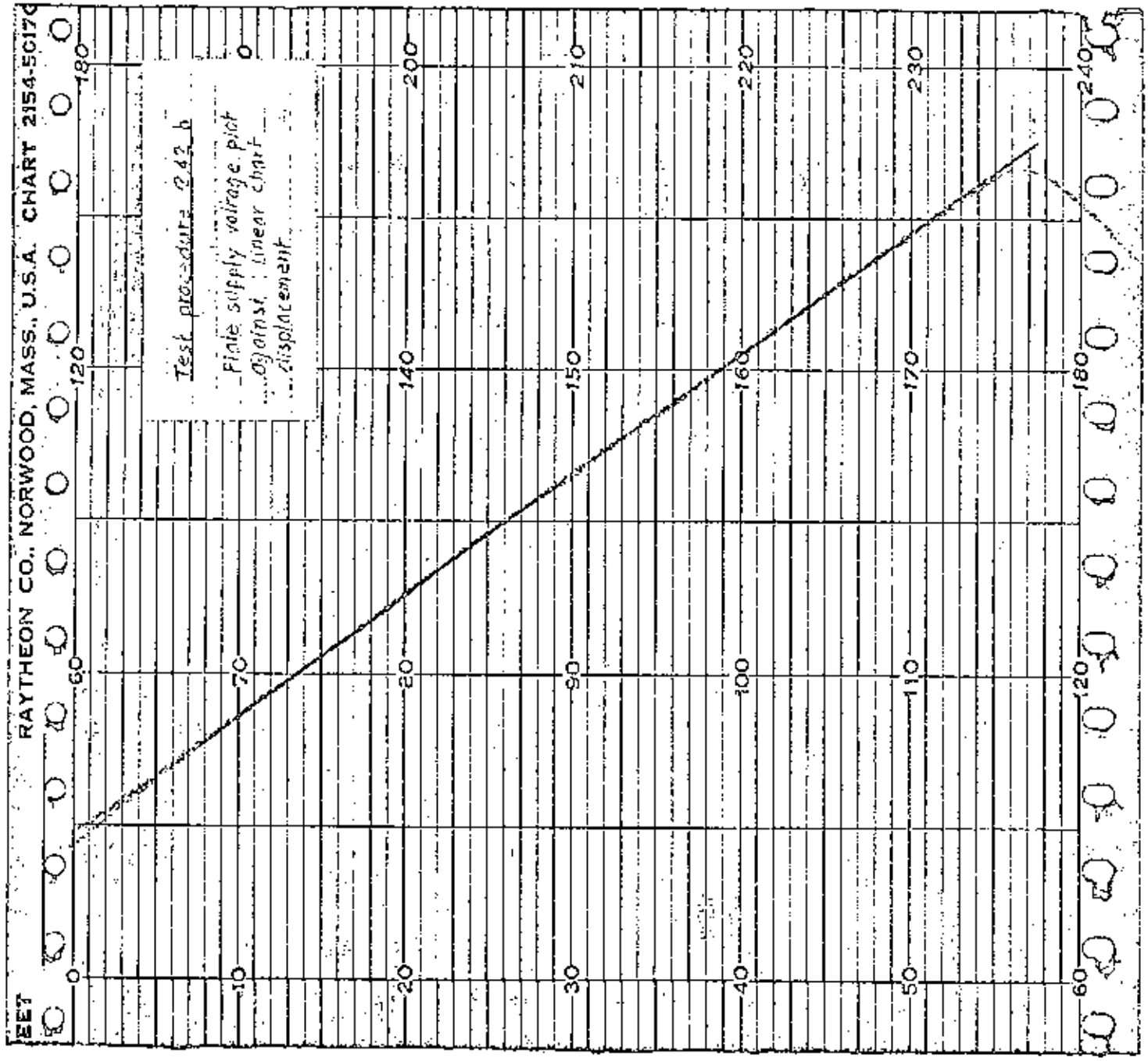


Fig. R60 Plate voltage supply linearity

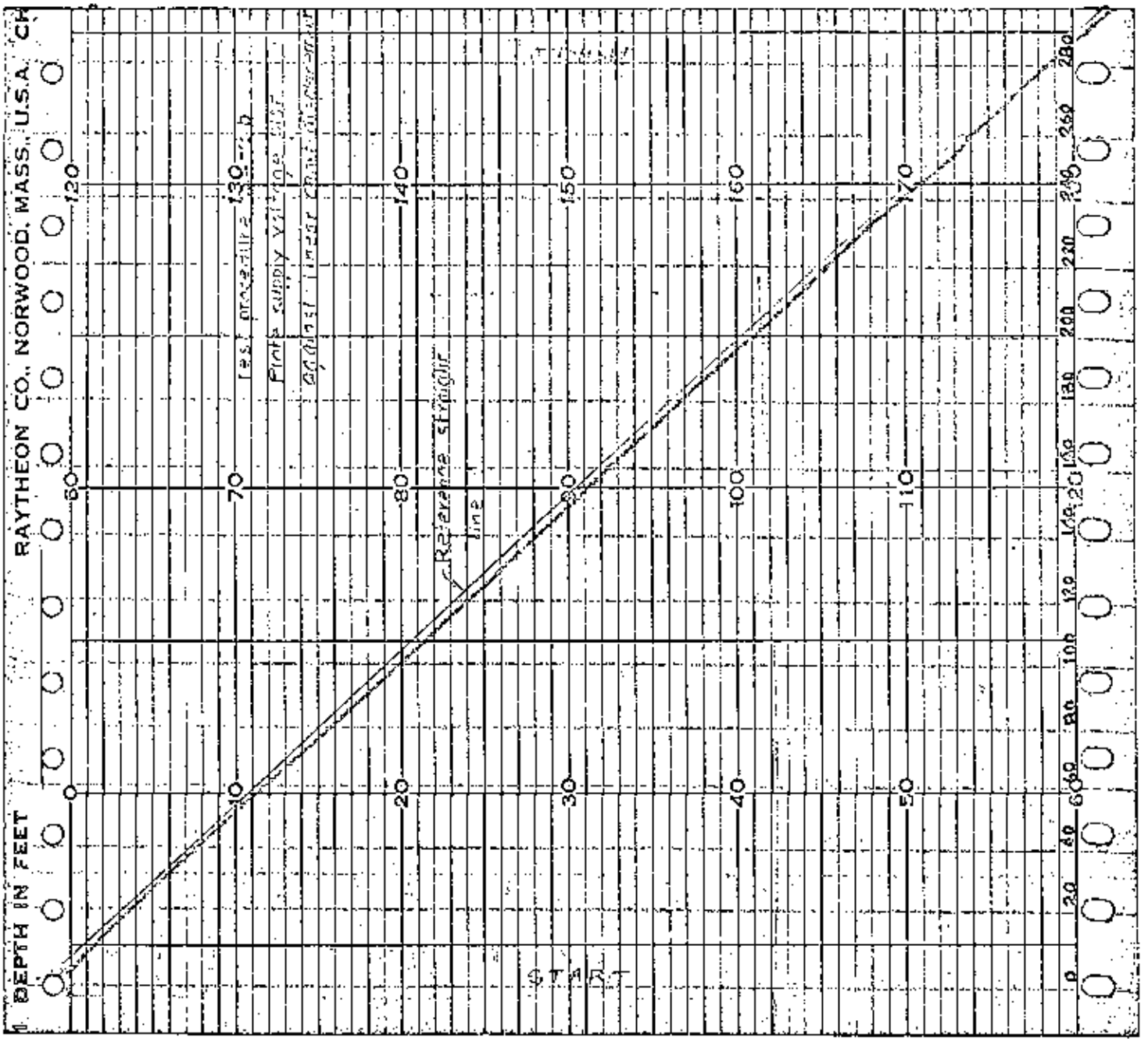


Fig. A 6b Plate voltage supply linearity

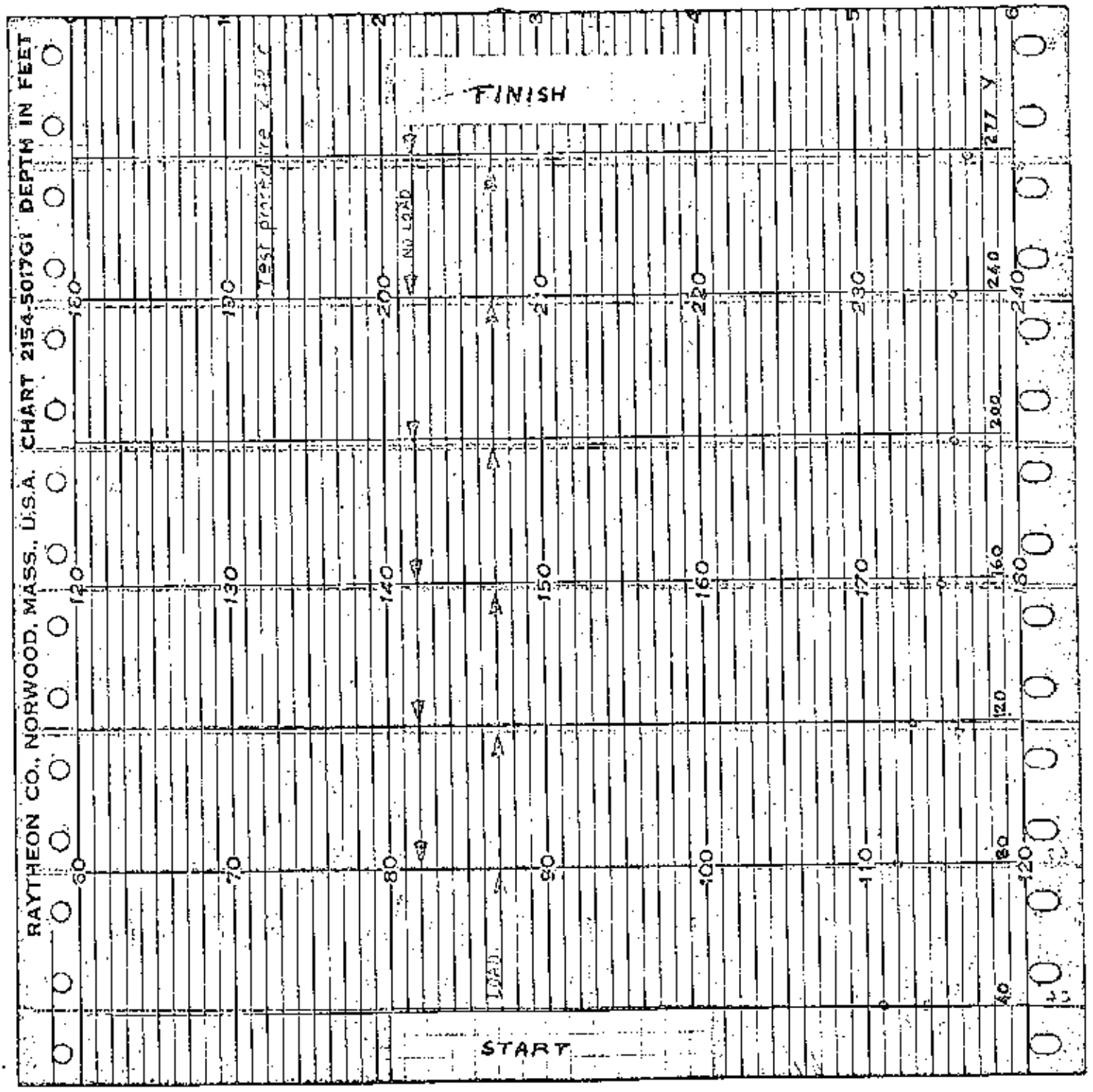


Fig. 27 Plot of plate voltage scale,

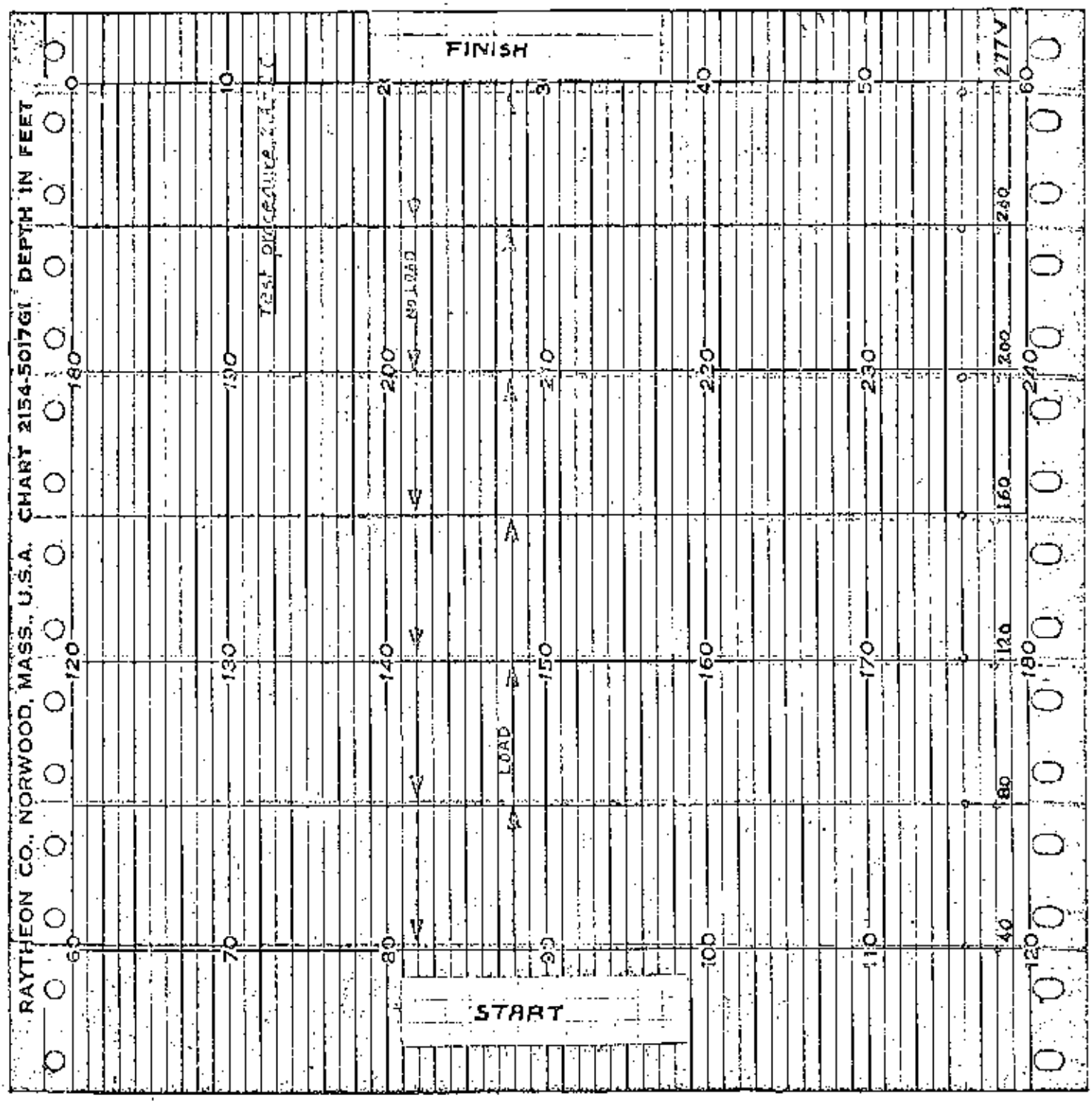


Fig. 8 Plot of plate voltage scale

Test data 2.4.3

Input and output voltage tracking test of buffer amplifiers.

BUFFER AMPLIFIER FOR POSITIVE RETURN OF GRID VOLTAGE SUPPLY UNIT											
Input voltage	0	.25	.50	.75	1.0	1.25	1.5	1.75	2.0	2.25	2.5
Output voltage	-.57	-.32	-.07	+.17	+.42	+.67	+.91	+1.16	+1.40	+1.65	+1.91
Voltage difference	.57	.57	.58	.58	.58	.58	.59	59	.60	.60	.59

BUFFER AMPLIFIER FOR VOLTAGE COMPARATOR							
Voltage drop	0	0.42	0.87	1.29	1.70	2.12	2.56
Output Voltage	2.5	2.09	1.67	1.26	0.85	0.48	0.04
Plate current ma.	0	1	2	3	4	5	6

Fig. R 9 a. Test data of buffer amplifiers.

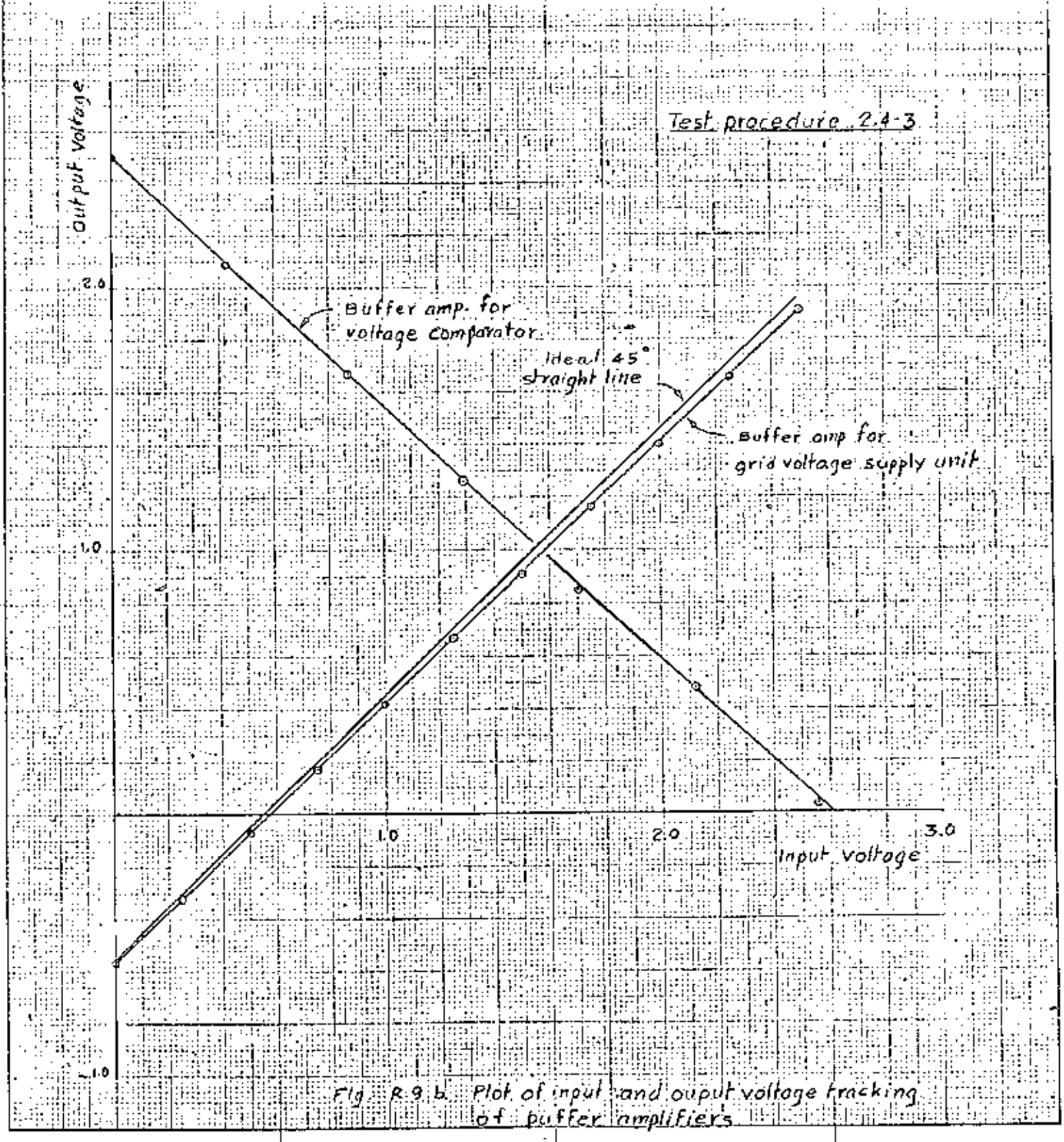


Fig. R.9.b. Plot of input and ouput voltage tracking of buffer amplifier's

Test data 2.44

Plate characteristics of vacuum tubes, tested by AVO tube tester

Plate current ma.						
Plate voltage	60	100	150	175	220	260
Grid voltage	VT1 ECC 83 Pin 1,2,3, TELEFUNKEN					
- 1.1	0	.31	1.12	1.6	2.6	3.2
- 1.52	0	.05	.51	.98	1.95	2.5
- 2.01	0	0	.10	.33	1.07	1.58
- 2.50	0	0	0	.04	.4	.75
	VT2 6C4 - Pin 5,6,7 HITACHI					
-5.5	0	1.4	6.1	9.2	17.5	21.8
- 6.0	0	.87	5.0	7.8	15.7	19.8
- 7.0	0	.33	3.0	5.6	12.0	16.5
-10.0	0	.05	.78	2.02	6.4	9.0
	VT3 ECC 82 Pin 1,2,13 TELEFUNKEN					
-5.5	0	.75	4.7	7.6	15	19
-6.0	0	.5	3.9	6.6	14	17.5
-7.0	0	.15	2.3	4.6	10.7	14.5
-10.0	0	0	.34	1.1	4.5	7.5

Fig. R 10

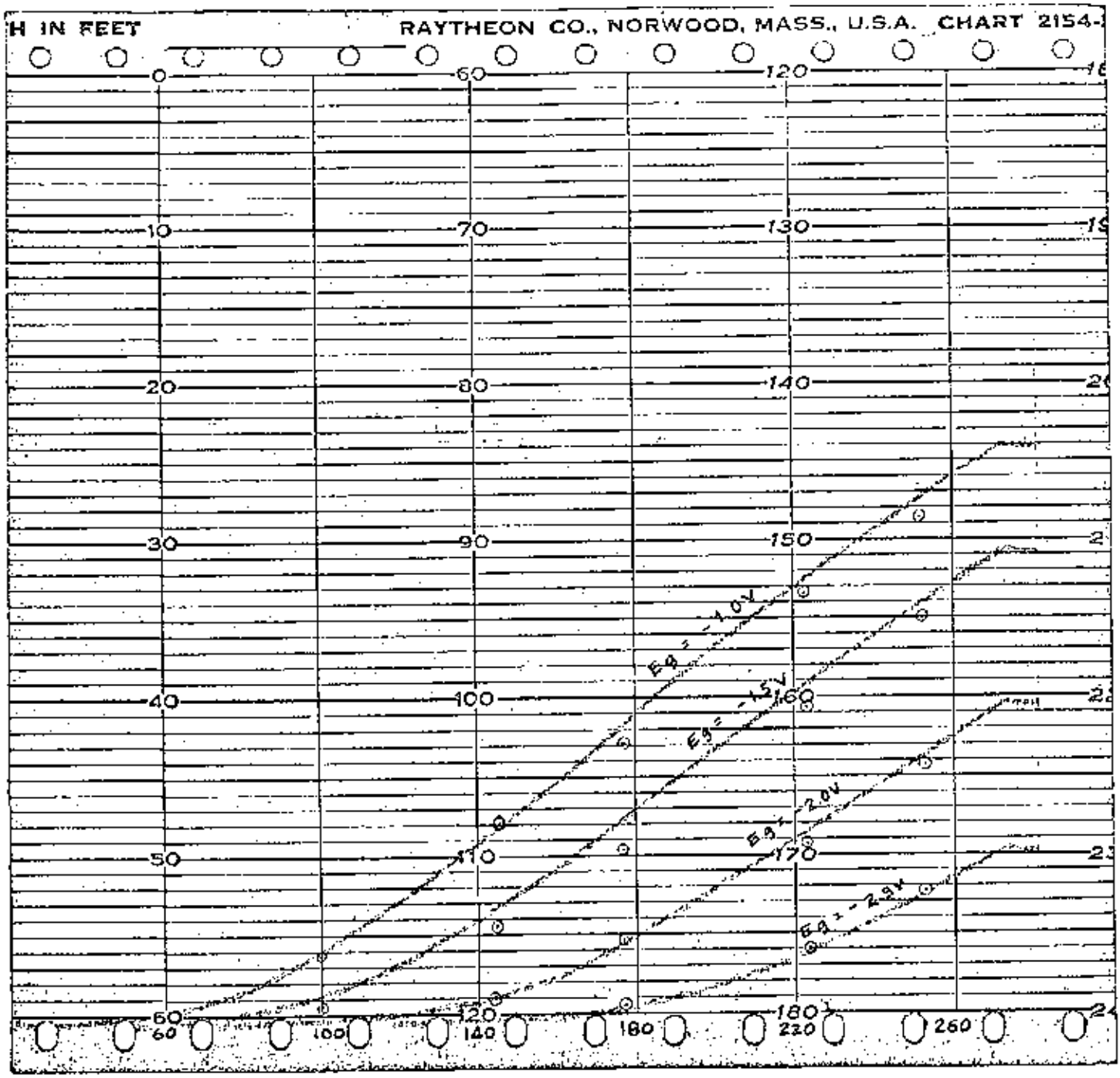


Fig. R11

Plate characteristics of VT1

ECC 83, High-mu twin triode, Telefunken

Pin No. , 1,2,3.

Remark: Manual plot of the VT2 is also shown in :

in this chart

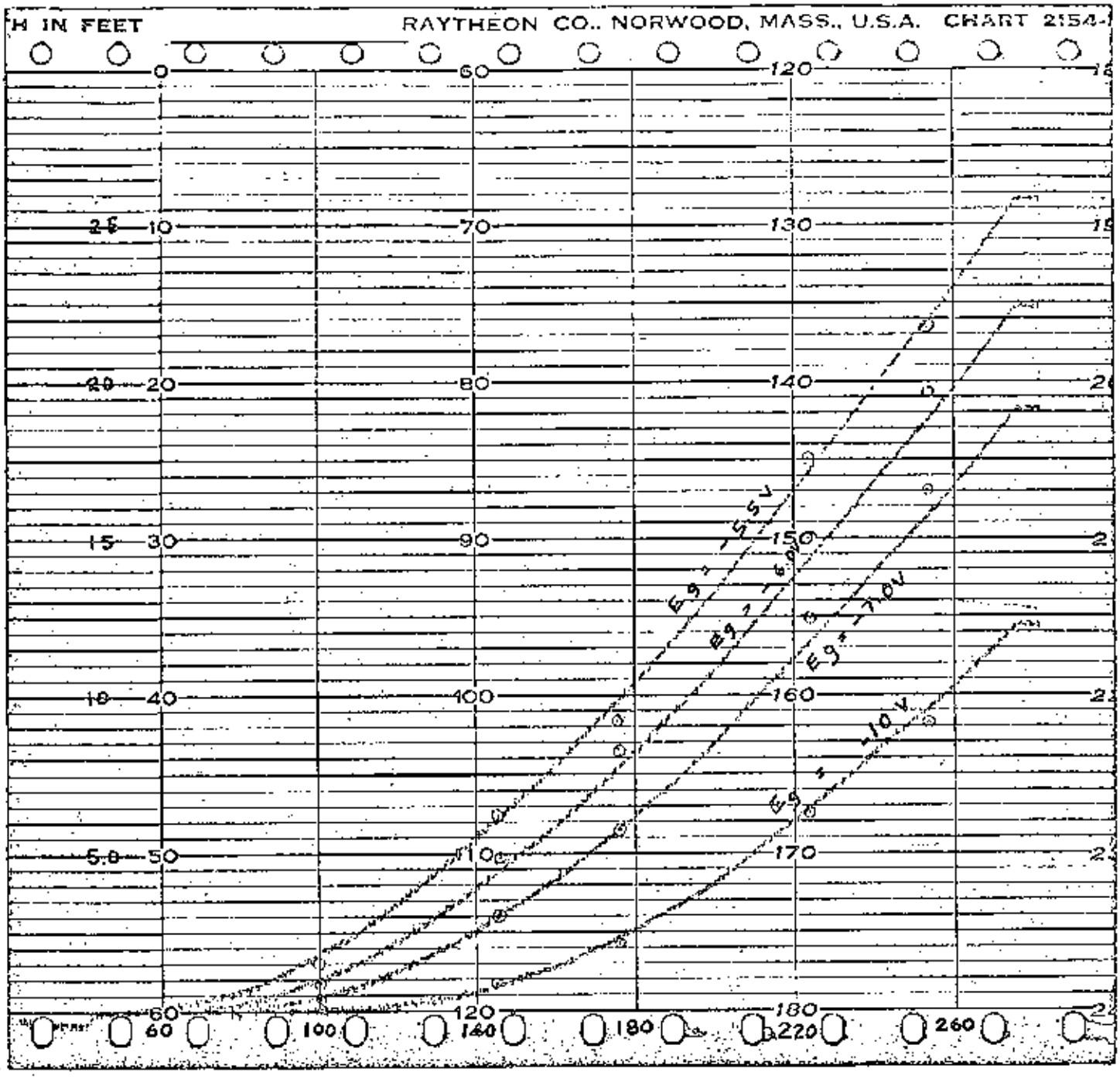


Fig. R12

Plate characteristics of VT2

6C4 , power triode , Hitachi

Pin no. , 5,6,7,

Remark :Manual plot of the VT2 is also shown in this chart.

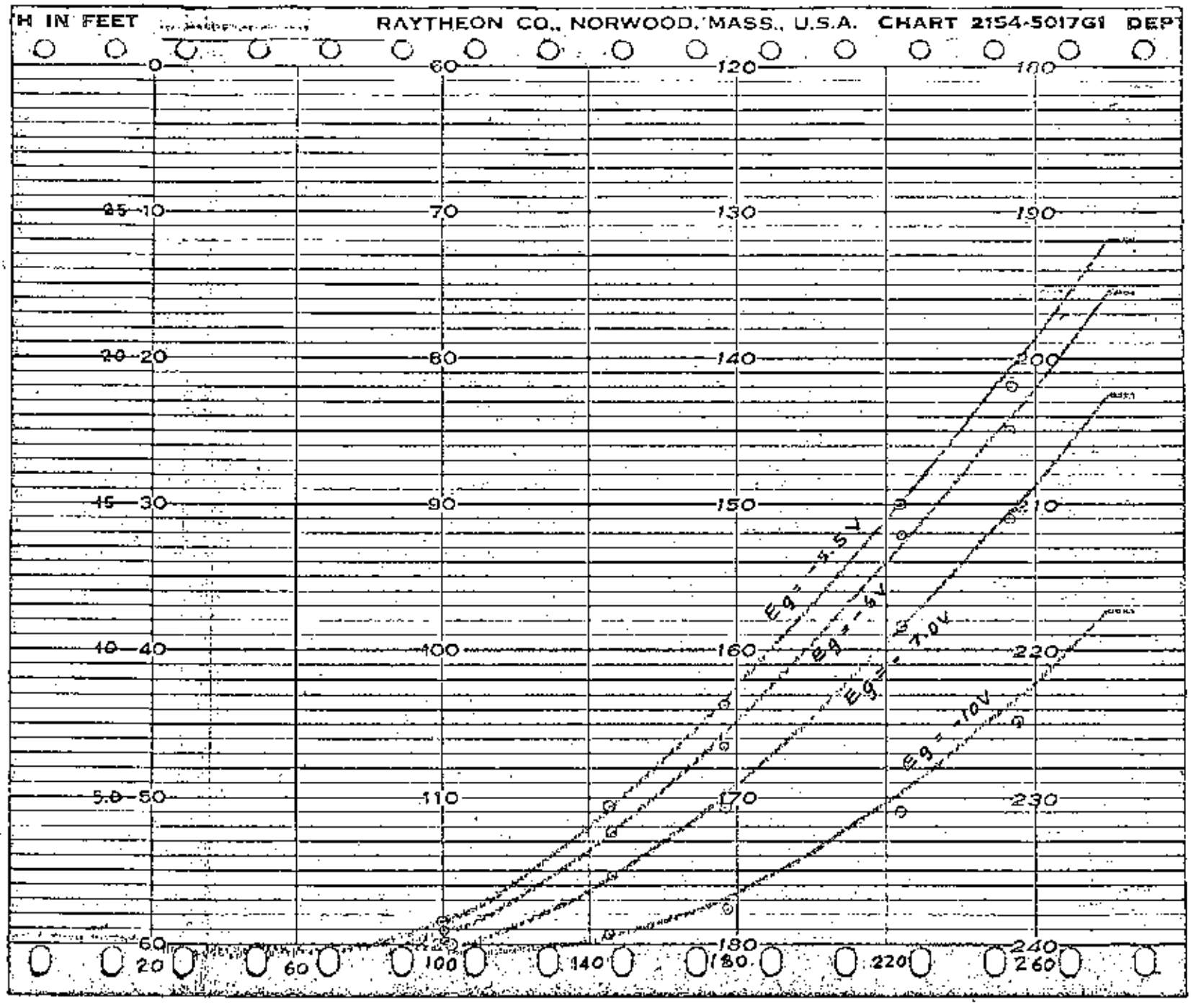


Fig. R13

Plate characteristics of VT3

ECC 82 , Medium-mu twin triode, Telefunken

Pin no., 1,2,3,

Remark Manual plot ot the VT3 is also shown in this chart

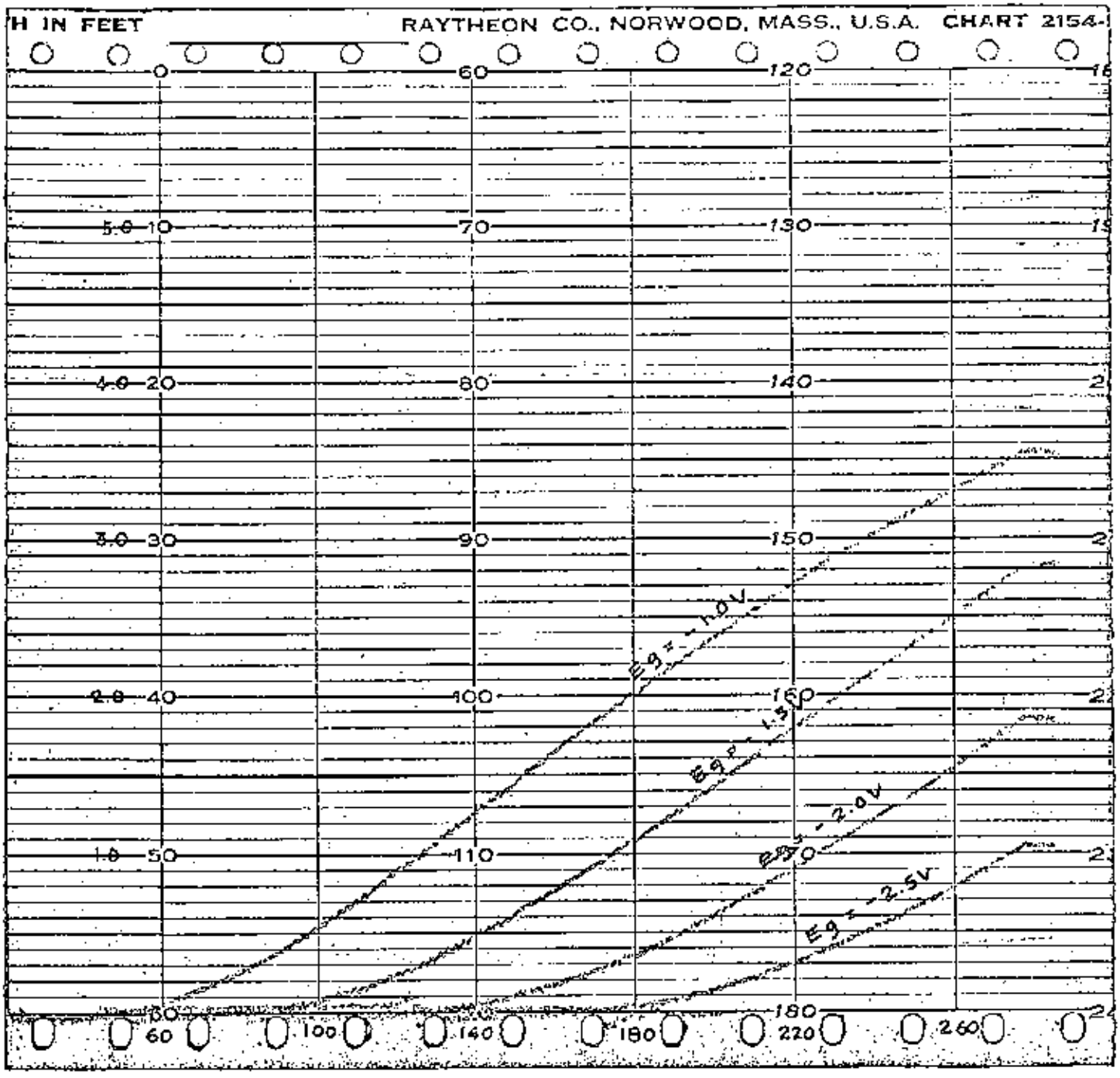


Fig. R14

Plate characteristics of VT1

ECC 83, High - mu twin triode, Telefunken

Pin no., 6,7,8,

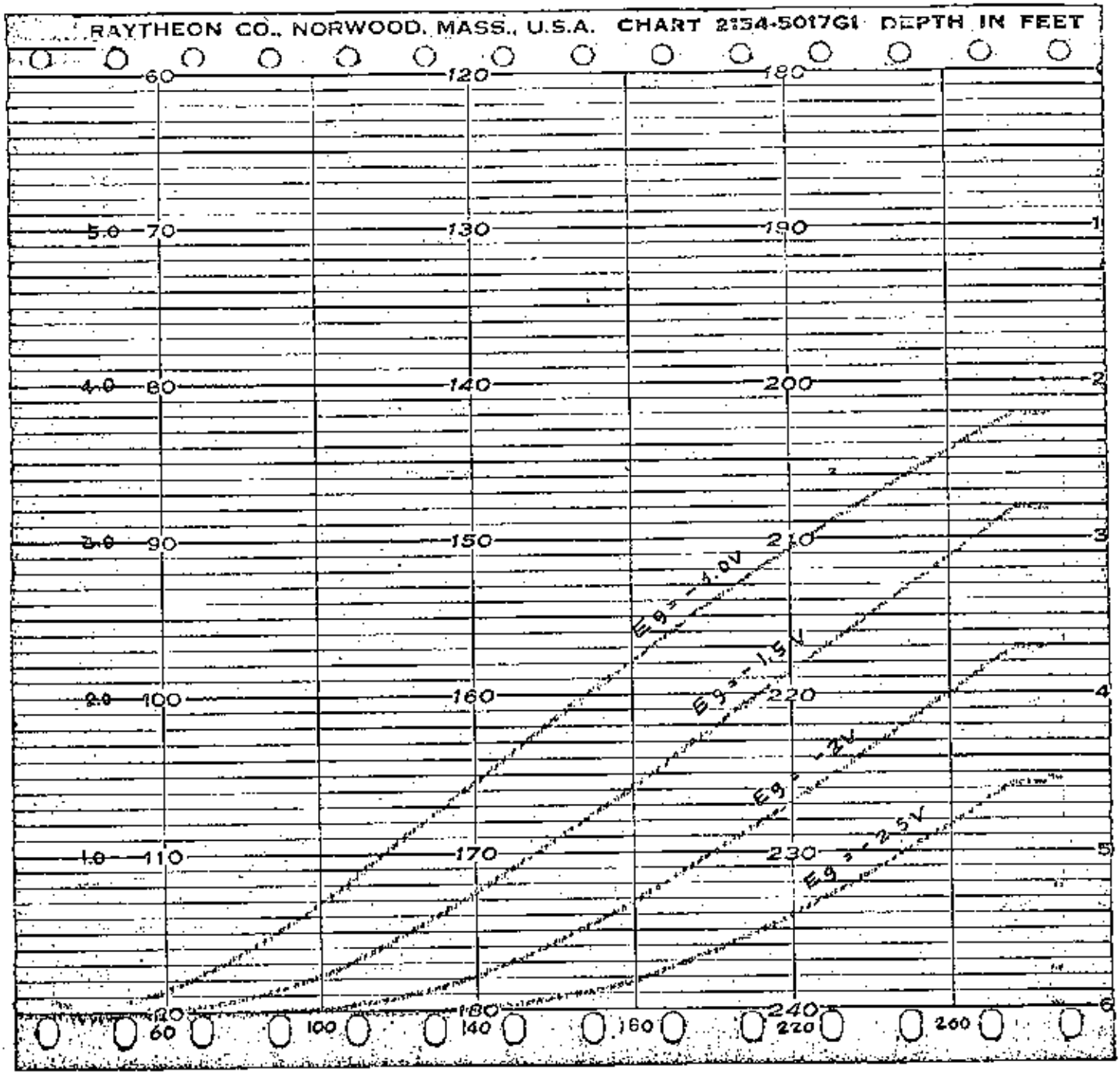


Fig. R15

Plate characteristics of VT4

ECC 83, High - mu twin triode, Philips

Pin no., 6,7,8,

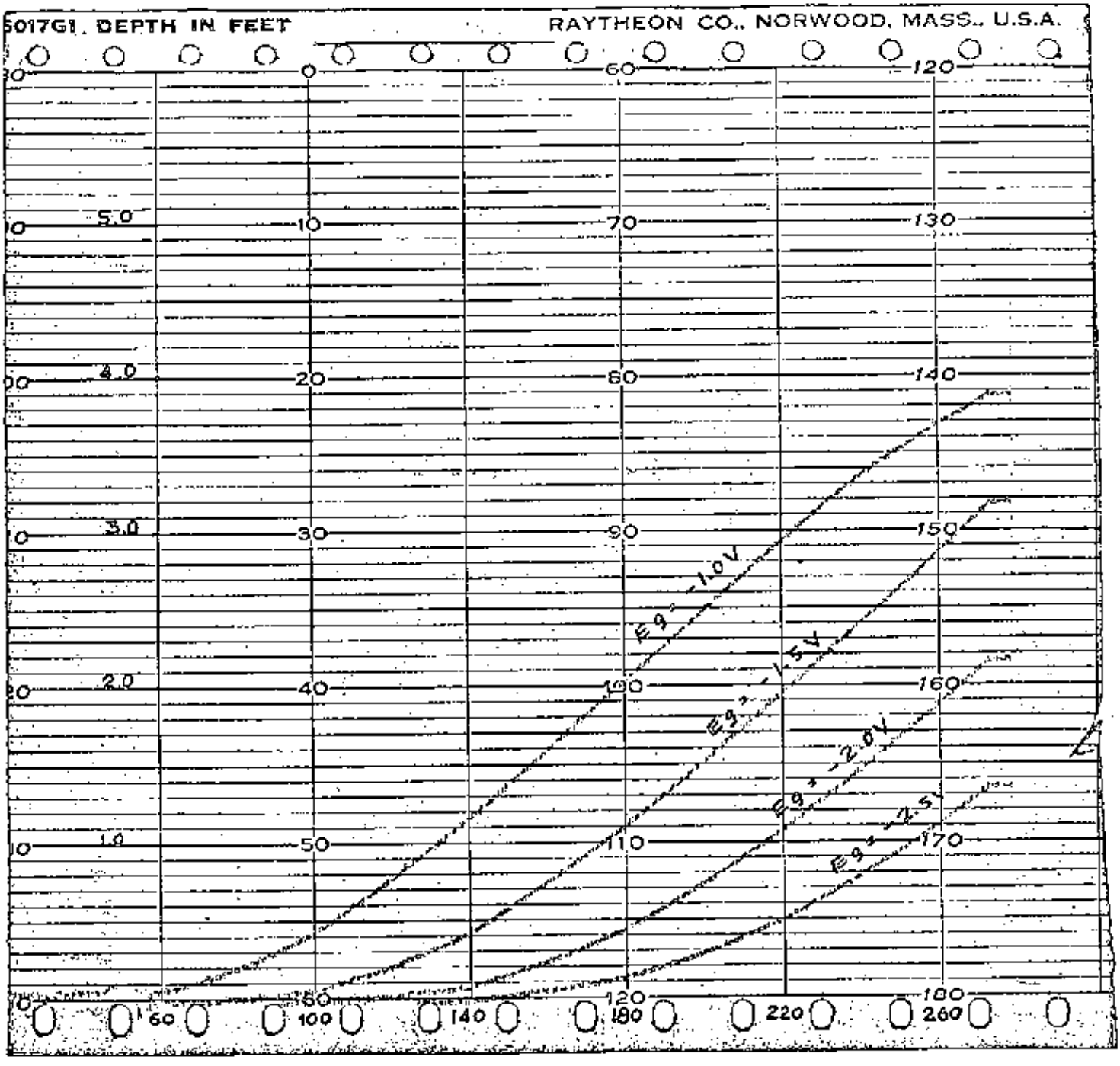


Fig. R16

Plate characteristics of VT4

ECC83, High - mu twin triode, Philips

Pin no., 1,2,3,

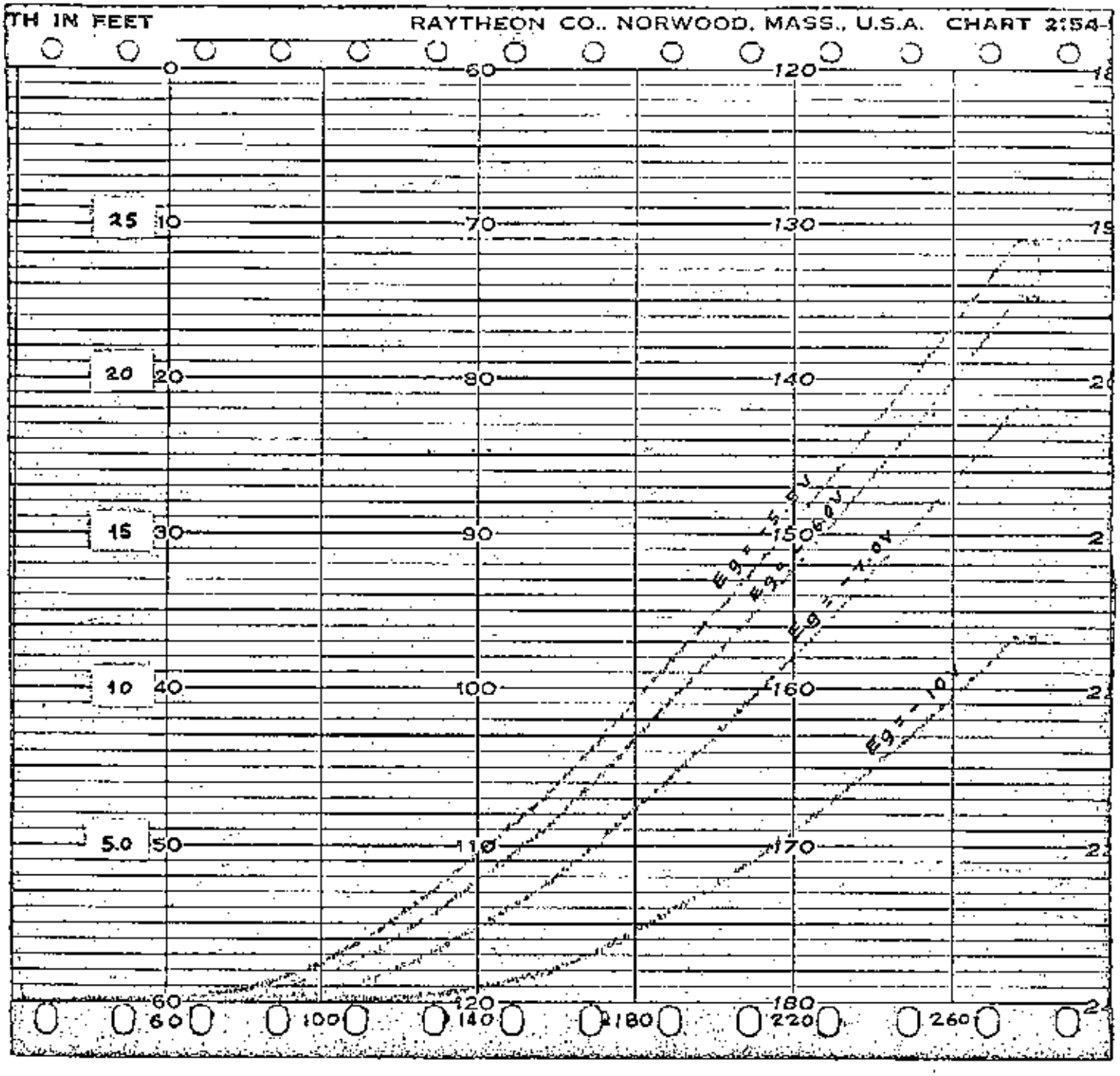


Fig. R17

Plate characteristics of VT3

ECC 82, Medium - mu twin triode, Telefunken

Pin no., 6,7,8,

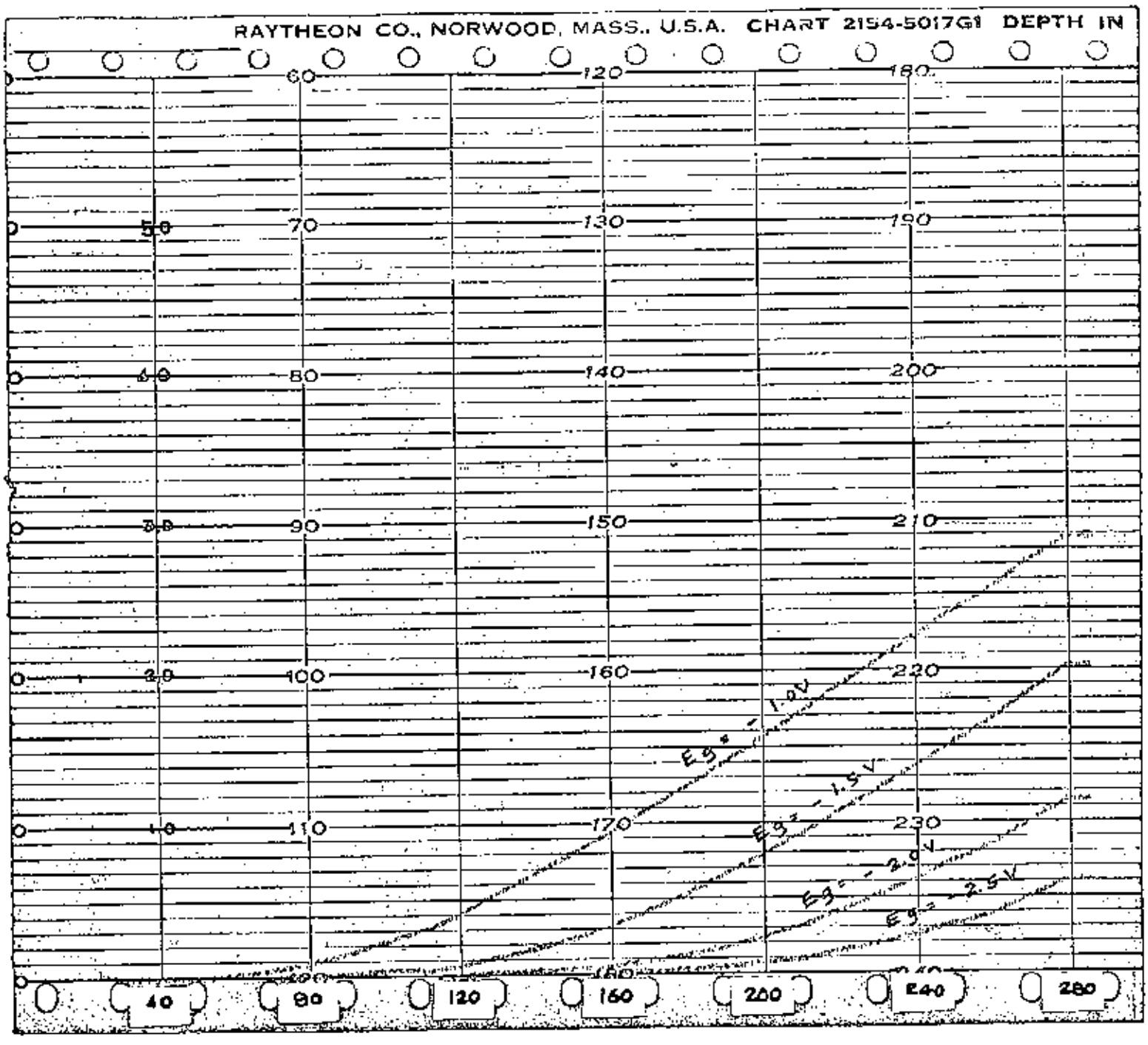


Fig. R18

Plate characteristics of VT5

12AX7, High - mu twin triode, Hitachi

Pin no., 1,2,3,

Remark VT5 is a used tube

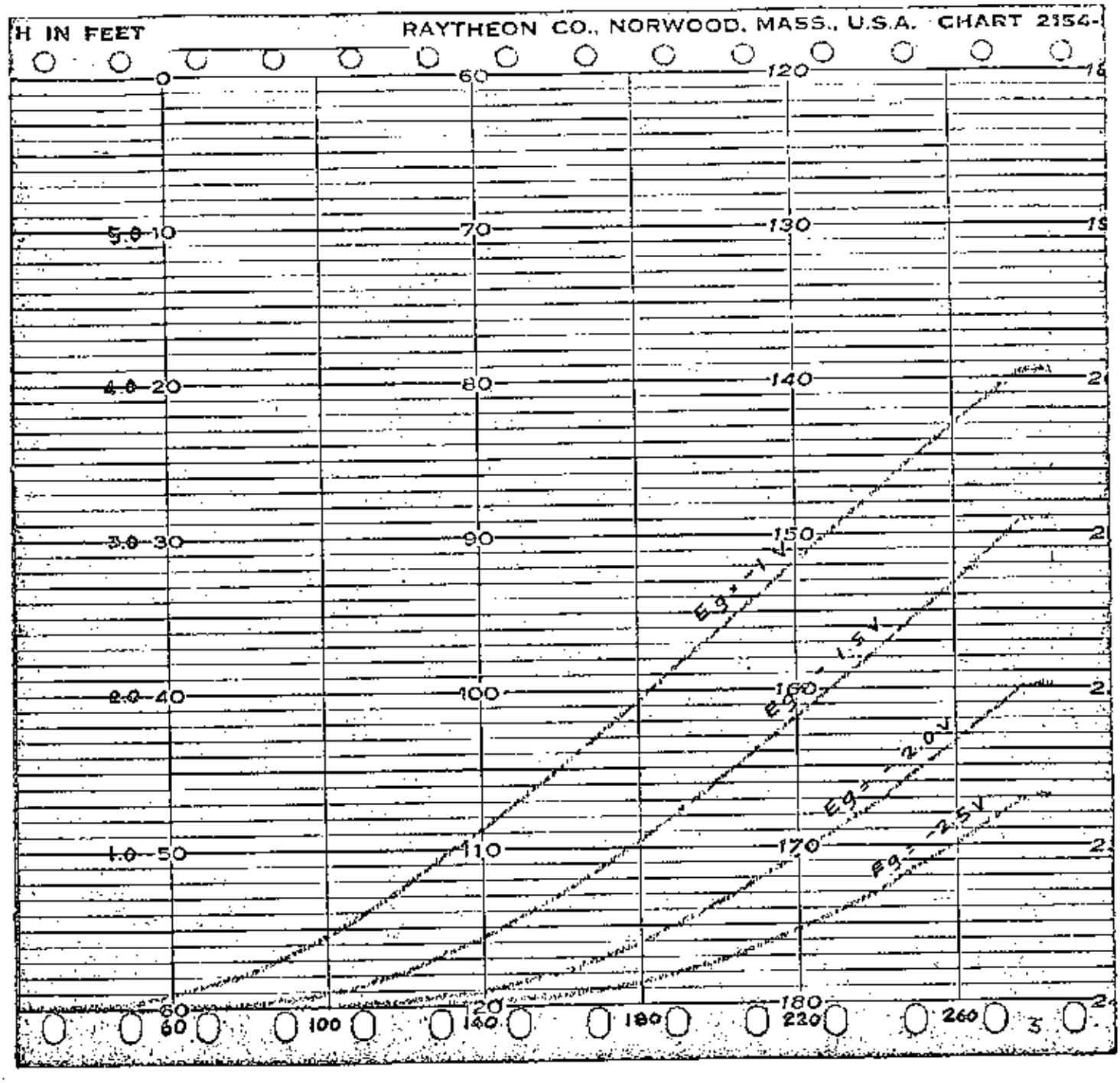


Fig. R19

Plate characteristics of VT6

12AX7, High-mu twin triode, Haltron

Pin no., 1,2,3,

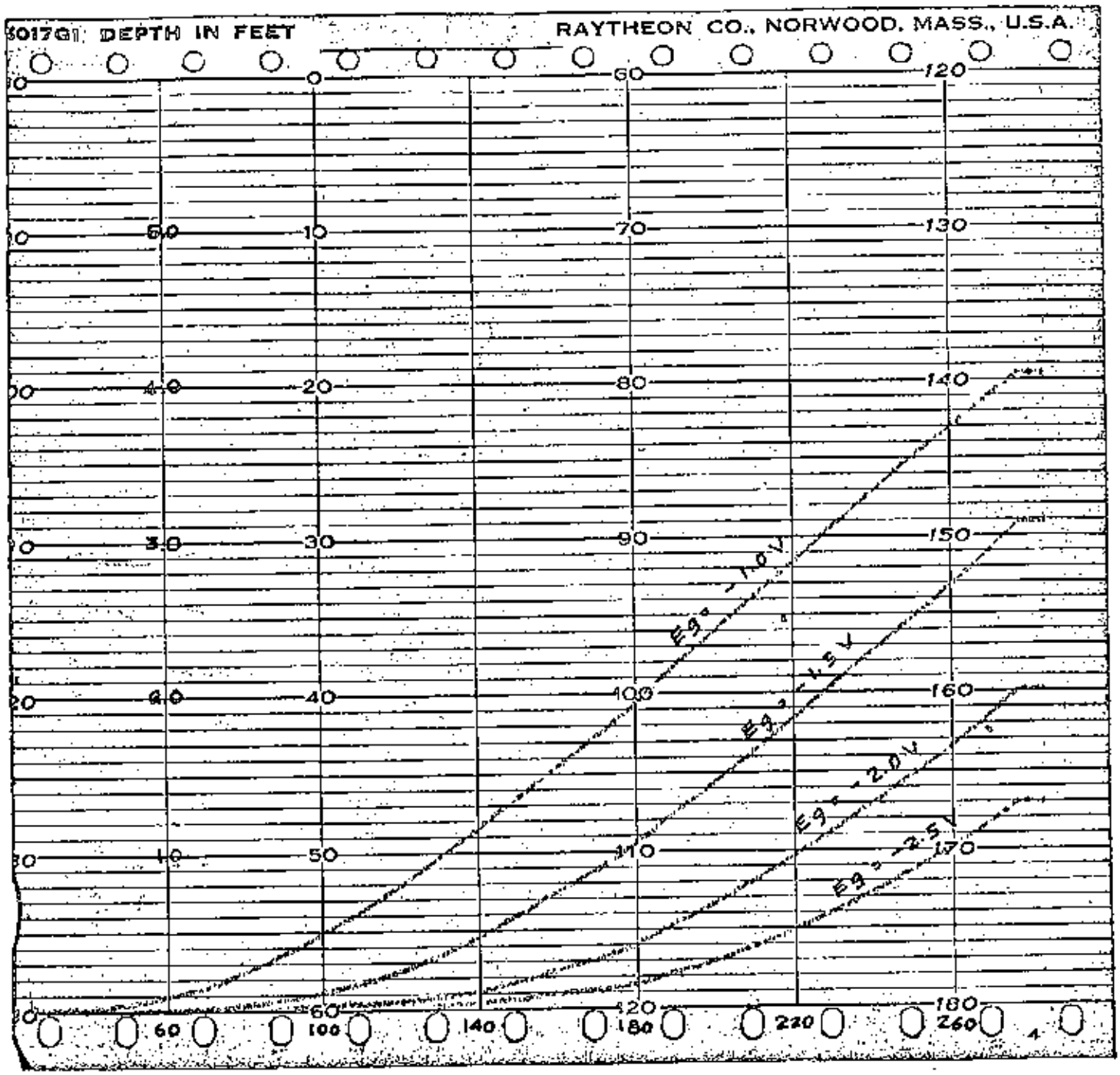


Fig. R20

Plate characteristics of VT6

12AX7, High - mu twin triode, Haltron

Pin no., 1,2,3,

Remark This curve is the repetition plot of figure R19

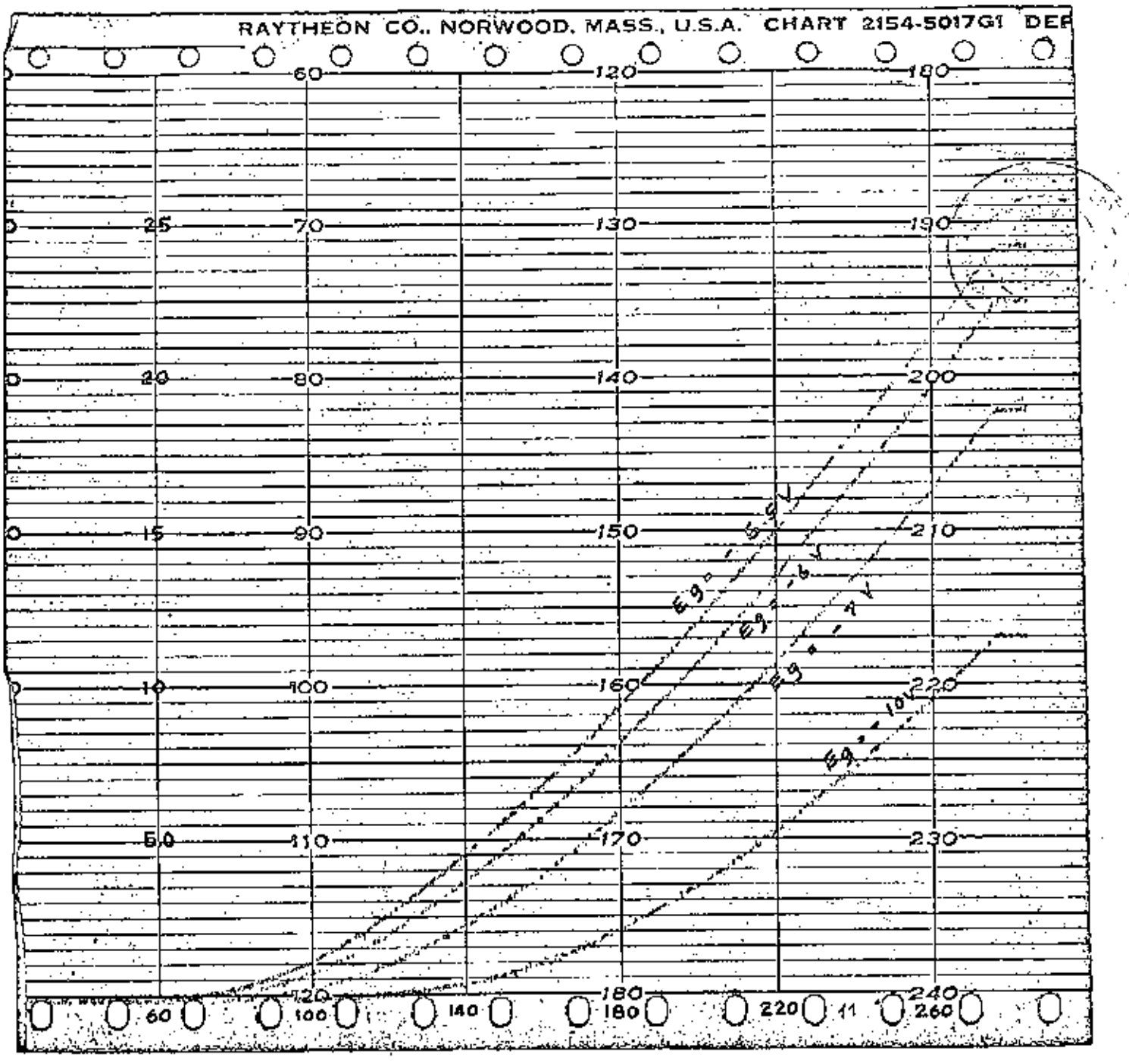


Fig. R21

Plate characteristics of VT7

12AU7, Medium - mu twin triode, Telefunken

Pin no., 6,7,8,

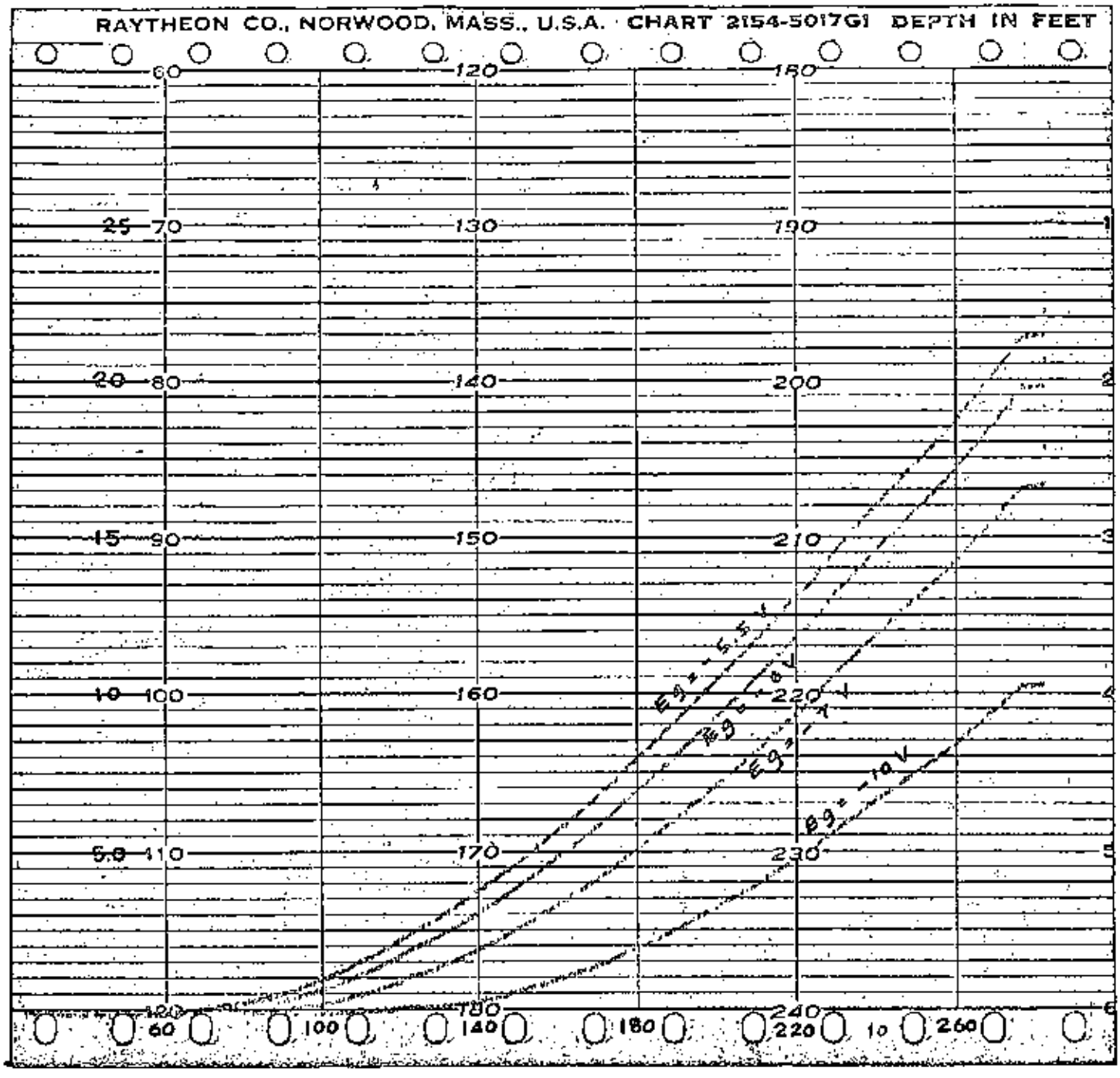


Fig. R22

Plate characteristics of VT8

12AU7, Medium - mu twin triode, Toshiba

Pin no. 6,7,8,

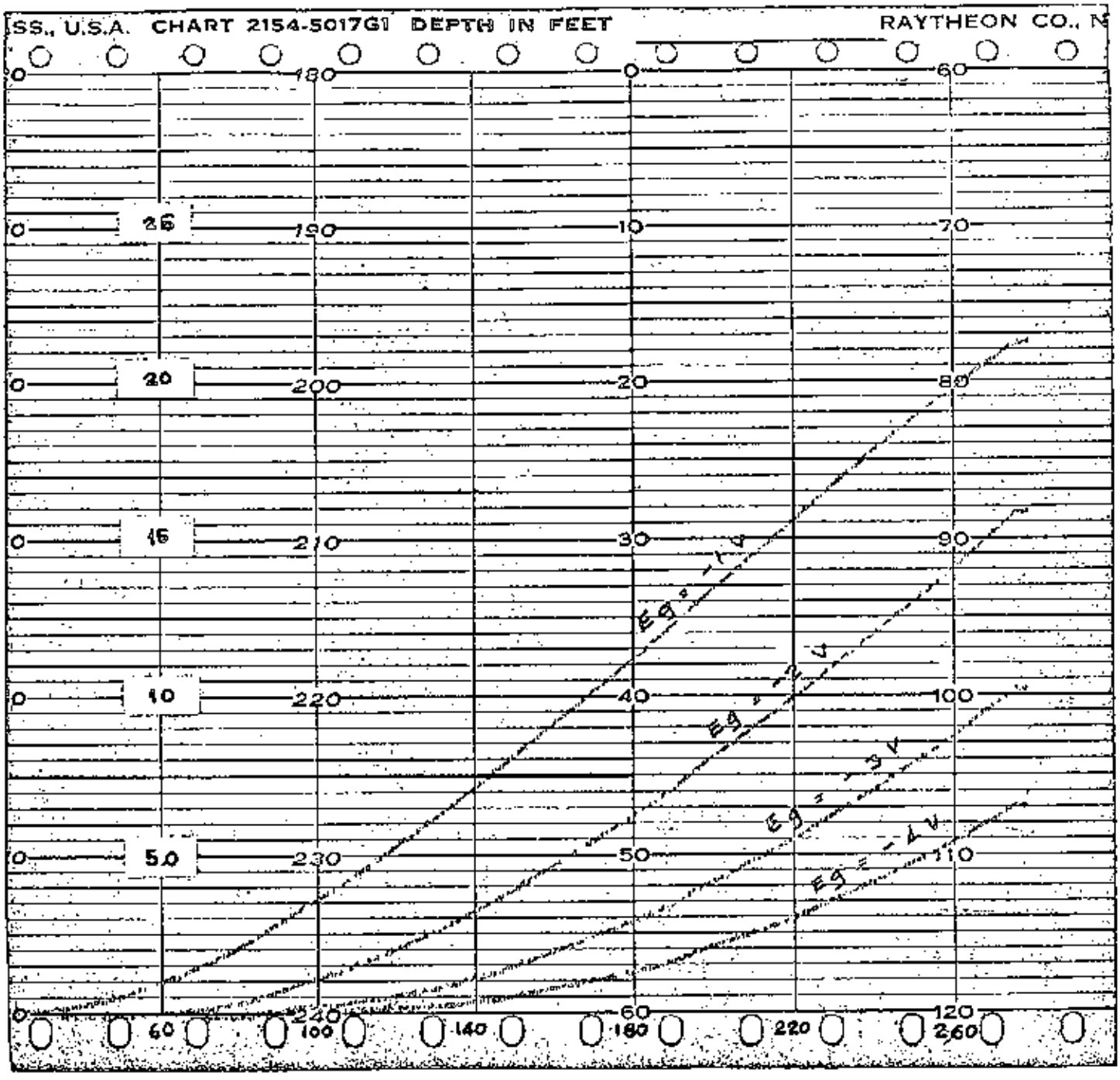


Fig. R23

Plate characteristics of VT9

12AT7, High-mu twin triode, Toshiba

Pin no., 1,2,3,

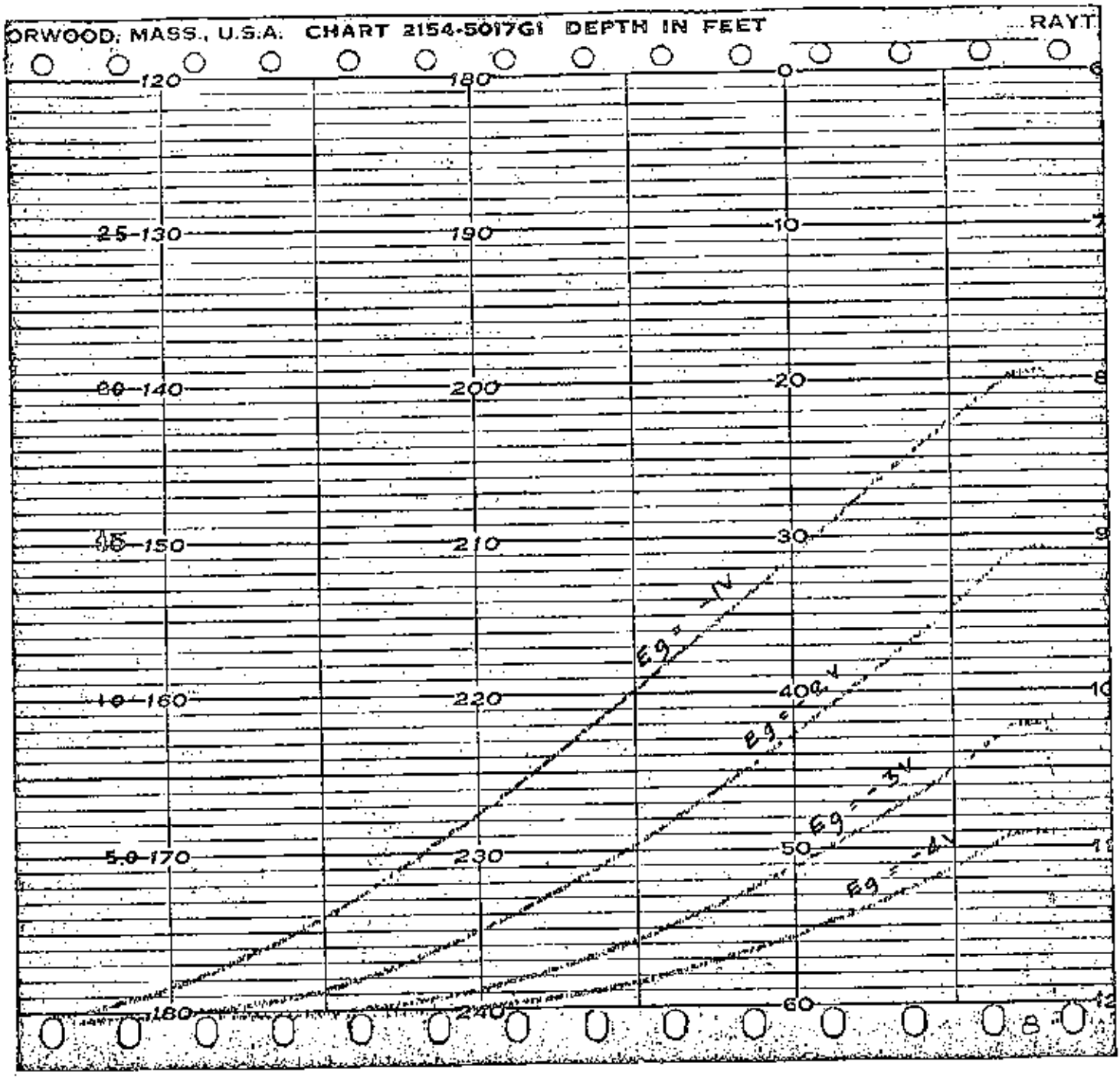


Fig. R24

Plate characteristics of VT10

12AT7, High-mu twin triode, Philips.

Pin no., 1,2,3.

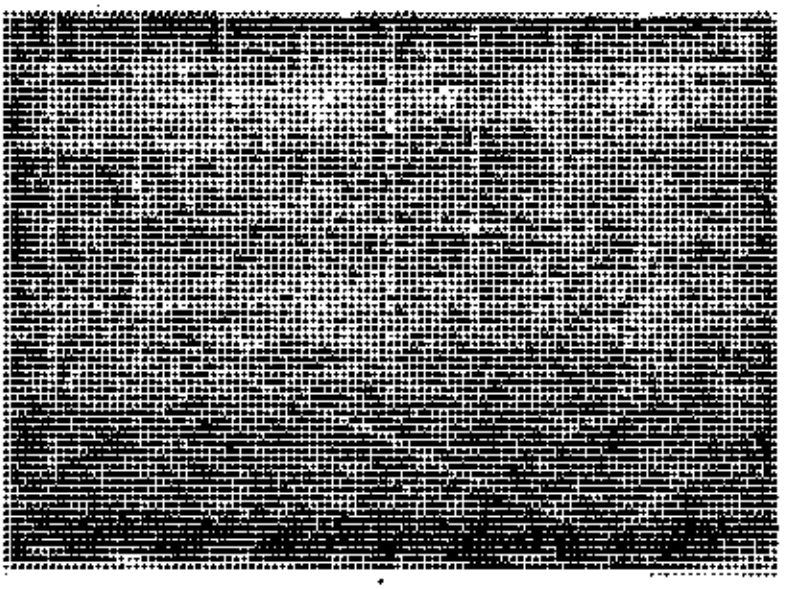


Fig. R25

Upper Triggering pulse from light sensing transistor, 10 V/cm.

Lower Linear sweep from out put of buffer amplifier, 1 V/cm.

Sweep 5ms/cm.

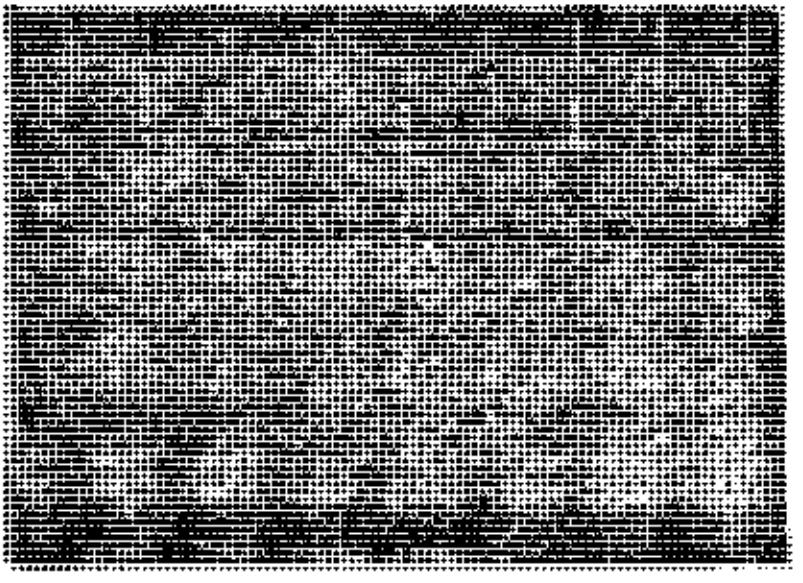


Fig. R26

Upper Comparator output voltage, produced from 1.5 V constant input, 5 V/cm.

Lower Linear sweep from output of buffer amplifier, 1V/cm.

Sweep Non scale, external synchronized pulse from light triggering unit

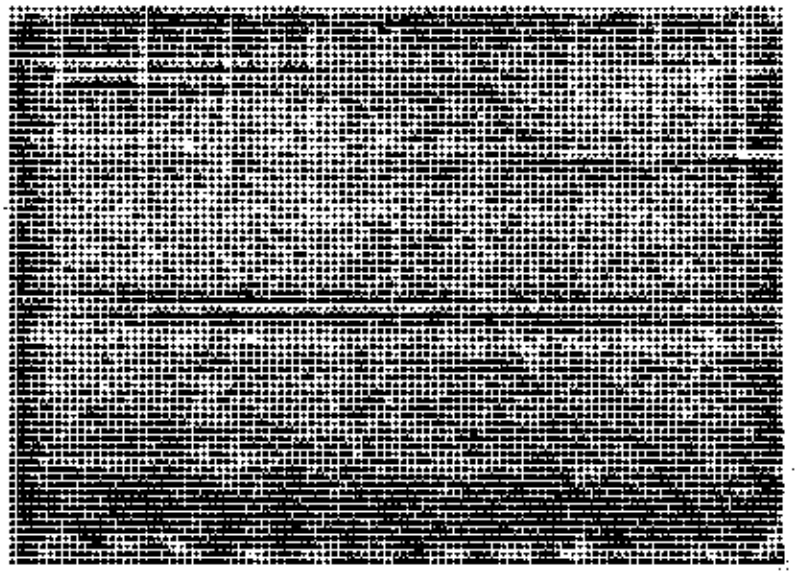


Fig. R27

Upper Comparator output voltage wave form, 5 volts/cm

Lower Output from schmitt trigger , 10 volts/cm

Sweep 1 ms/cm , delay 12ms

Fig. R28

Upper Linear sweep from output of buffer amplifier, 0.5volts/cm

Lower Voltage drop across cathode resistor, 6ma scale, 1 volts/cm

Sweep 2 ms/cm, delay 10 ms

Tested condition Plate voltage = 250 volts , grid voltage was adjusted sothat cathode current was equally spaced between 3.5 ma to 0.5 ma . Tested by ECC 63

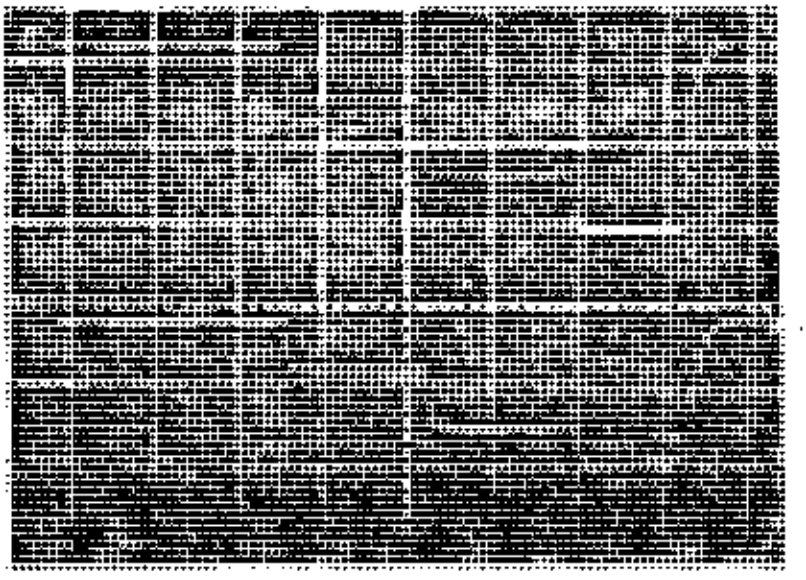


Fig. R29

Upper Voltage between grid to ground 1volt/cm

Lower Voltage drop across cathode resistor 0.5 volt/cm

Sweep 2 ms/cm , delay 10 ms

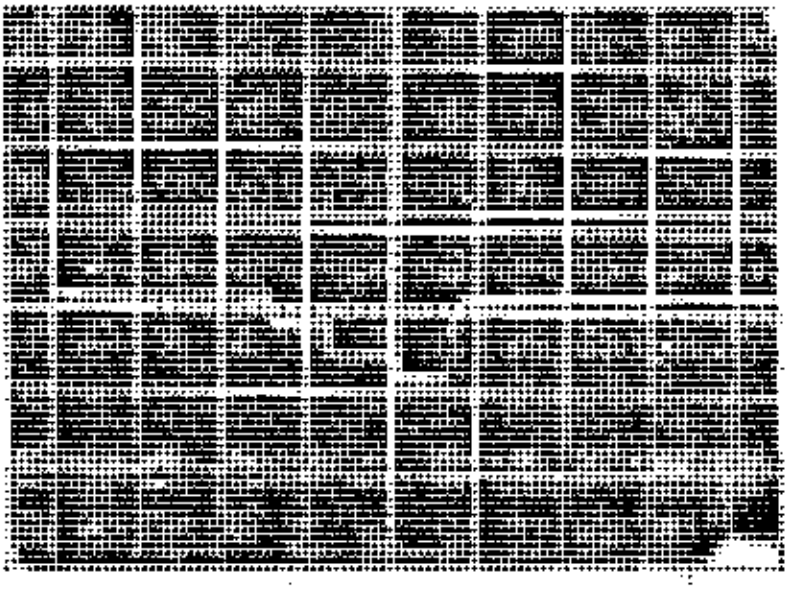


Fig. R30

Upper Marking pulse from stylus trolley. 100 volts/cm

Lower Voltage drop across cathode resistor. 1 volts/cm

Sweep 5 ms/cm

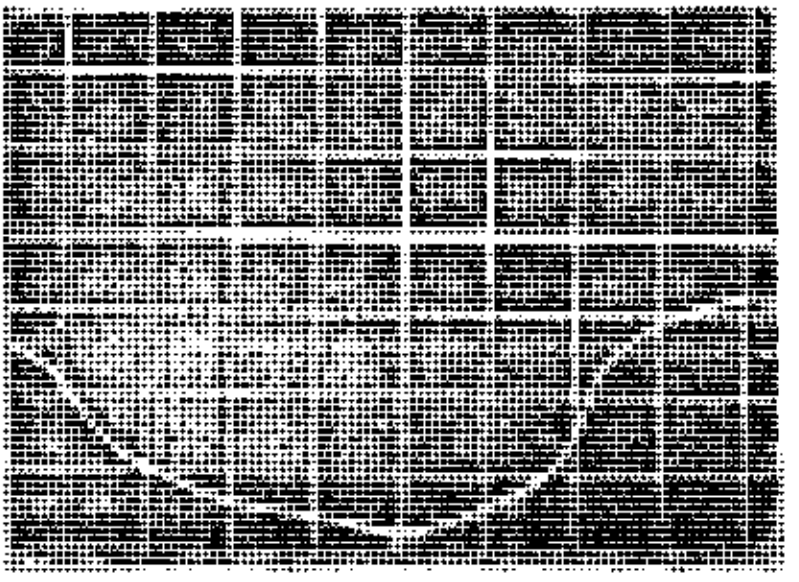


Fig. R31

Upper Marking pulse from output of schmitt trigger, 1volt/cm
Lower Voltage from comparator limitter, 0.1 volt/cm
Sweep 5ms/cm , delay 12ms

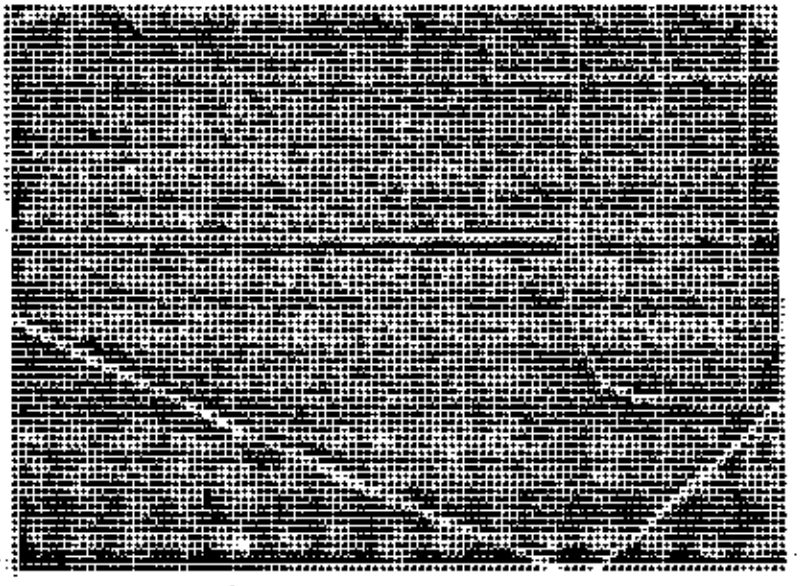


Fig. R32

Upper Gate pulse from Monostable sweepwidth control , 10 volt/cm
Lower Linear sweep from output of buffer amplifier, 1volt/cm
Sweep 5 ms/cm

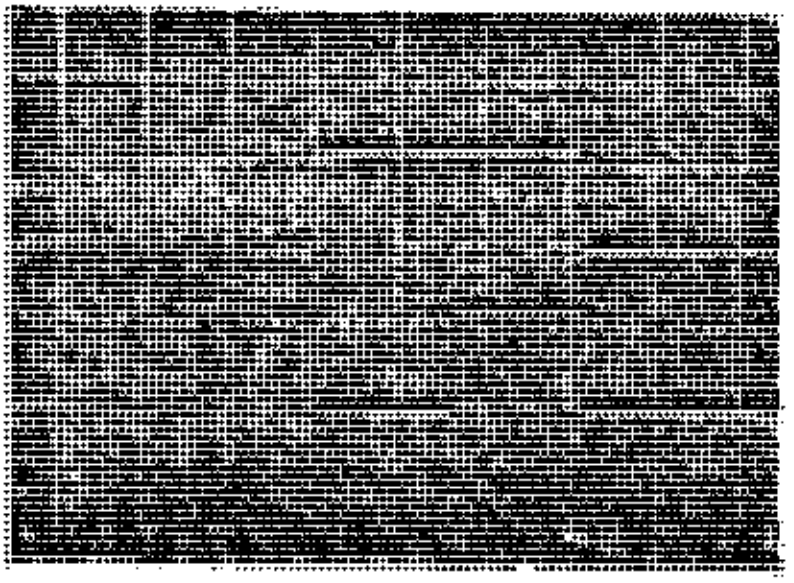


Fig. R33

Upper Signal from collector of TR 15 , 10 volt/cm

Lower Signal from collector of TR 12 , 10 volt/cm

Sweep 2 ms/cm, delay 7.5 ms

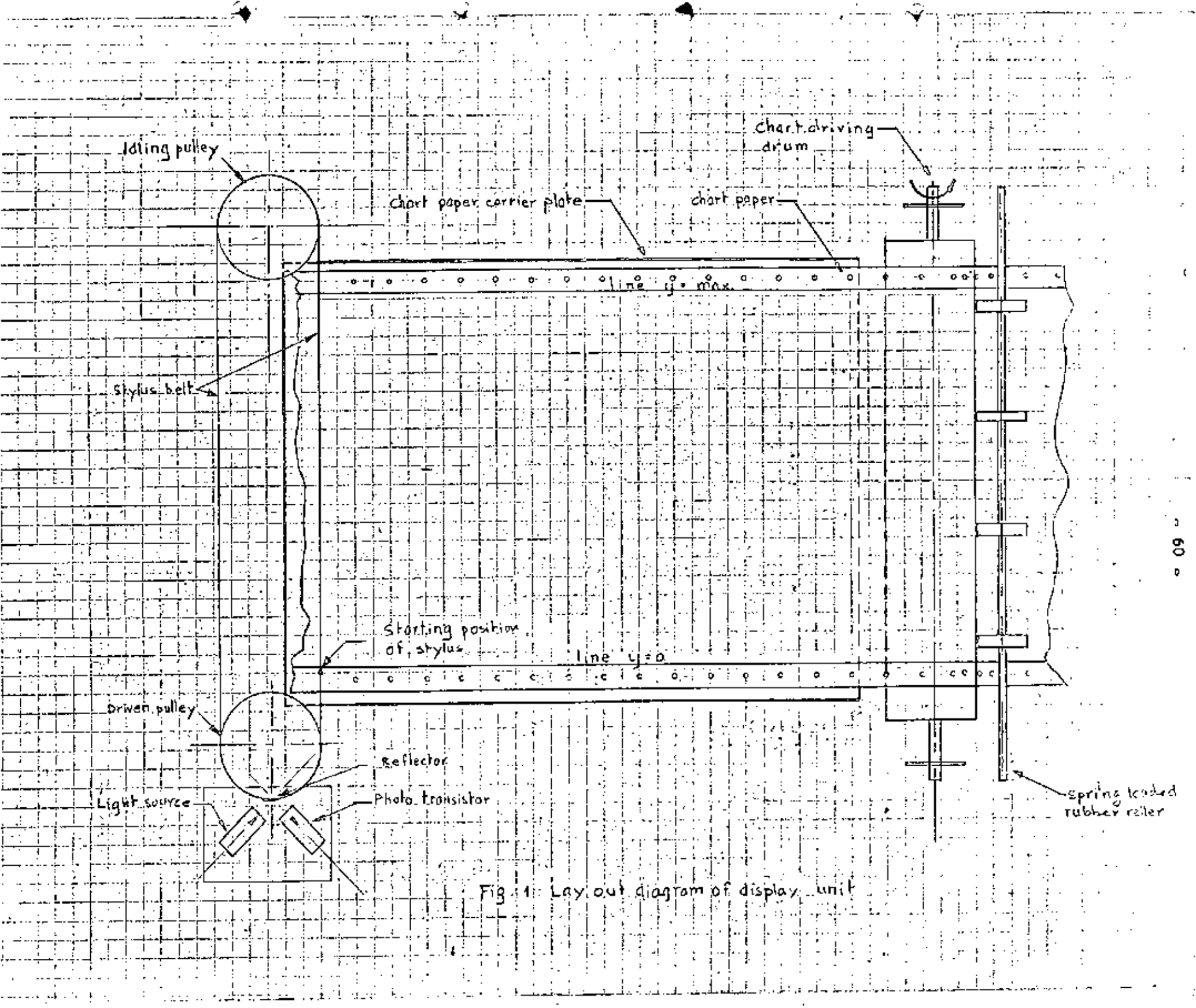


Fig. 1: Lay out diagram of display unit

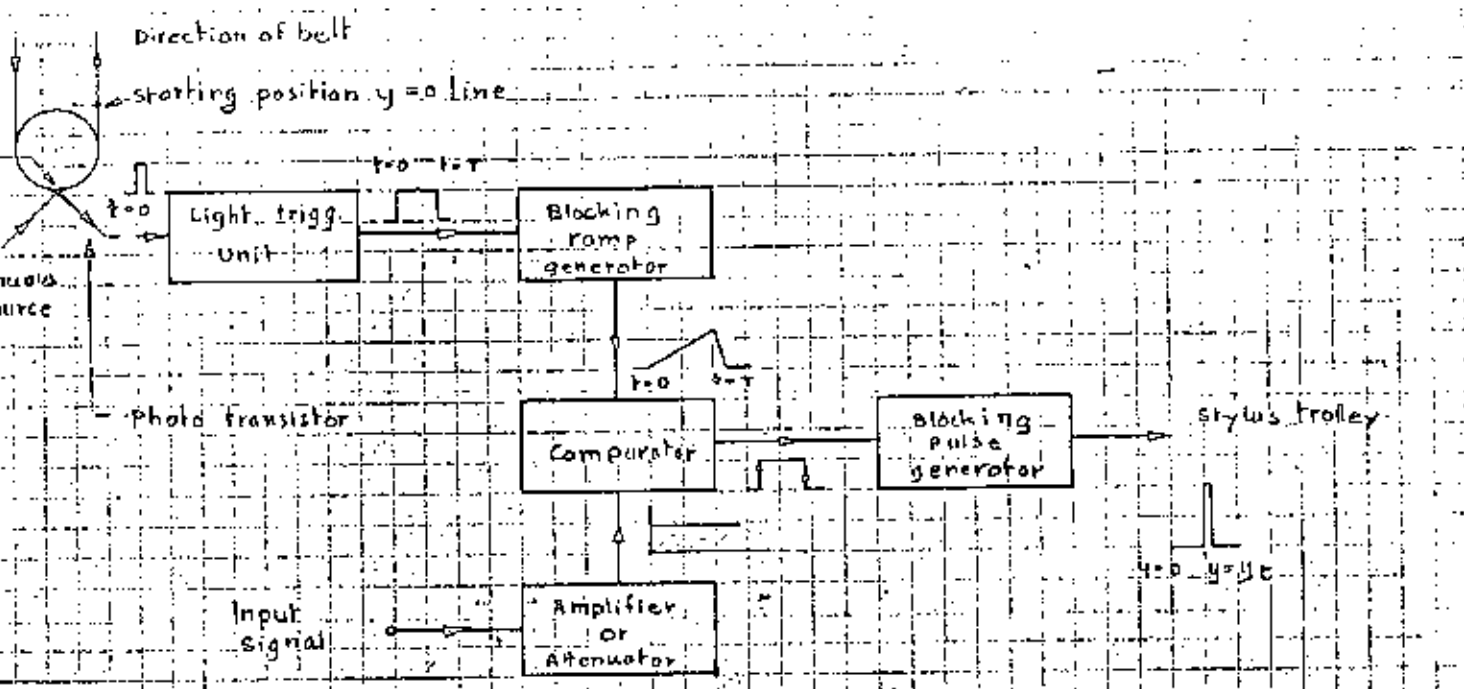


Fig. 2 a Block diagram show function of electronic circuits

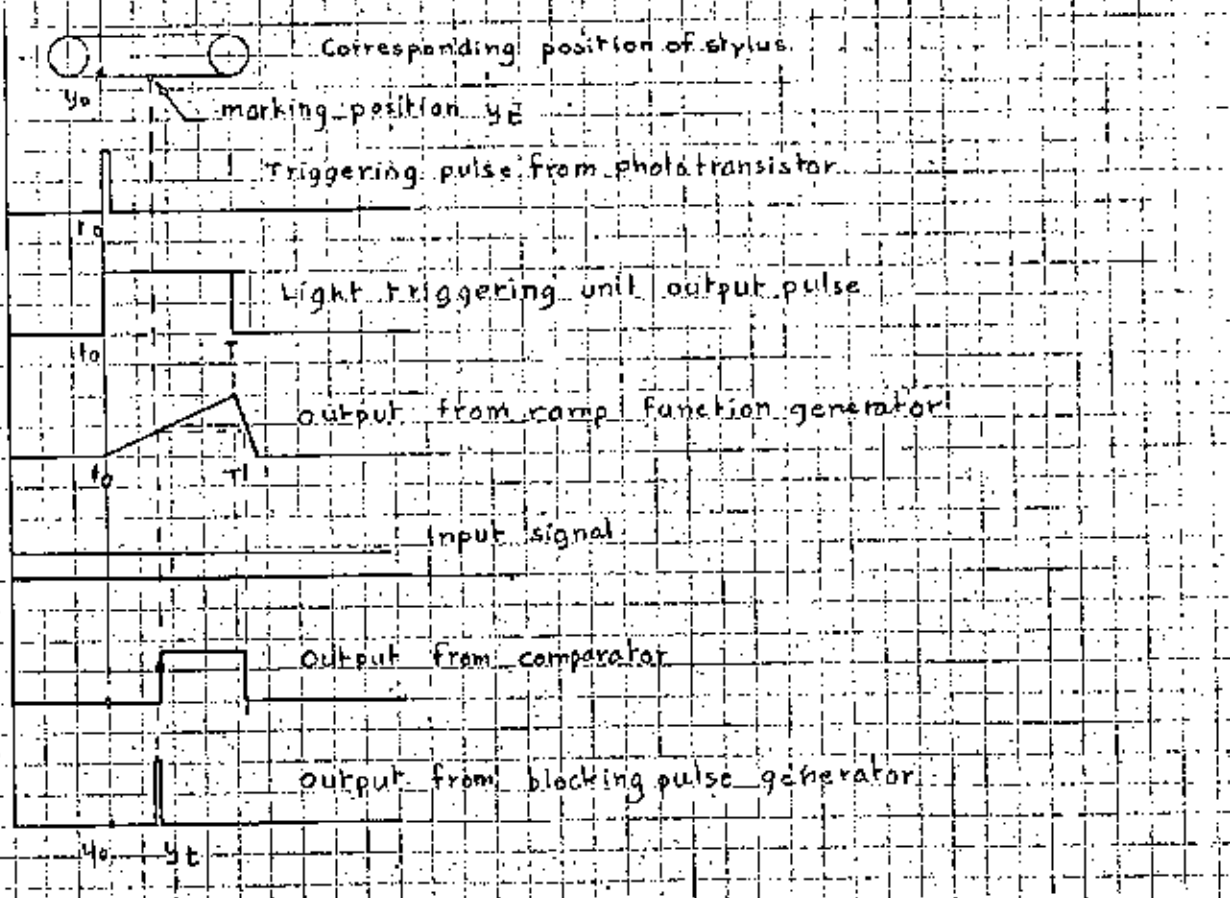


Fig. 2 b Circuit Wave form

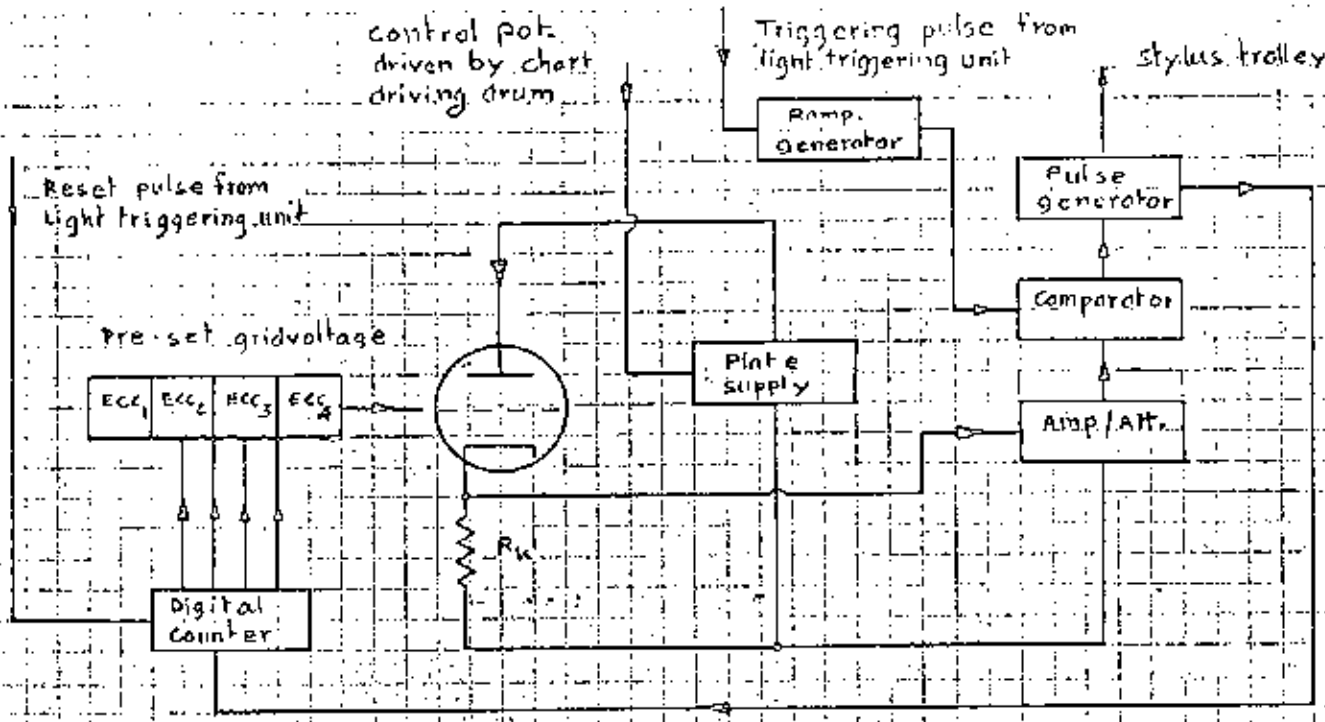


Fig. 3.a Functional diagram of the vacuum-tube characteristic plotter

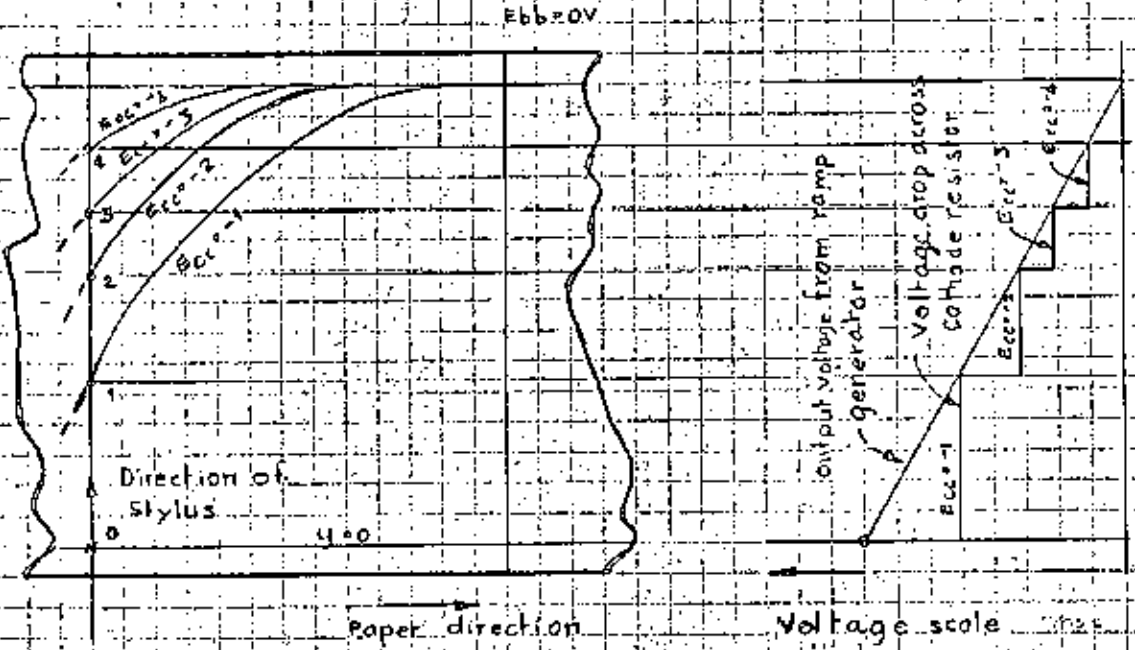


Fig. 3.b Sequence of plotting operation

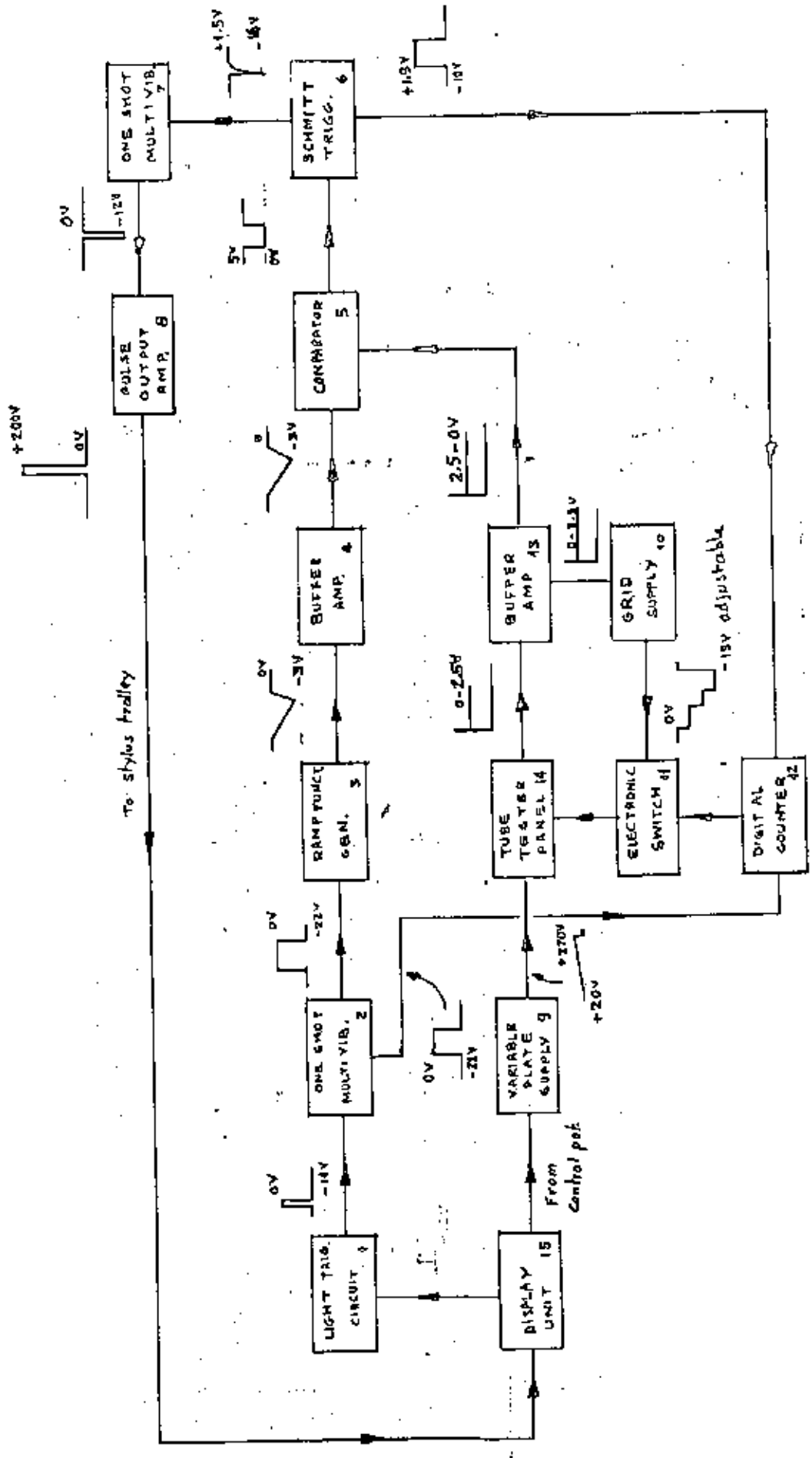


Fig. 4a. Functional Block Diagram

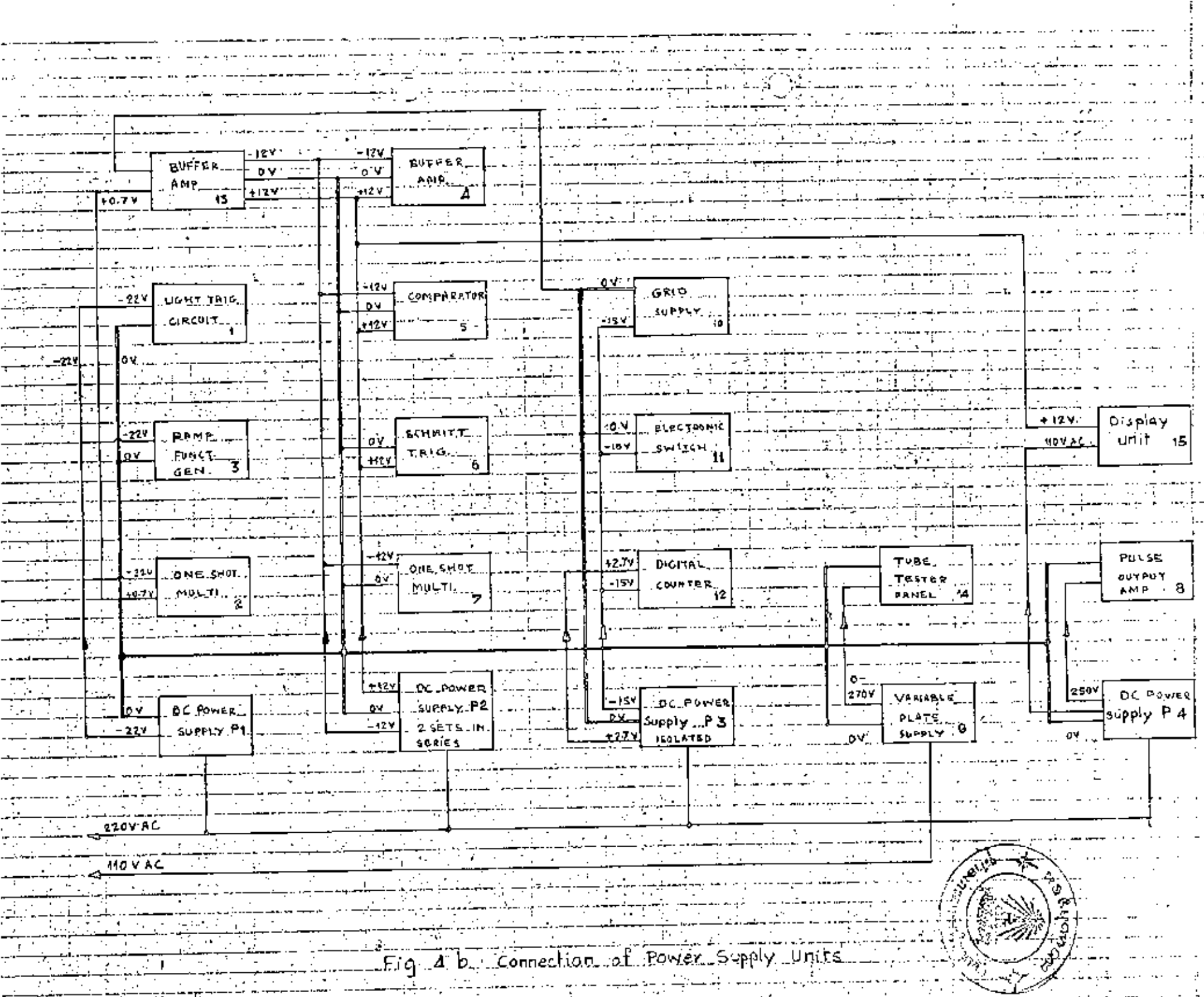


Fig 4 b. Connection of Power Supply Units

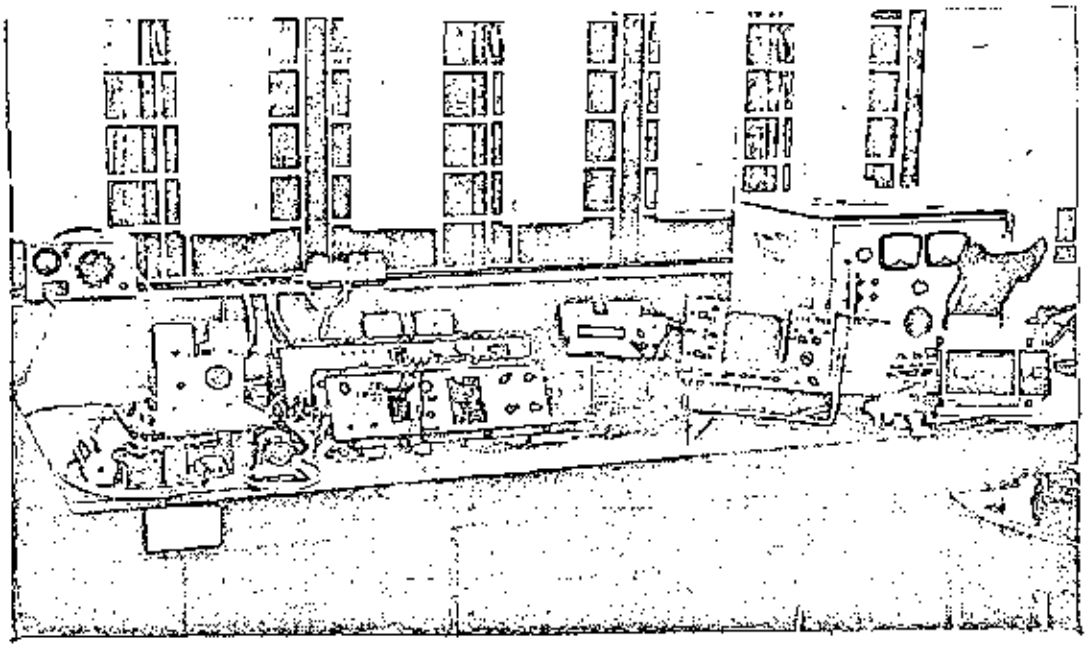


Fig. 5a General view of the test bench.

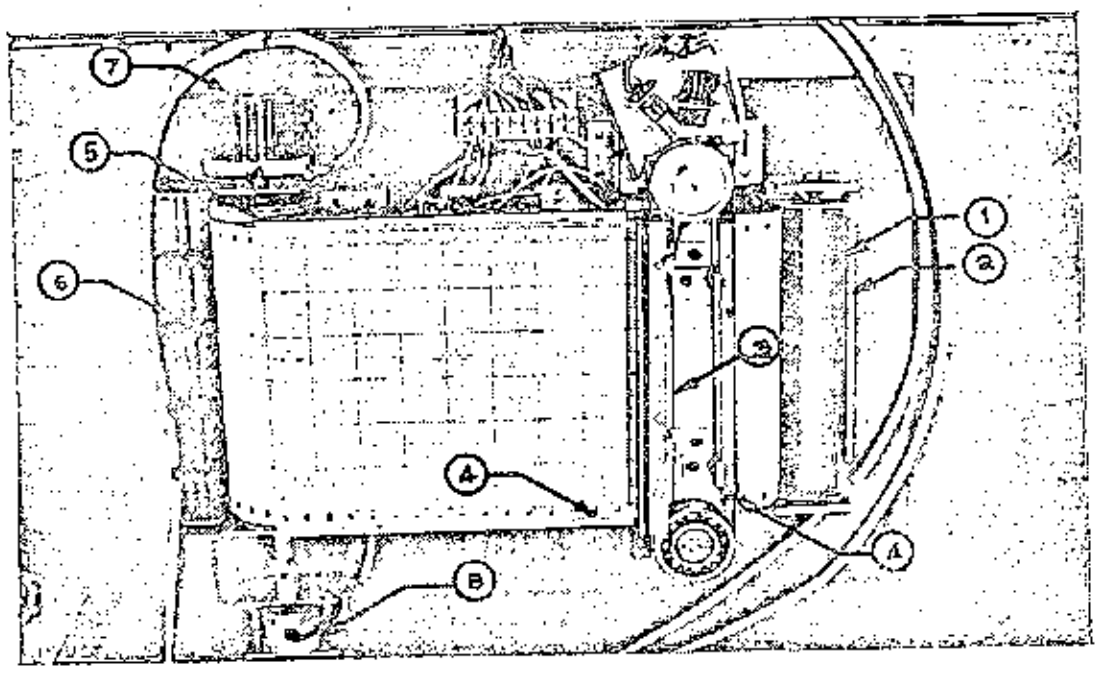


Fig. 5b Display unit assembly

① Chart paper spool
② Paper compartment
③ Slot between paper carrier plate
④ Guide block
⑤ Chart driving drum
⑥ Spring loaded rubber roller
⑦ Potentiometer
⑧ Chart drive motor

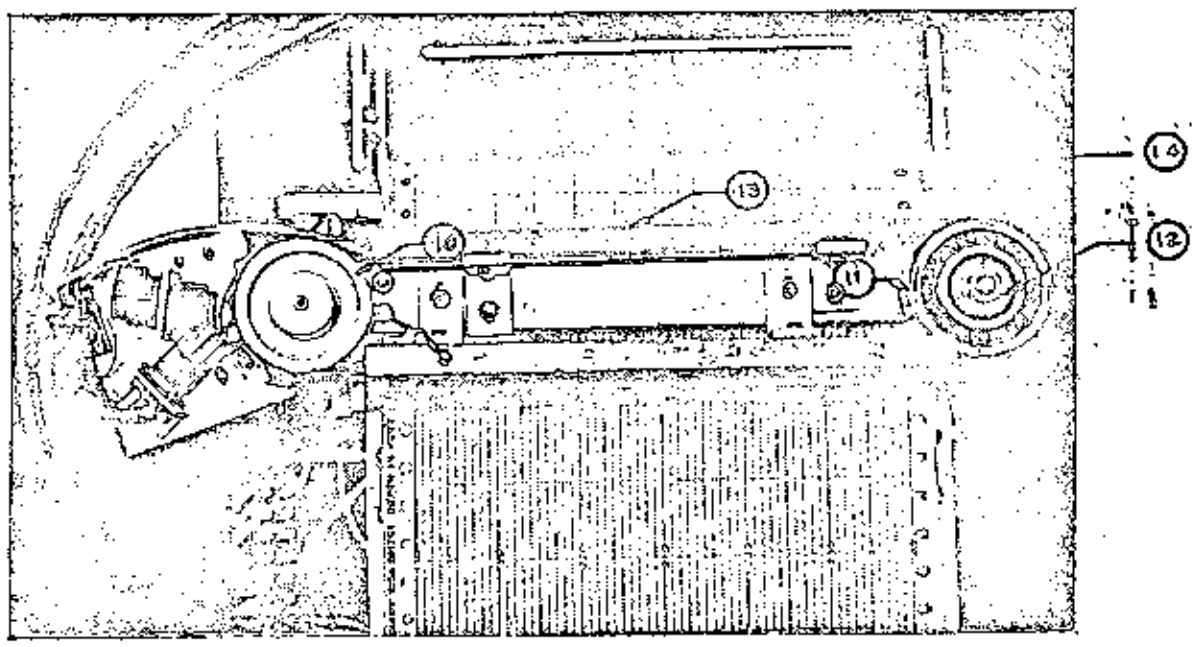
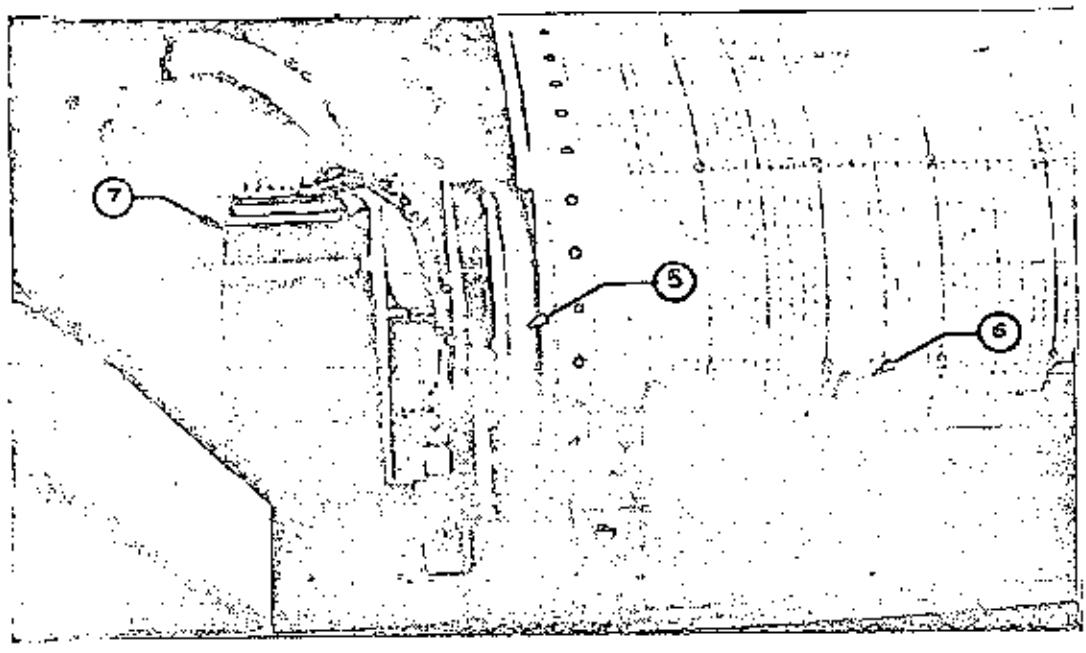


Fig. 5c. Stylus driving unit

(10) : Driving pulley
(11) : Idling pulley
(12) : Brass sleeve
(13) : Plexiglass guide block
(14) : Belt



5 Chart driving drum

6 Spring loaded rubber roller

7 Potentiometer for plate voltage Control Unit.

8 Chart drive motor

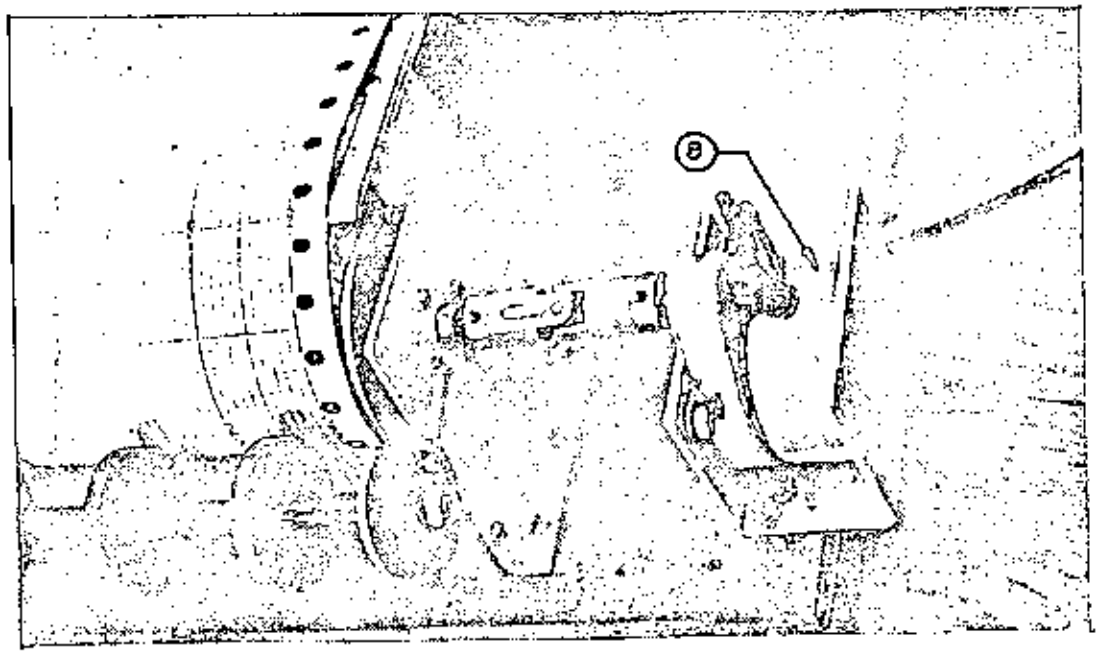


Fig. 5C Paper take up mechanism

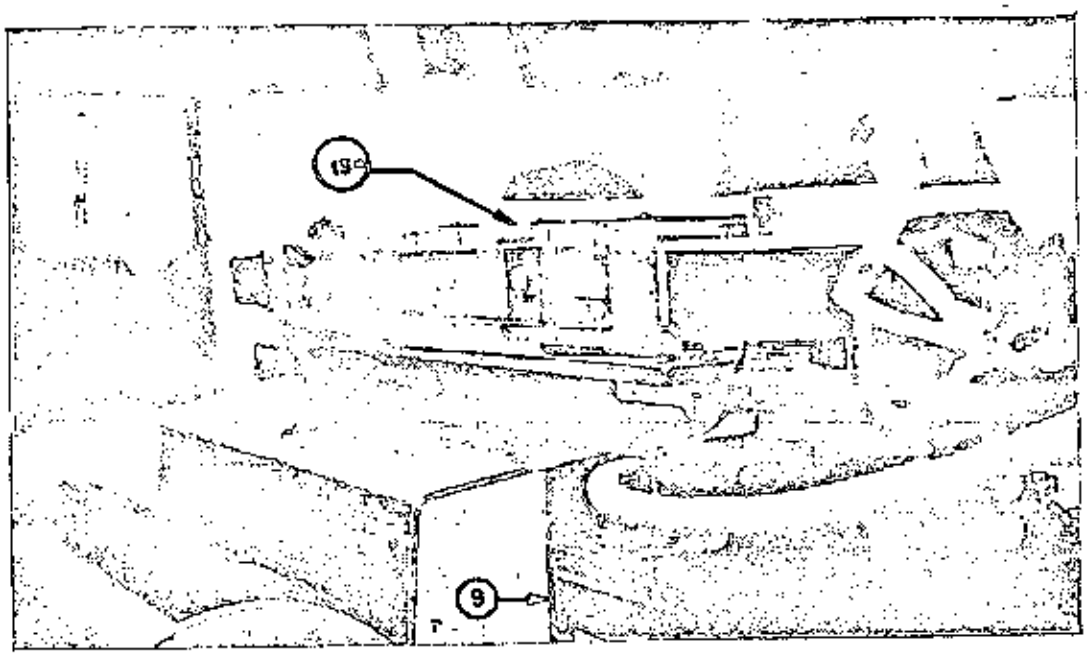


Fig. 5d. Outer plexiglass guide block

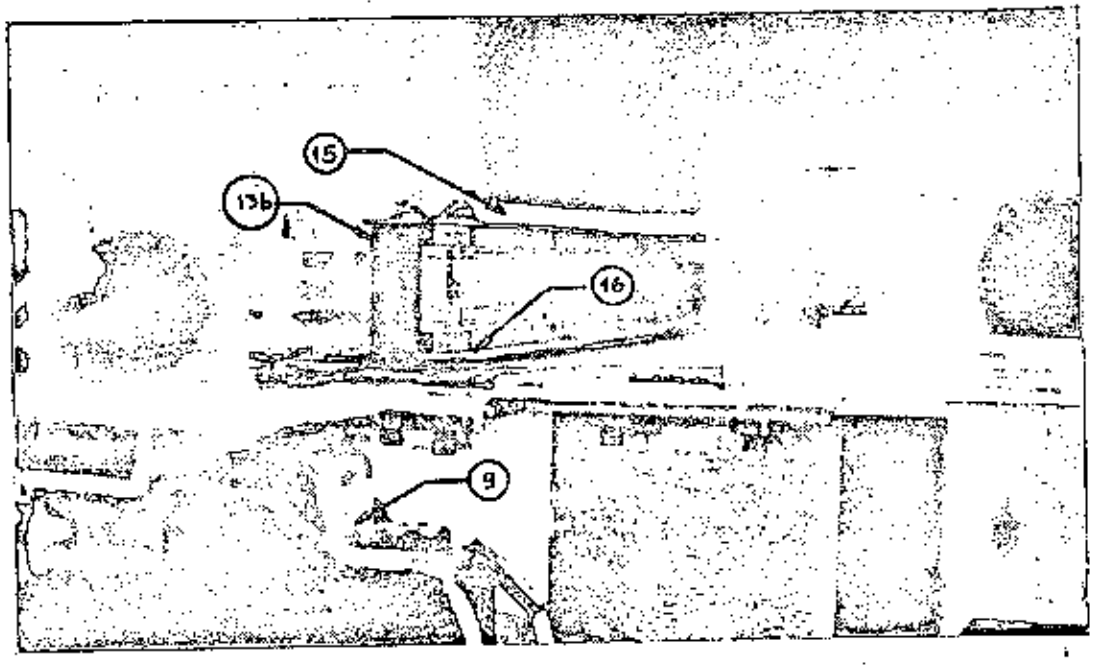


Fig. 5e. Inner Plexiglass guide block

(9) Stylus driving motor

(15) Stylus trolley

(16) Stylus guide plate

(13a) Outer plexiglass guide block

(13b) Inner plexiglass guide block

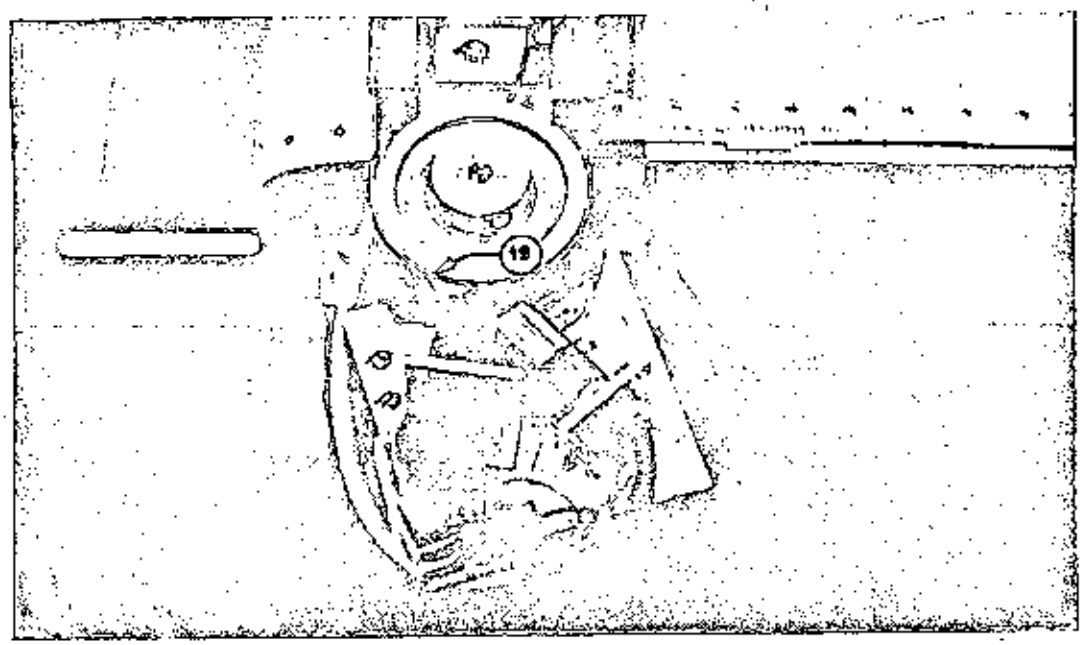


Fig. 58 Light triggering unit

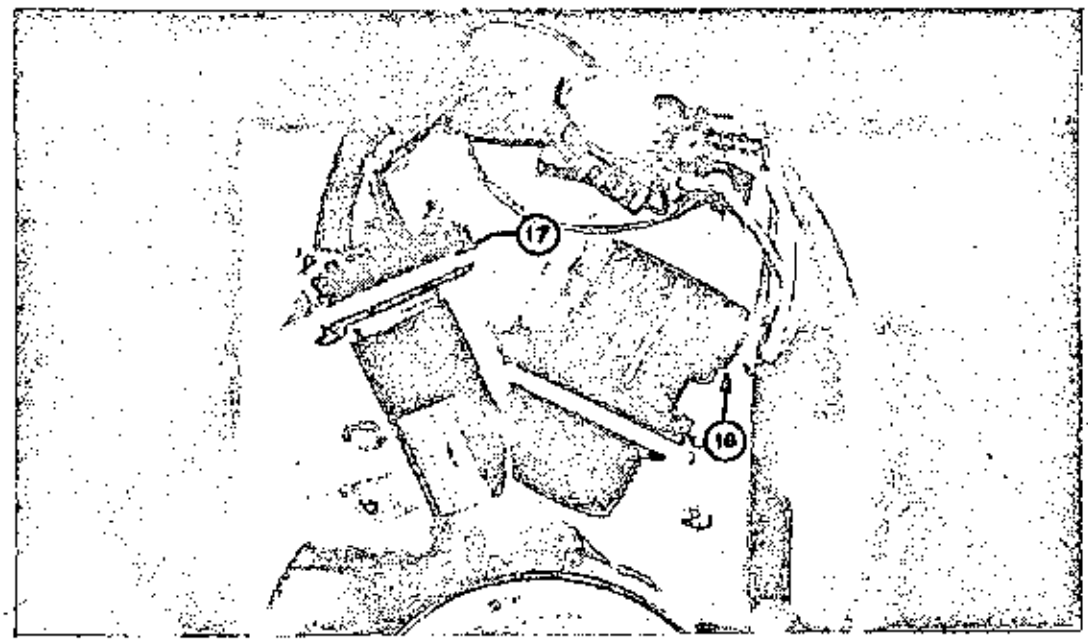


Fig. 59. Close up of light triggering unit.

(17) Light source (18) Photo transistor

(19) Aluminium foil reflector

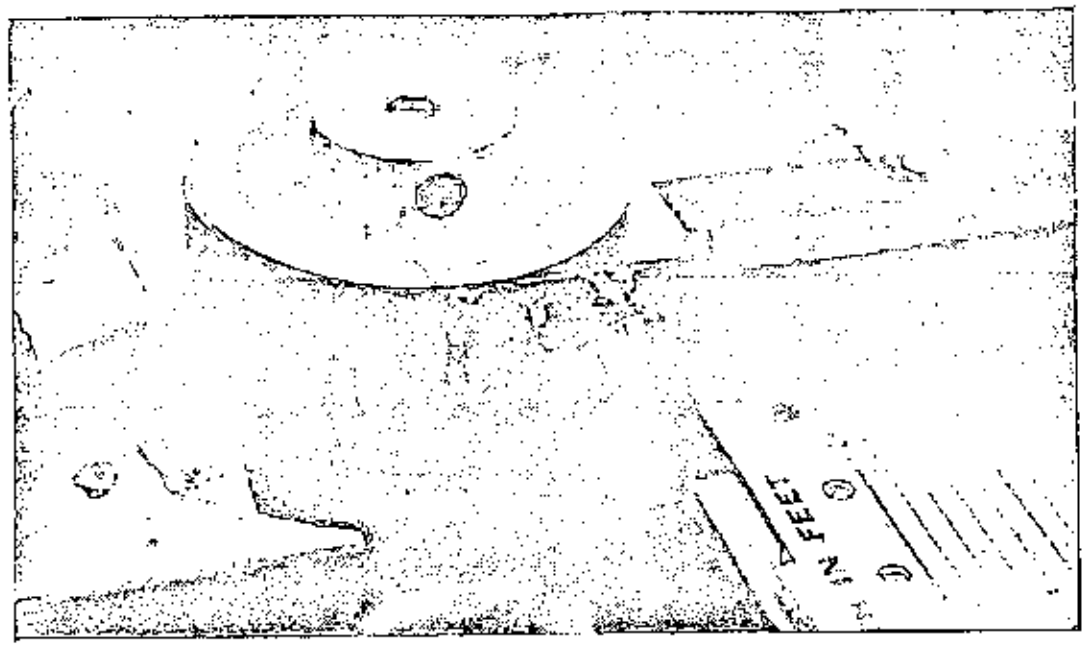


Fig. 5h. Position of stylus in stylus holder.

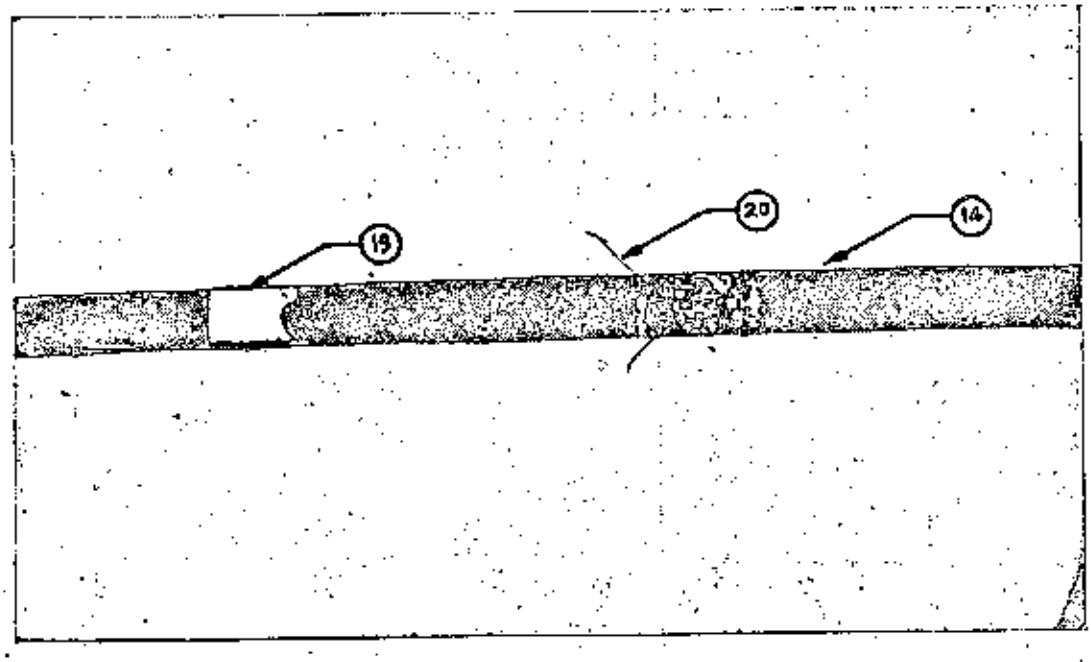


Fig. 5i. Position of aluminium foil reflector

(14) Stylus belt

(20) Stylus body

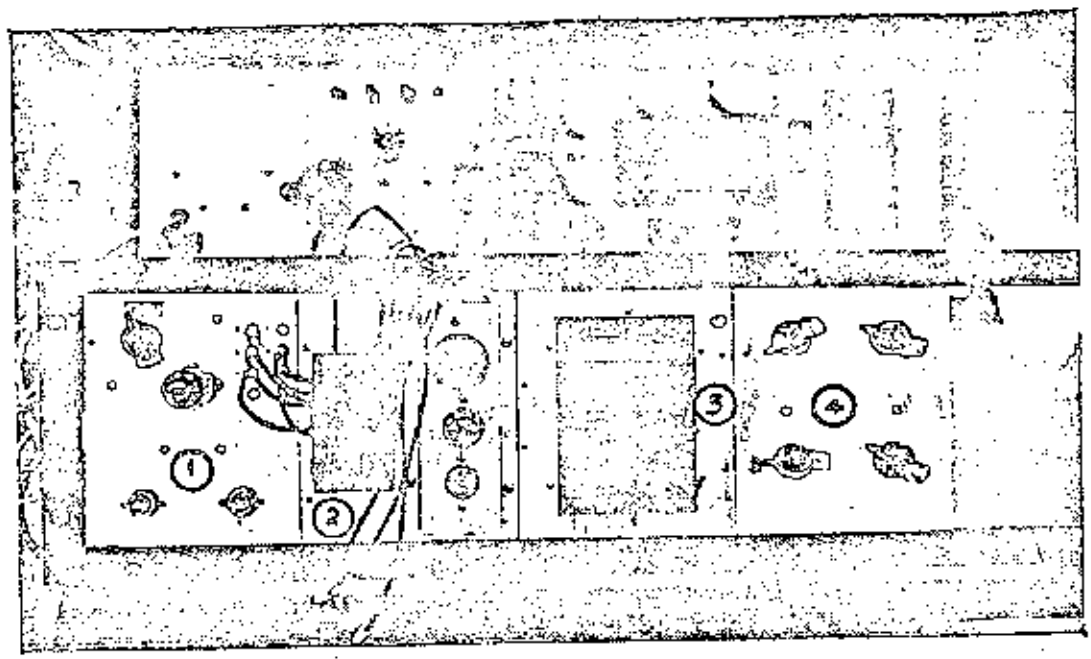


Fig. 6a. Test Chasis No. 1

(1) Difference amplifier for plate voltage control circuit

(2) Buffer amplifiers and Tube tester panel

(3) Digital pulse counter and Electronic selector switch

(4) Grid voltage supply unit

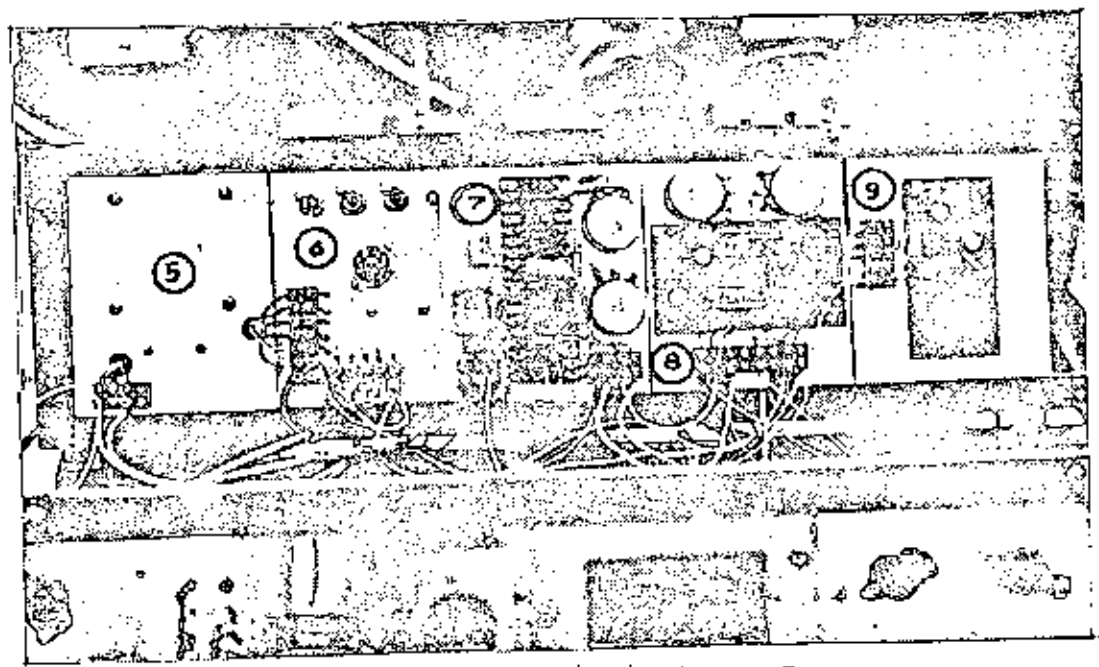


Fig. 6b Test chasis no. 2

(5) Power supply for pulse output amplifier

(6) Pulse amplifier and switch for motors

(7) Light triggering circuit and ramp function generator

(8) Buffer amp., Comparator, monostable for trace width control.

(9) Schmitt trigger circuit.

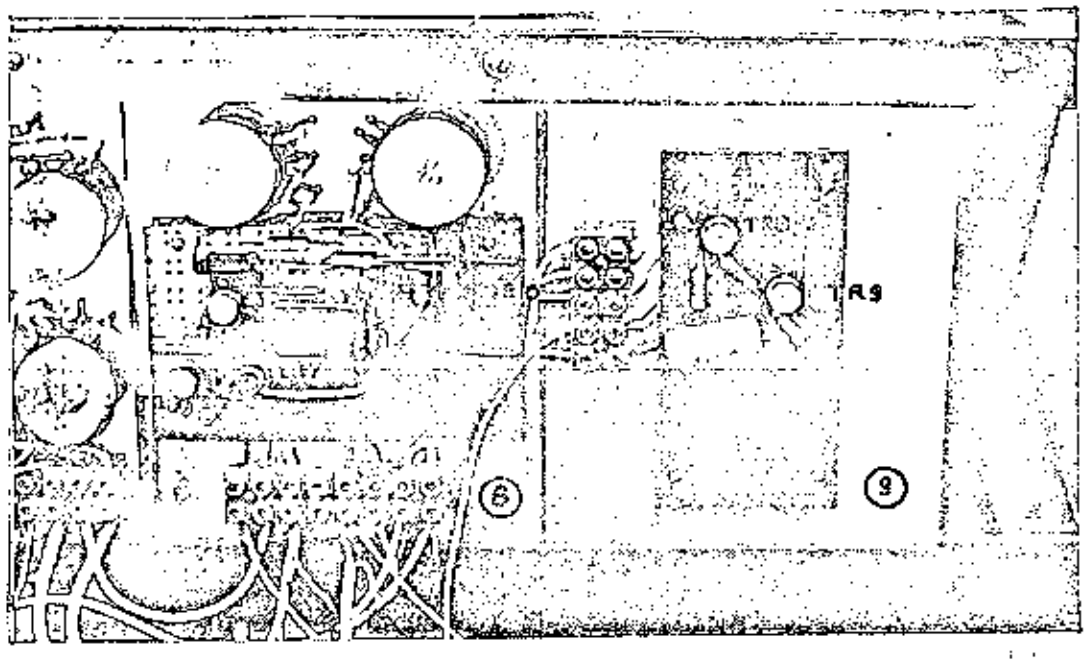


Fig. 6 c close up view of circuit board, no. 8 and no. 9

Consisting of : Buffer amplifier , Voltage comparator , monostable for trace width control and Schmitt trigger

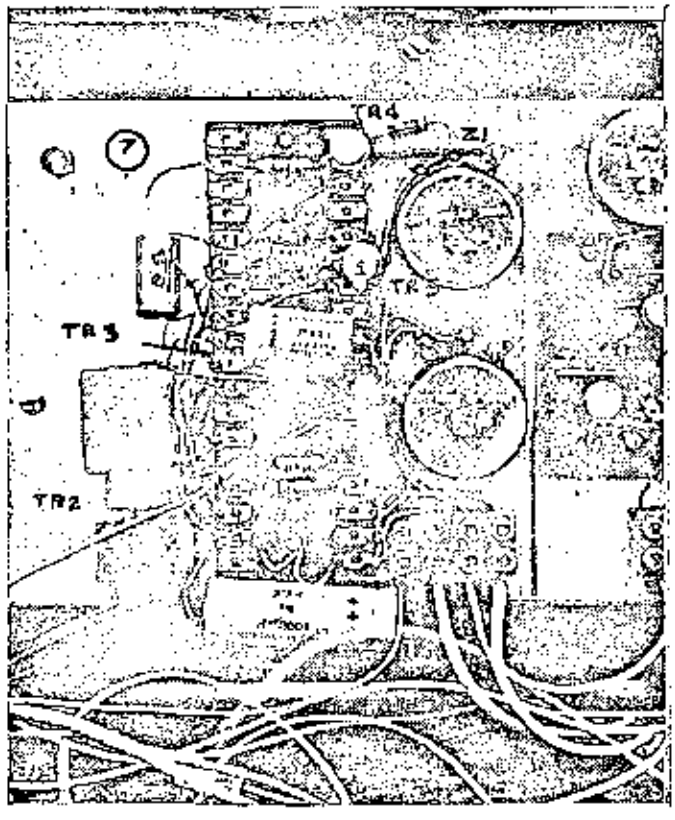


Fig. 6 d close up view of circuit board no. 7

consisting of :

Light triggering, mono stable for sweep width control and Ramp function generator.

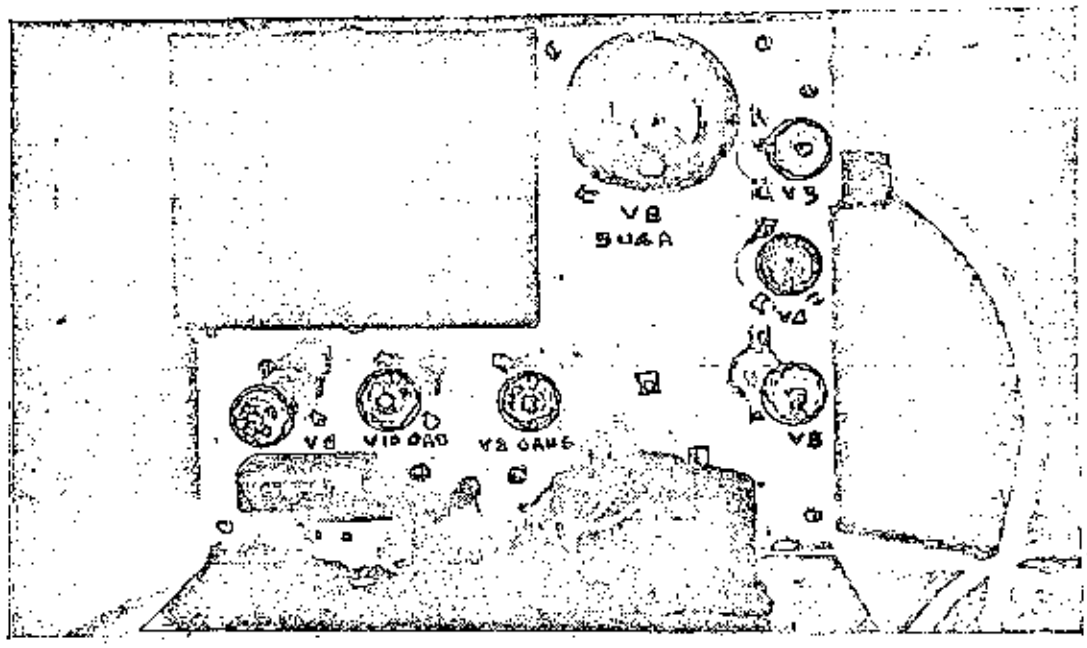


Fig. 6 e Close up view of Plate voltage supply unit

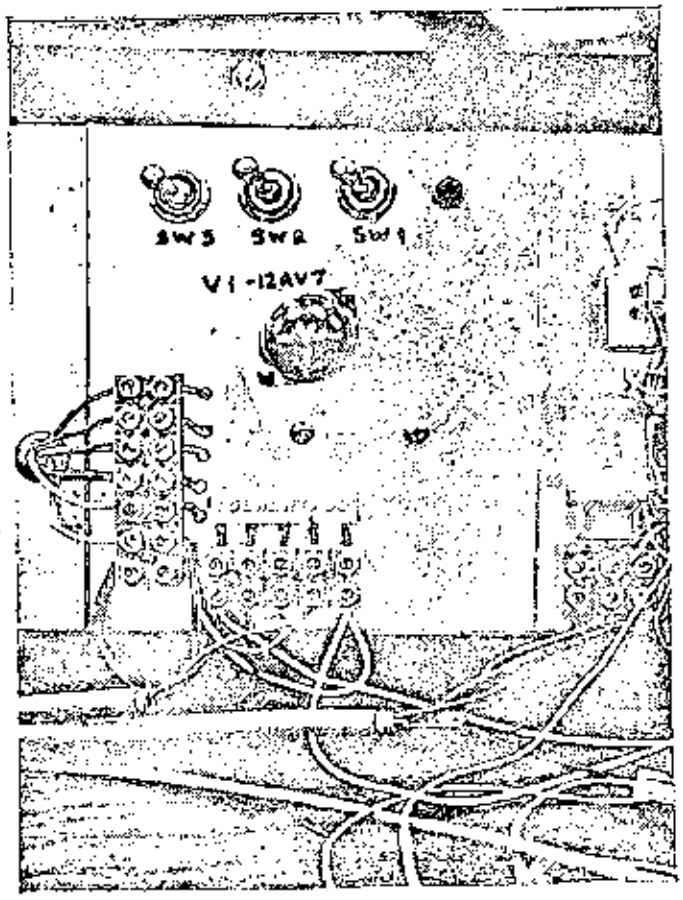


Fig. 6 f Close up view of circuit board no. 6. Pulse amplifier and switch for motors.

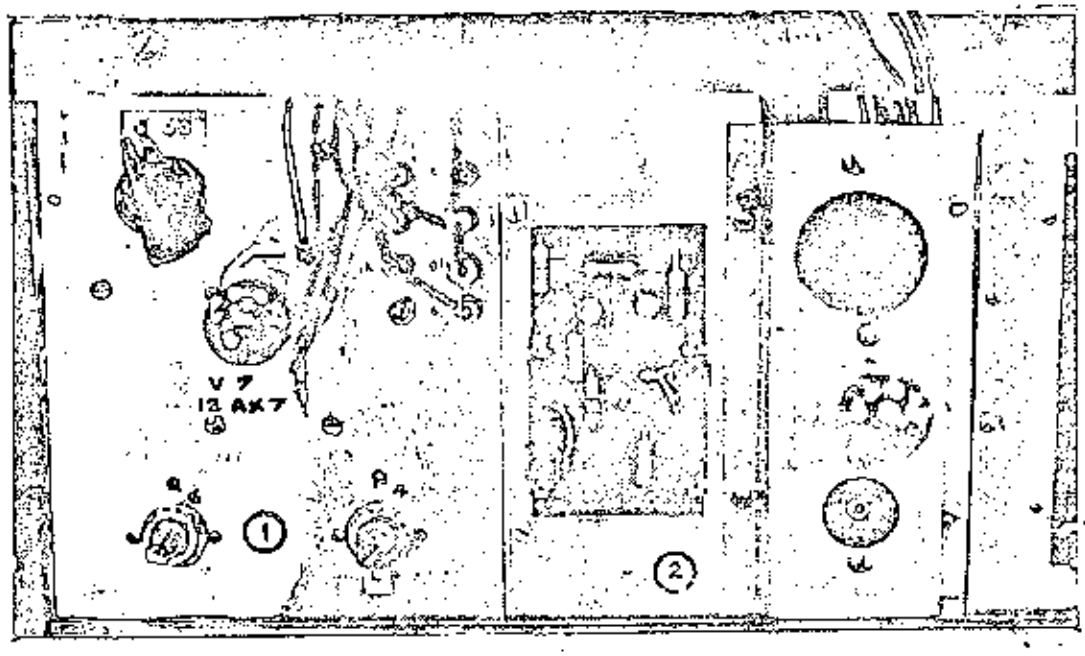


Fig. 6 g Close up view of circuit board no. 1 and 2

Consisting of : Difference amplifier for plate voltage supply unit
Buffer amplifiers and tube tester panel

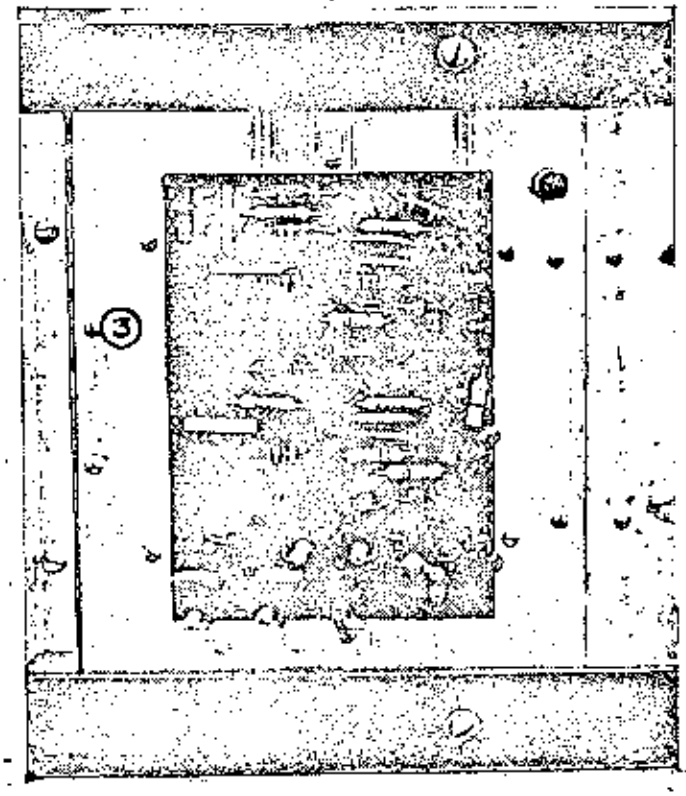


Fig. 6 h Close up view of circuit board no. 3

Consisting of : Digital pulse counter and Electronic selector switch

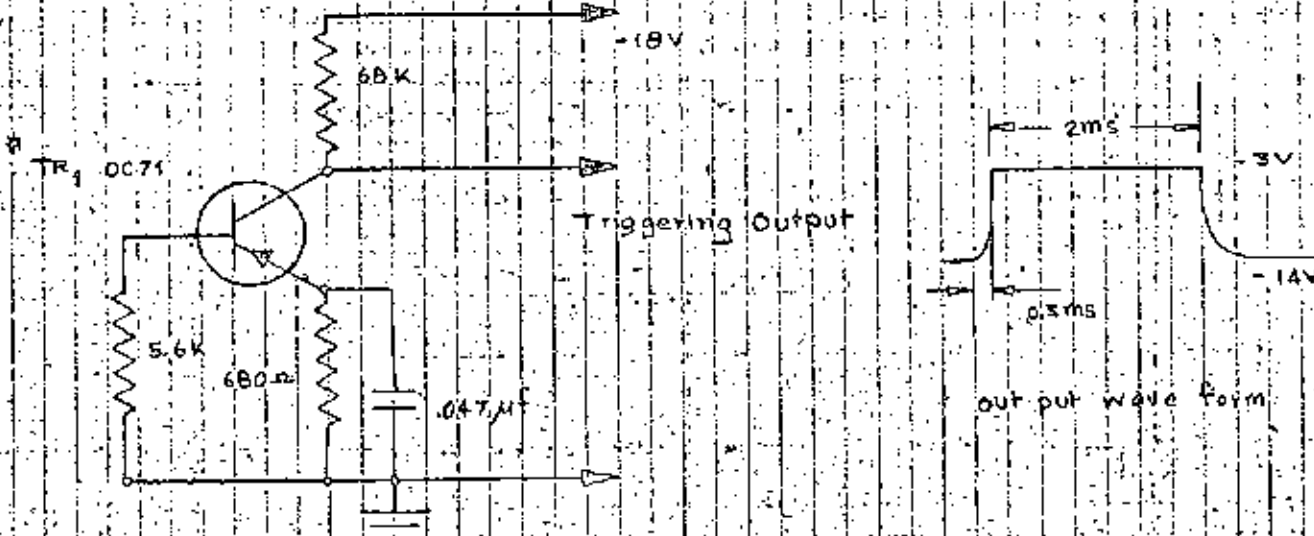


Fig. 6 i Schematic diagram of Light triggering circuit

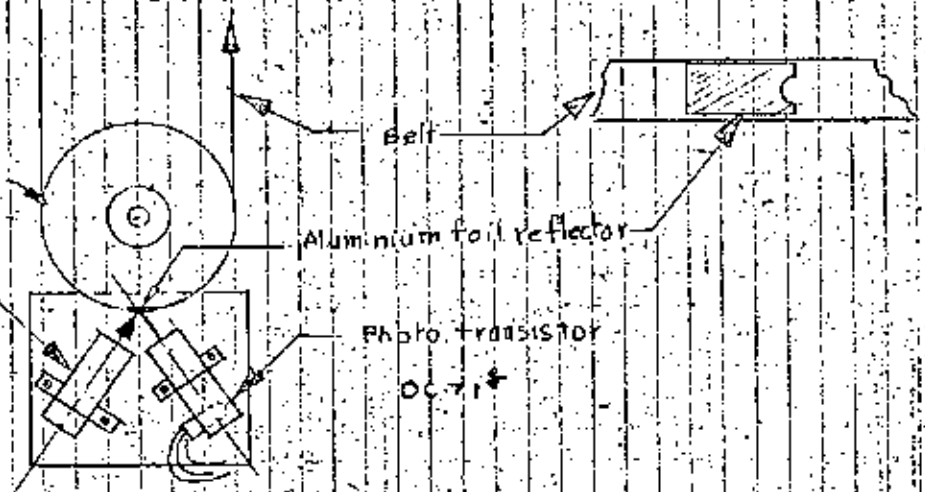


Fig. 6 j Layout diagram of light source and reflector

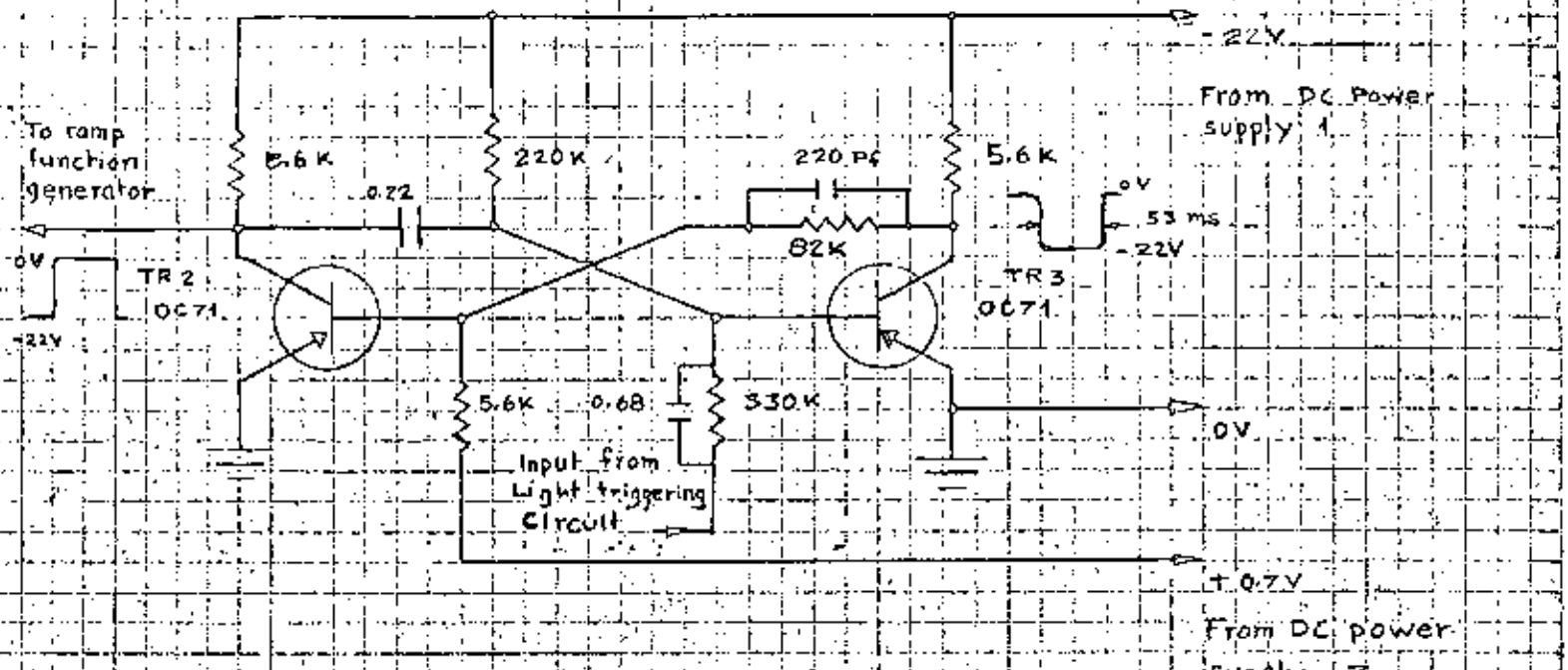


Fig. 7 Schematic diagram of one shot multivibrator for sweep width control

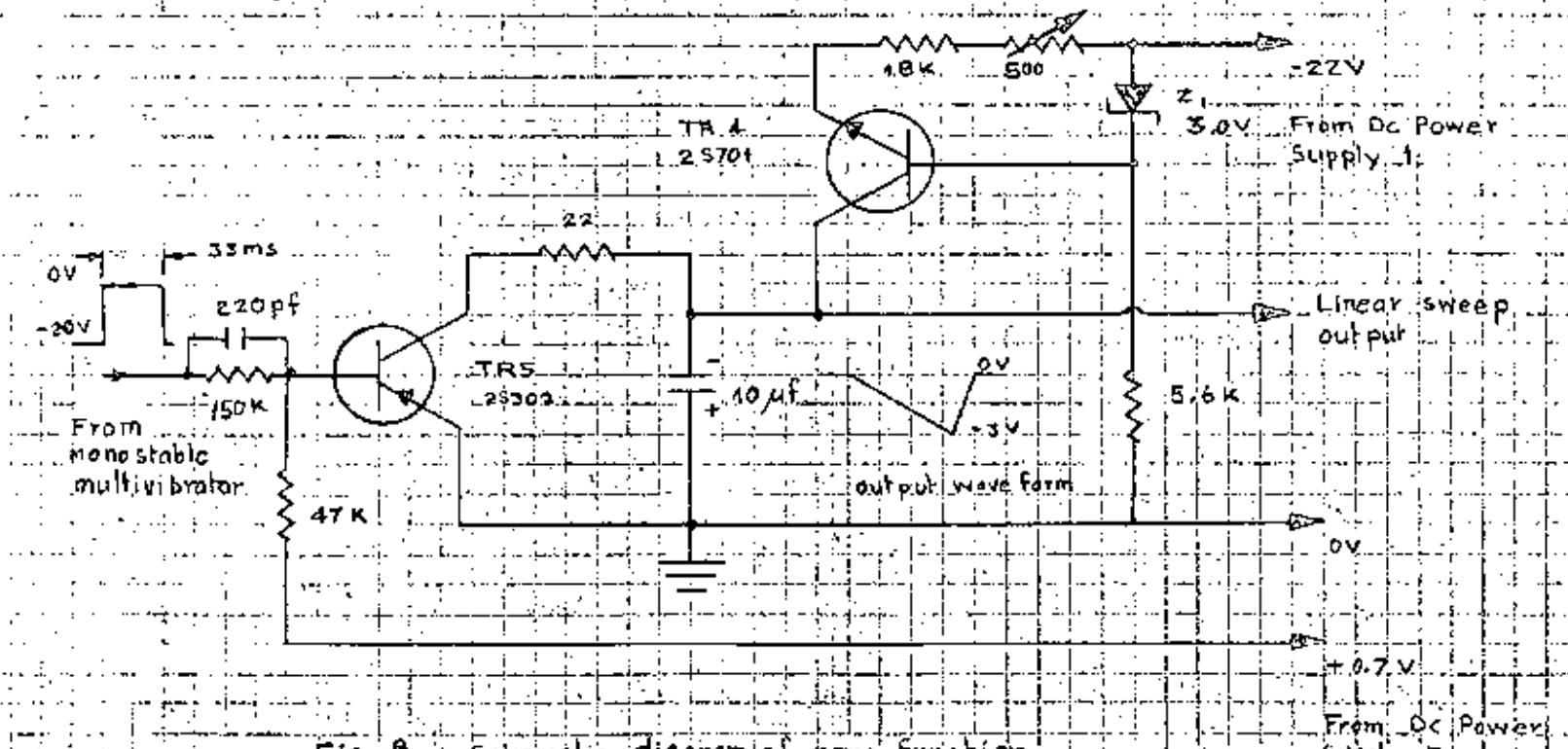


Fig. 8 Schematic diagram of ramp function generator

advance laboratory information

Semiconductors Limited

A31AY
OPERATIONAL OR
INSTRUMENTATION
AMPLIFIER

SL701B

Cheney Manor
Swindon Wiltshire
Swindon 6251

The A31AY is a monolithic epitaxial solid circuit high-gain d.c. amplifier intended primarily for use as an operational amplifier or in instrumentation applications. The circuit is not a complete functional block but is intended for use with thin-film or conventional components defining the gain and any special functions.

The circuit incorporates a balanced comparator input stage with an auxiliary balancing circuit to keep collector currents and voltages in the comparator closely matched. The circuit is thereby made tolerant of supply line variations.

The input d.c. offset voltage is typically 10mV and the offset current 0.1 μA. Open-loop Gain is approximately 70dB.

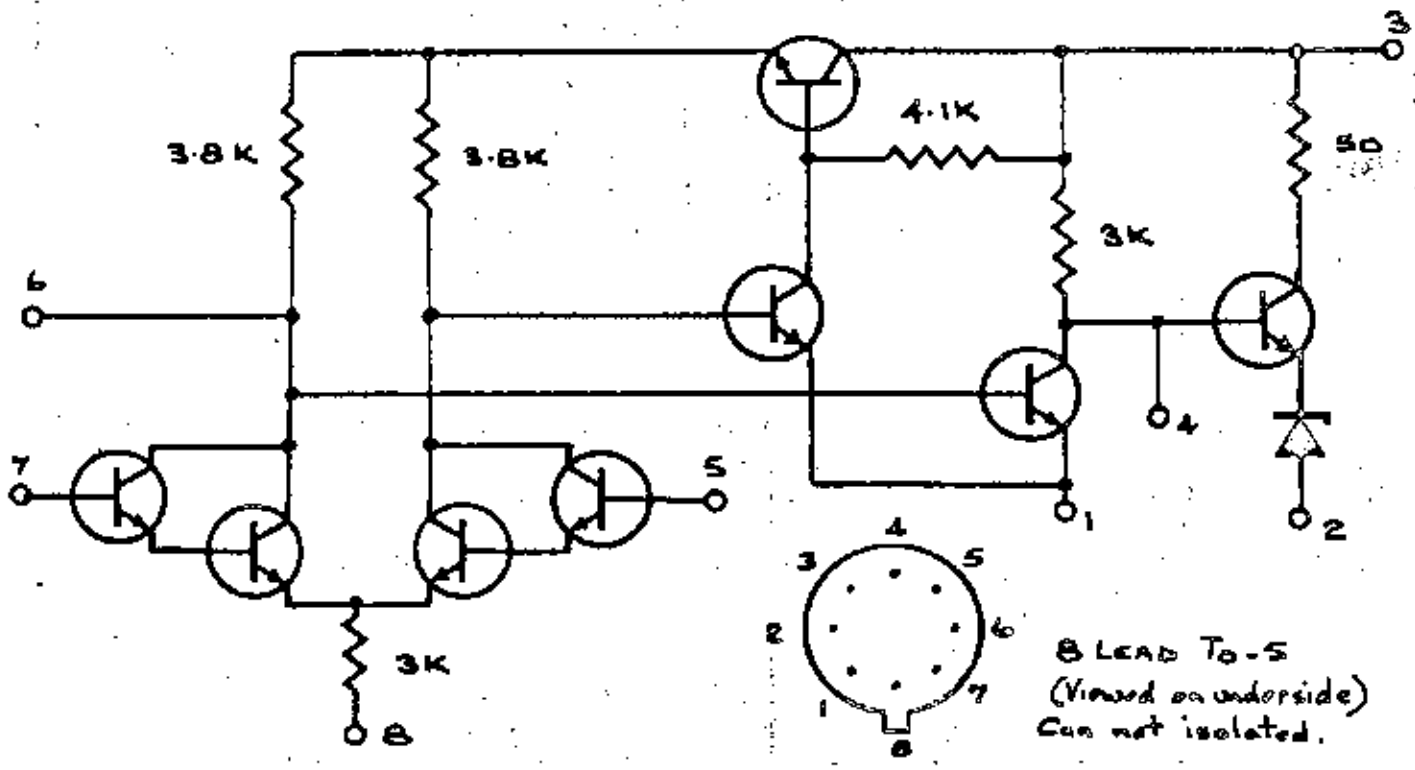


Fig. 9b Comparator amplifier.

ELECTRICAL CHARACTERISTICS

Positive supply voltage = 12V[a]
Negative supply voltage = -12V[a]
Ambient temperature = 25°C
Load (Pin 2 to -12V) = 2.2K

Characteristic	Min.	Typ.	Max.	Units	Test Conditions
Voltage gain[b]	68	-	78	dB	600 ohm source f = 1Kc/s
Upper cut-off frequency[b]	300	-	-	Kc/s	600 ohm source
Output swing before clipping[b]	8	-	-	Vpk-pk	600 ohm source f = 1Kc/s
Positive supply current	9	-	13	mA	
Negative supply current	6	-	9	mA	
Input offset voltage	-	10	-	mV	
Input offset current	-	0.1	-	μA	
Input base currents	-	0.3	-	μA	
Drift of offset voltage	-	15	-	μV/°C	25°C to 75°C
Change of offset with supplies	-	100	-	μV/V	

OPERATING NOTES

(a) Correct operation of the amplifier requires that the positive supply voltage be equal to or greater than the magnitude of the negative supply.

(b) A.C. parameters are measured with a feedback resistor of 100 K between output and Pin 5. Pin 5 is decoupled with a tantalum electrolytic greater than 30 μF. This establishes d.c. working conditions.

ABSOLUTE MAXIMUM RATINGS

These ratings are those which must not be exceeded if the circuit is not to be damaged: correct operation at the extremes is not guaranteed.

Storage temperature range.	$-55^{\circ}C$ to $175^{\circ}C$
Free air operating temperature range ($\pm$ 12V supplies, 2.2K load resistor to -12V supply).	$-55^{\circ}C$ to $+100^{\circ}C$
Positive supply voltage.	+14 V*
Negative supply voltage.	-14 V*
Maximum current from Pin 2.	20 mA

* Care must be taken that dissipation in the circuit does not give a chip temperature greater than $175^{\circ}C$.

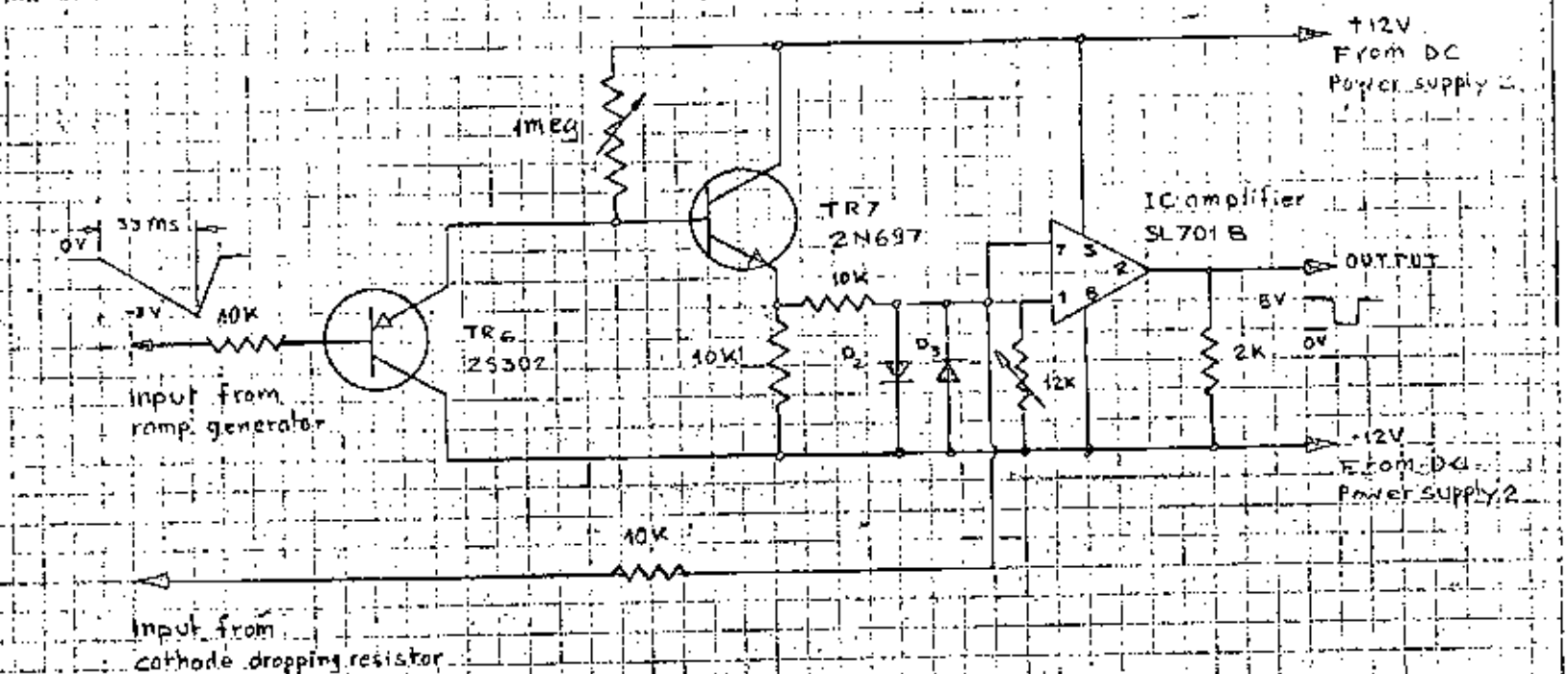


Fig 9a Buffer Amplifier and comparator

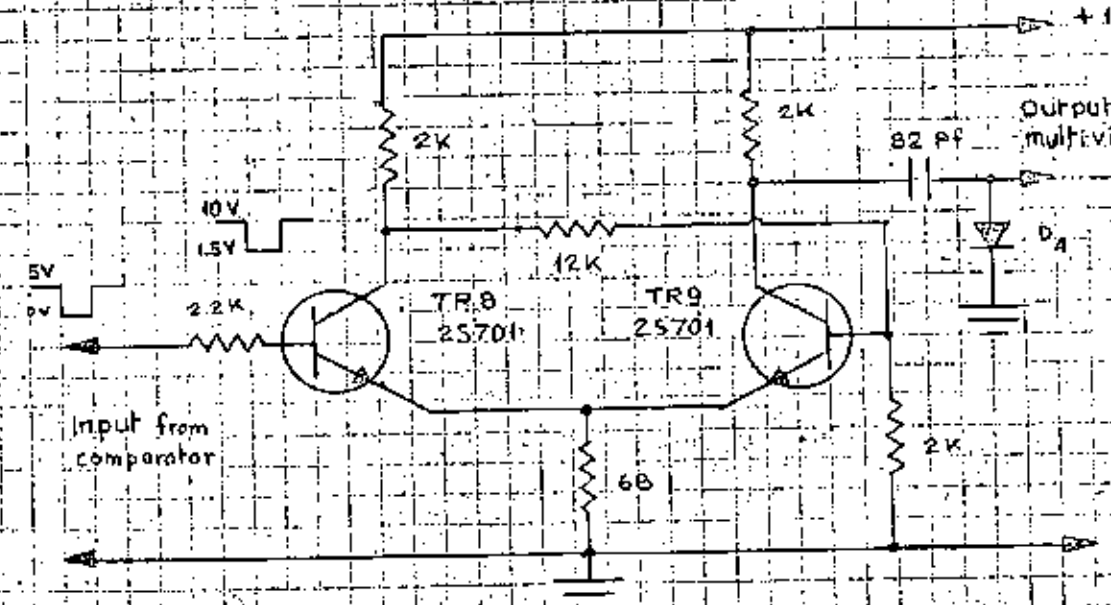


Fig 10 Schmitt trigger Circuit

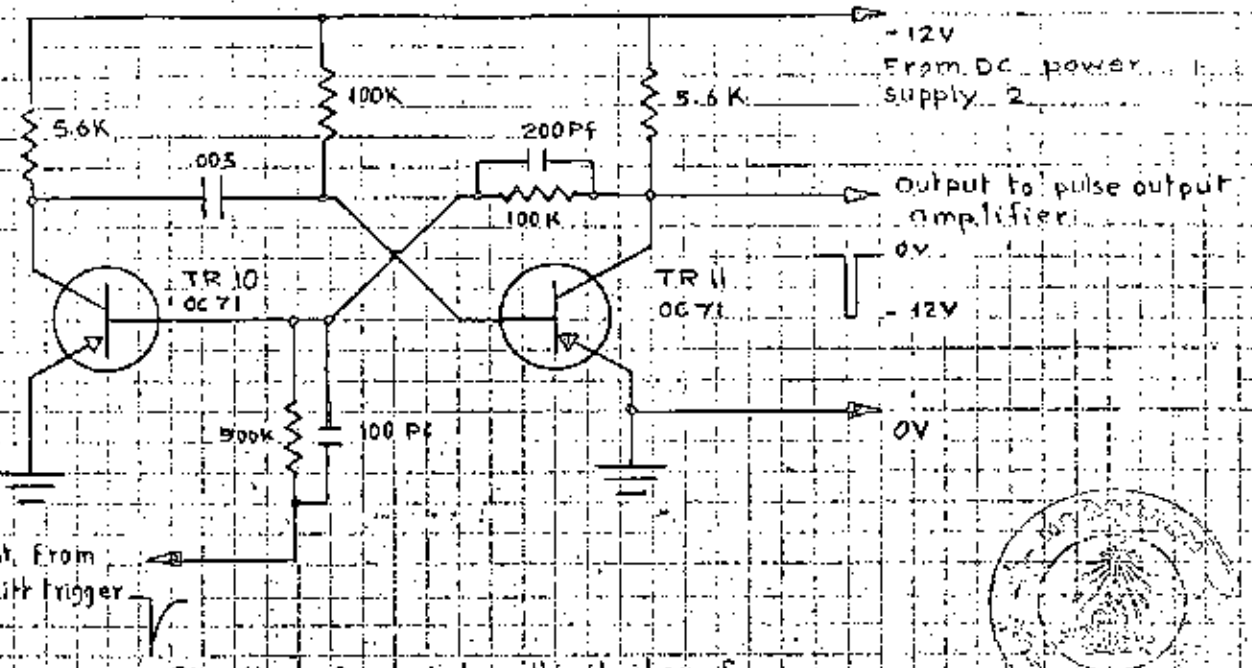


Fig. 11 One shot multivibrator for trace width control

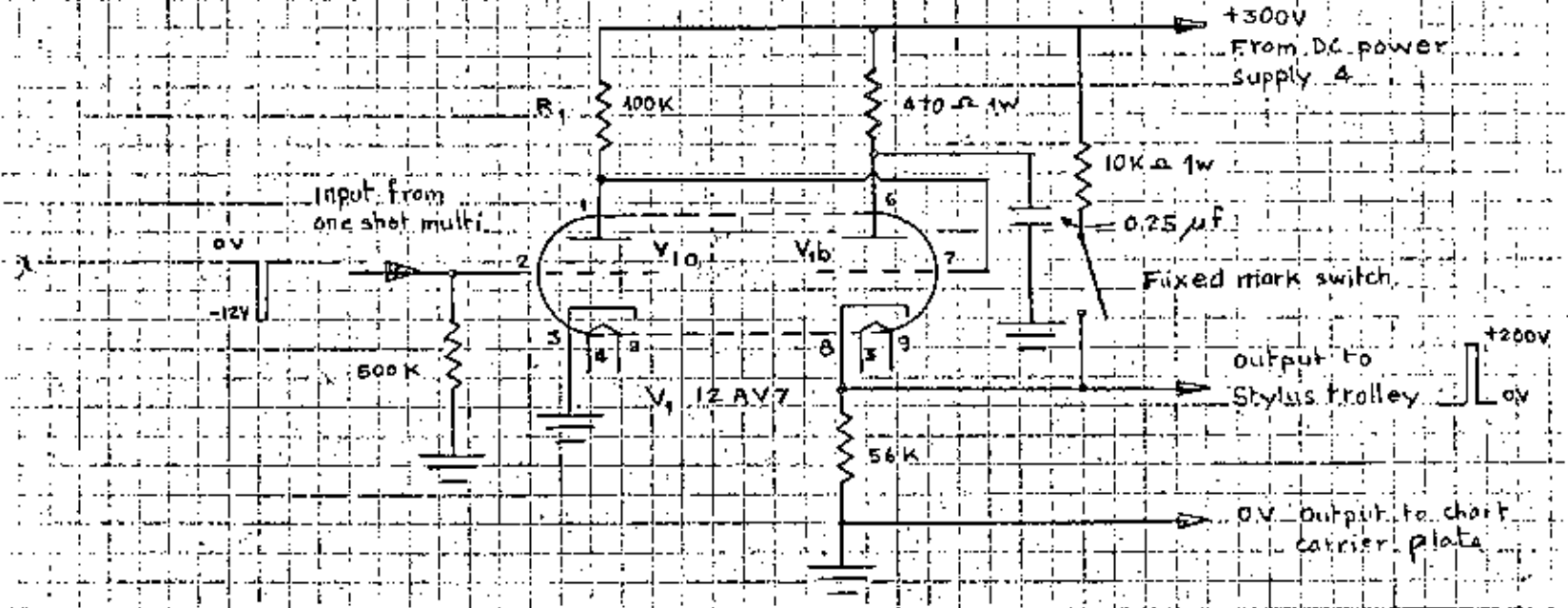


Fig. 12 Pulse output amplifier

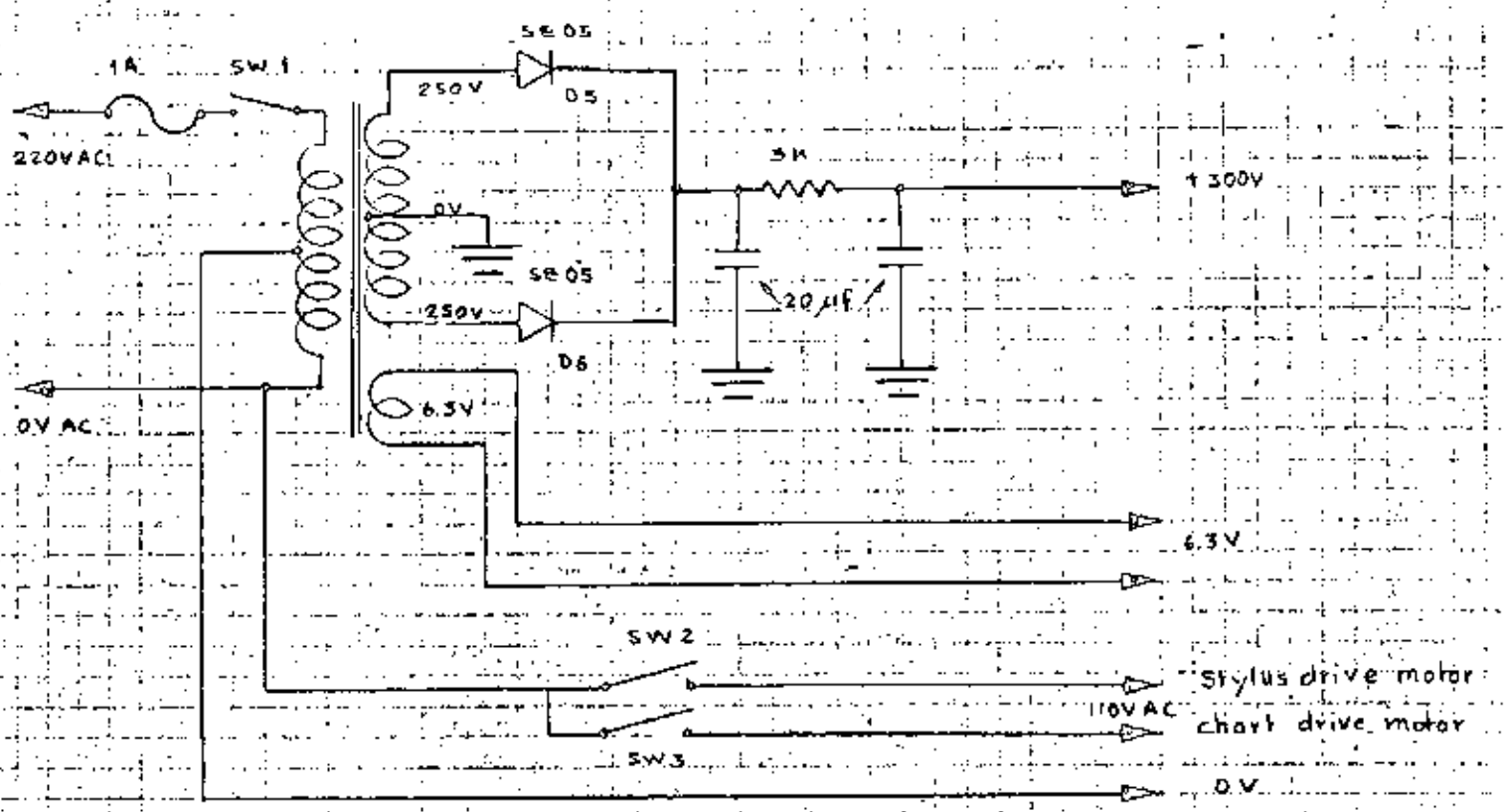


Fig 13 Power supply for pulse amplifier and display unit

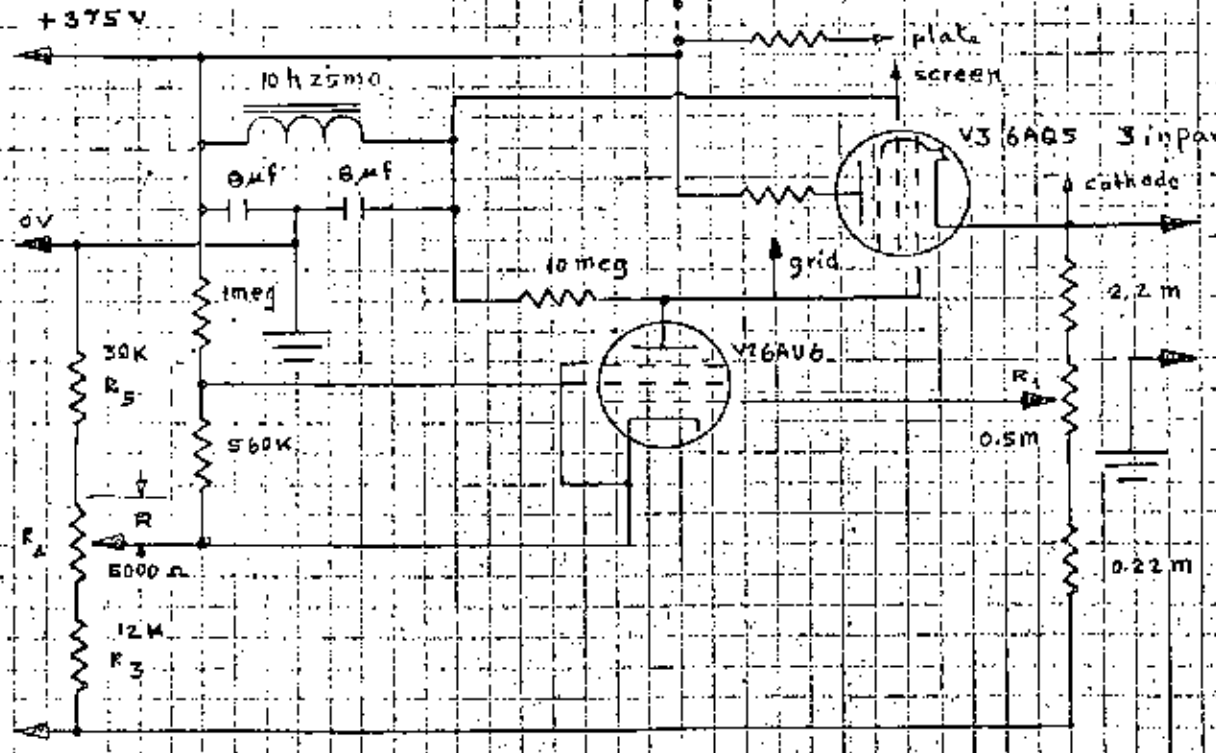


Fig. 14 Variable voltage power supply

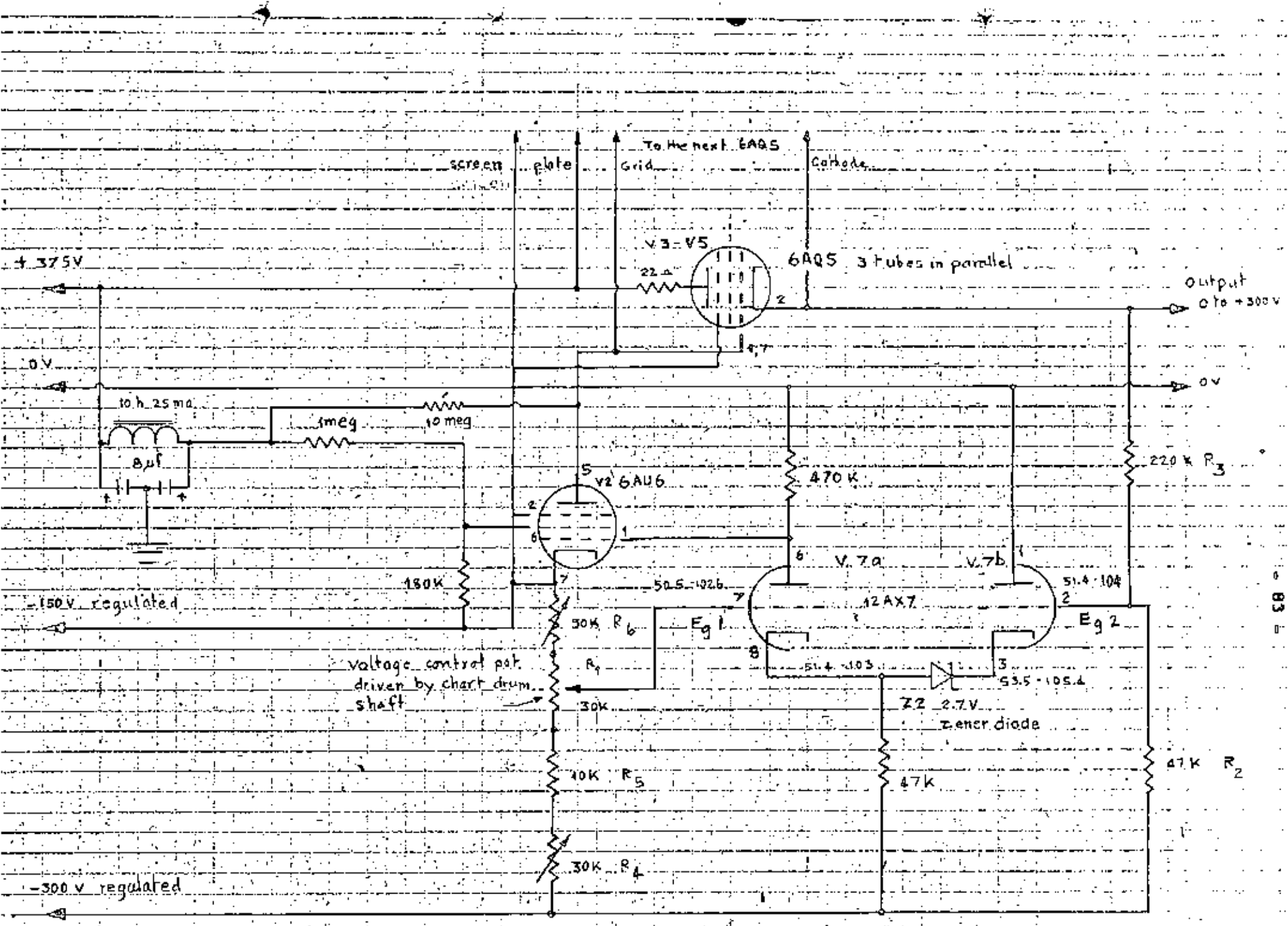


Fig. 15 Modified circuit of the adjustable regulated power supply

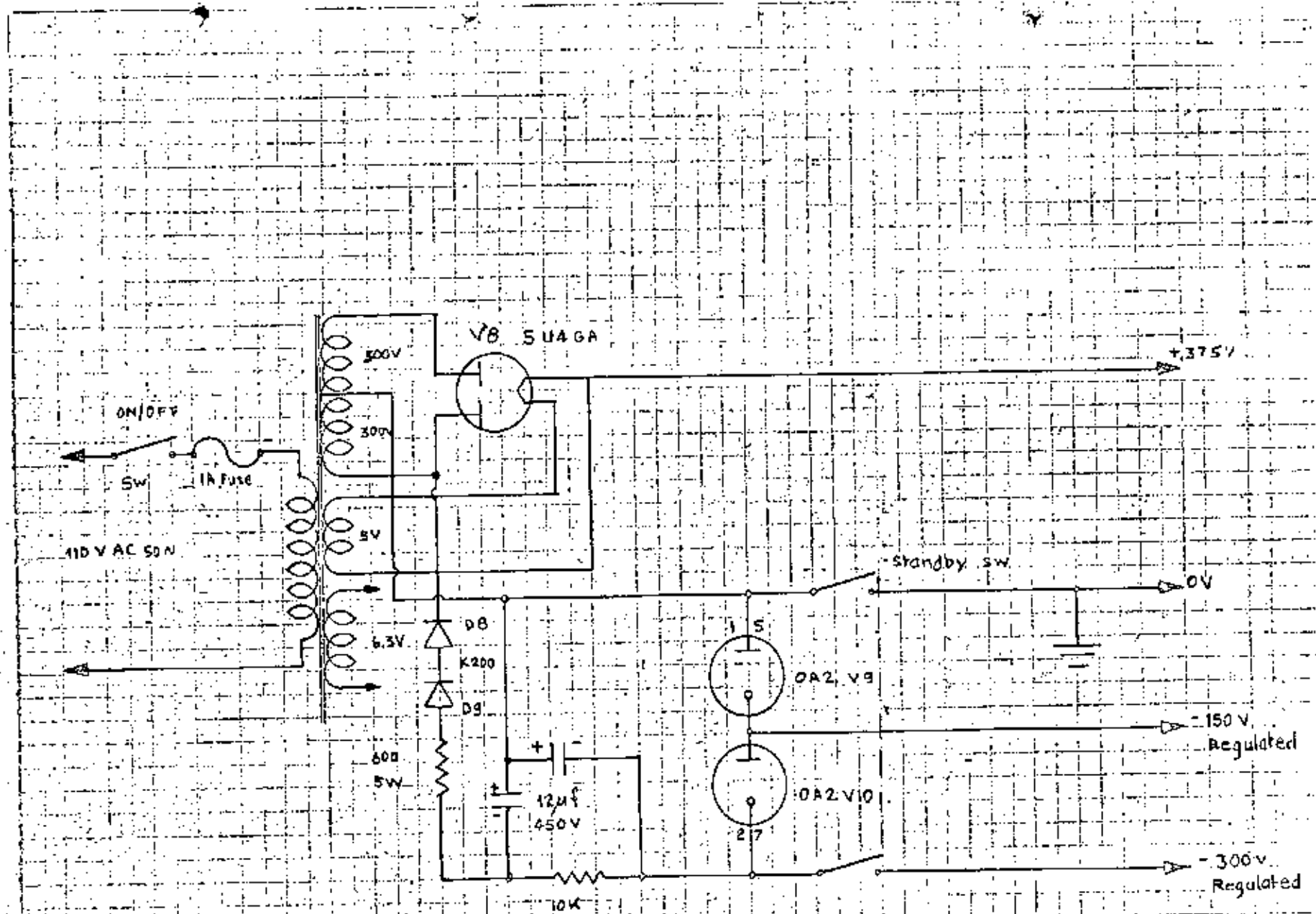
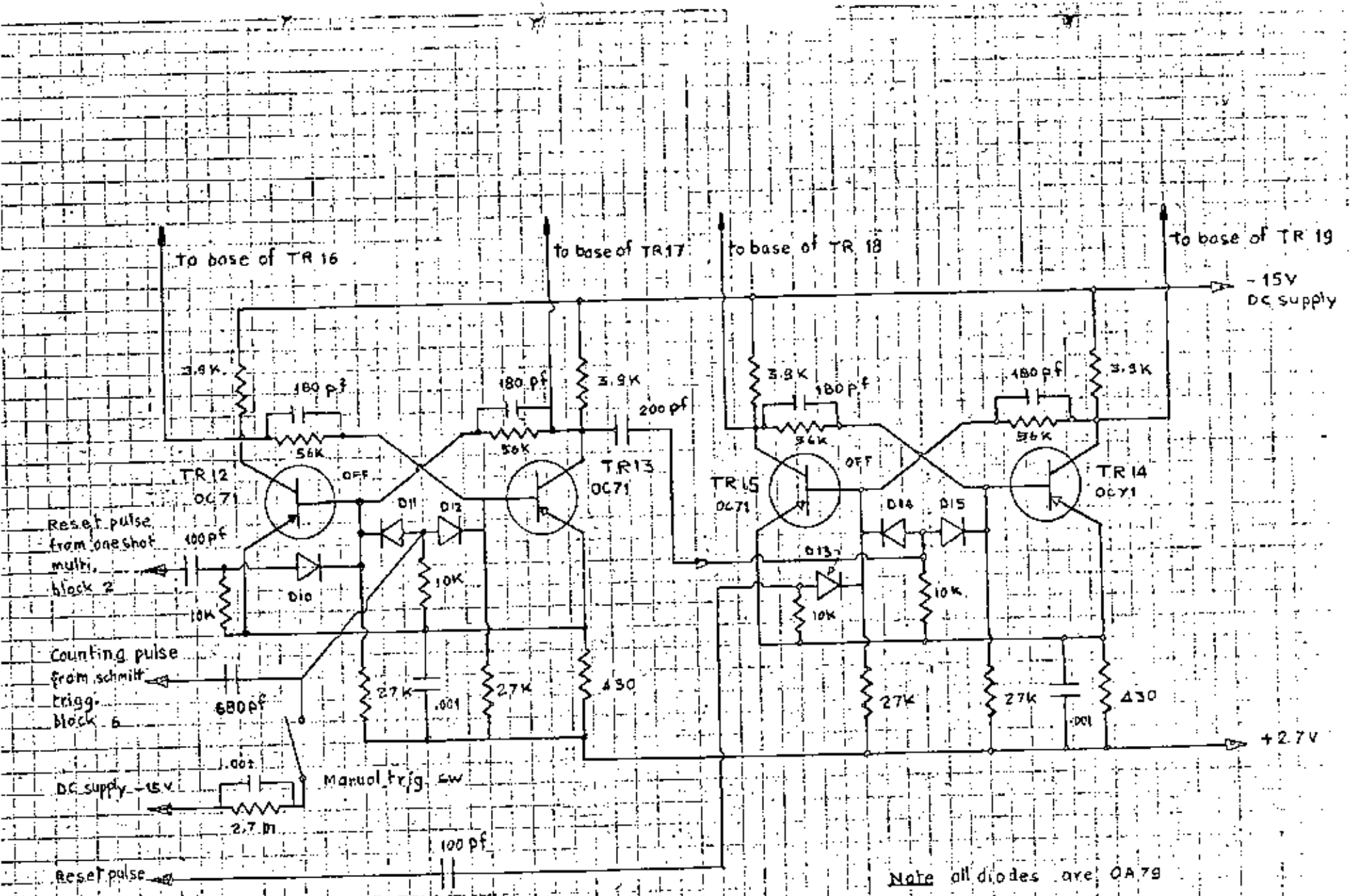


Fig. 16 Rectifier circuit for adjustable regulated power supply



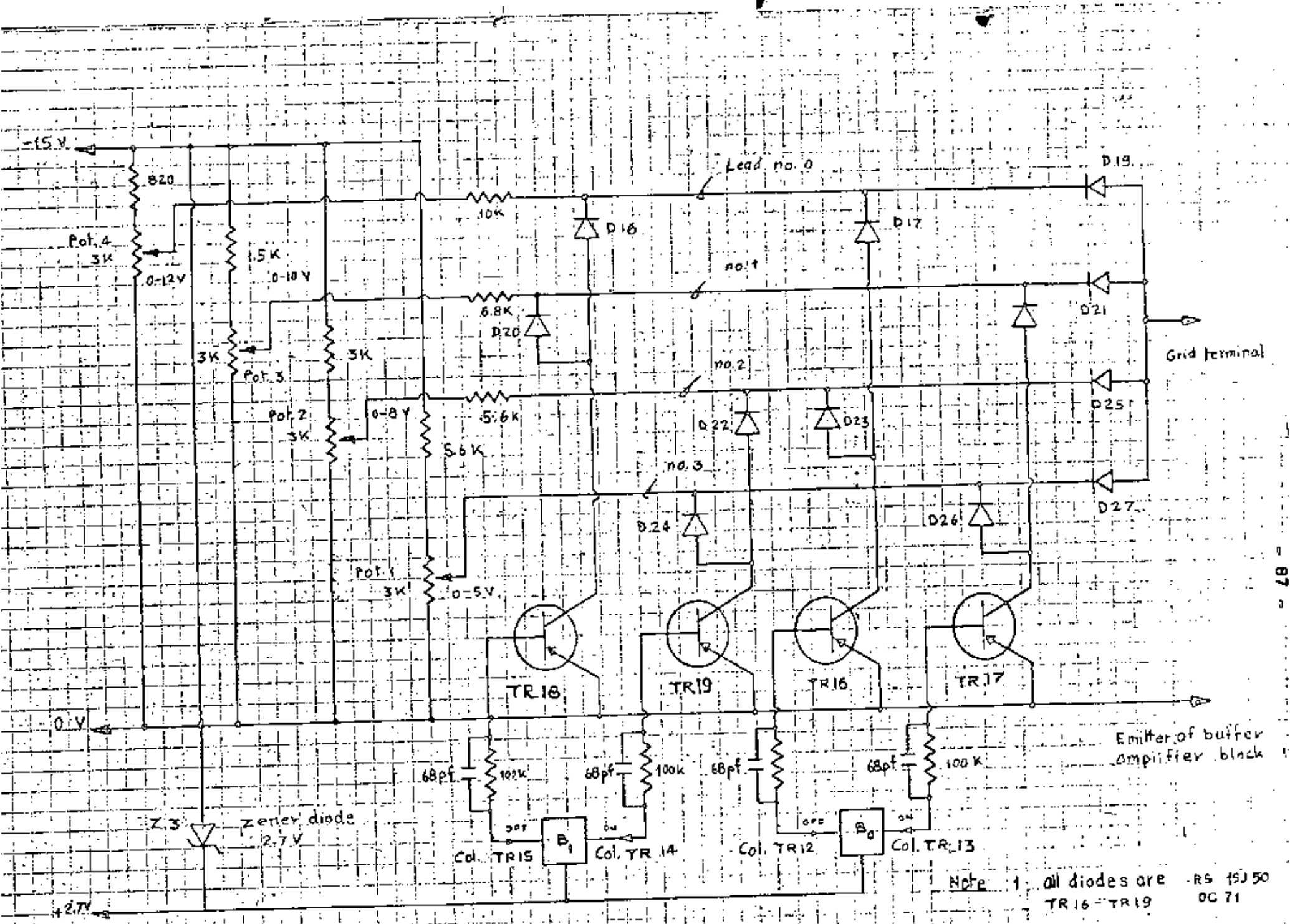
Note all diodes are OA 79

Fig. 17.a Digital pulse counter

Sequence of operation of the binary circuit (see fig. 4 block 12 and fig. 17 a)

Transistor	Reset Pulse	Marking pulse			Remark
		1st	2nd	3rd	
TR_{12}	-	+	-	+	+ = saturated - = cut off
TR_{13}	+	-	+	-	
TR_{15}	-	-	+	+	
TR_{14}	+	+	-	-	
TR_{16}	+	-	+	-	
TR_{17}	-	+	-	+	
TR_{18}	+	+	-	-	
TR_{19}	-	-	+	+	

Fig. 17 b



Note 1. all diodes are RS 1SJ 50
TR 16 - TR 19 OC 71

2. B_0 and B_1 are the binary circuits

Fig. 18. Electronic selector switches and Grid voltages supply

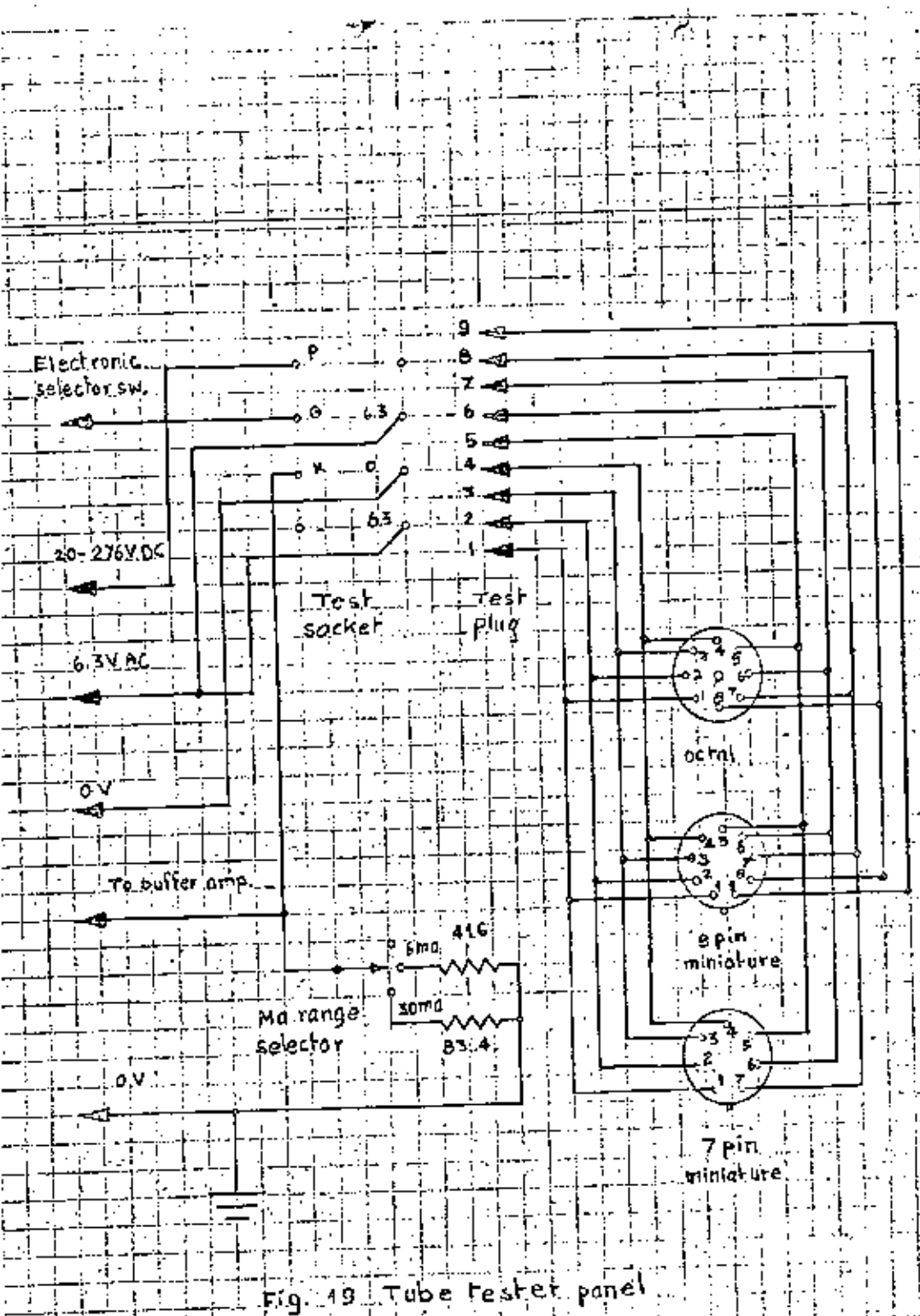


Fig. 19 Tube tester panel

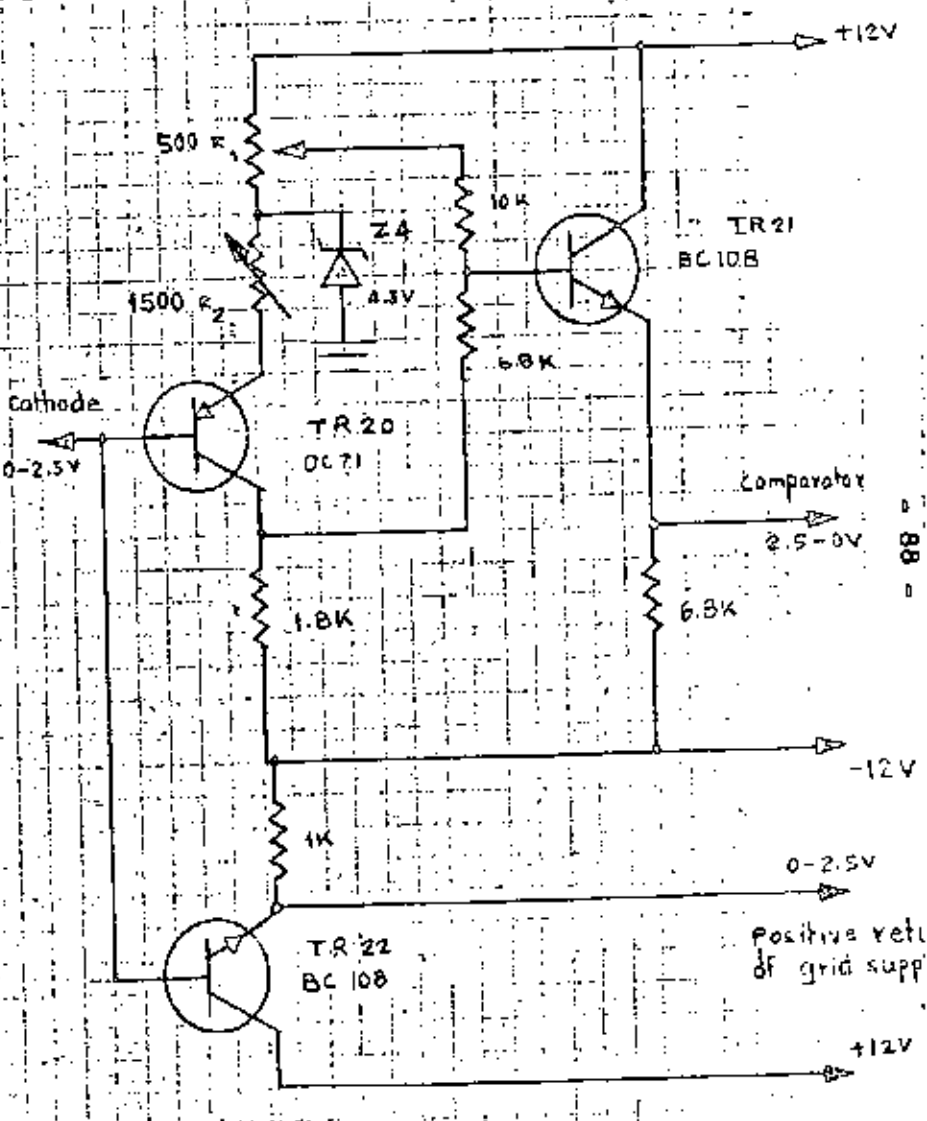


Fig. 20 Buffer amplifier

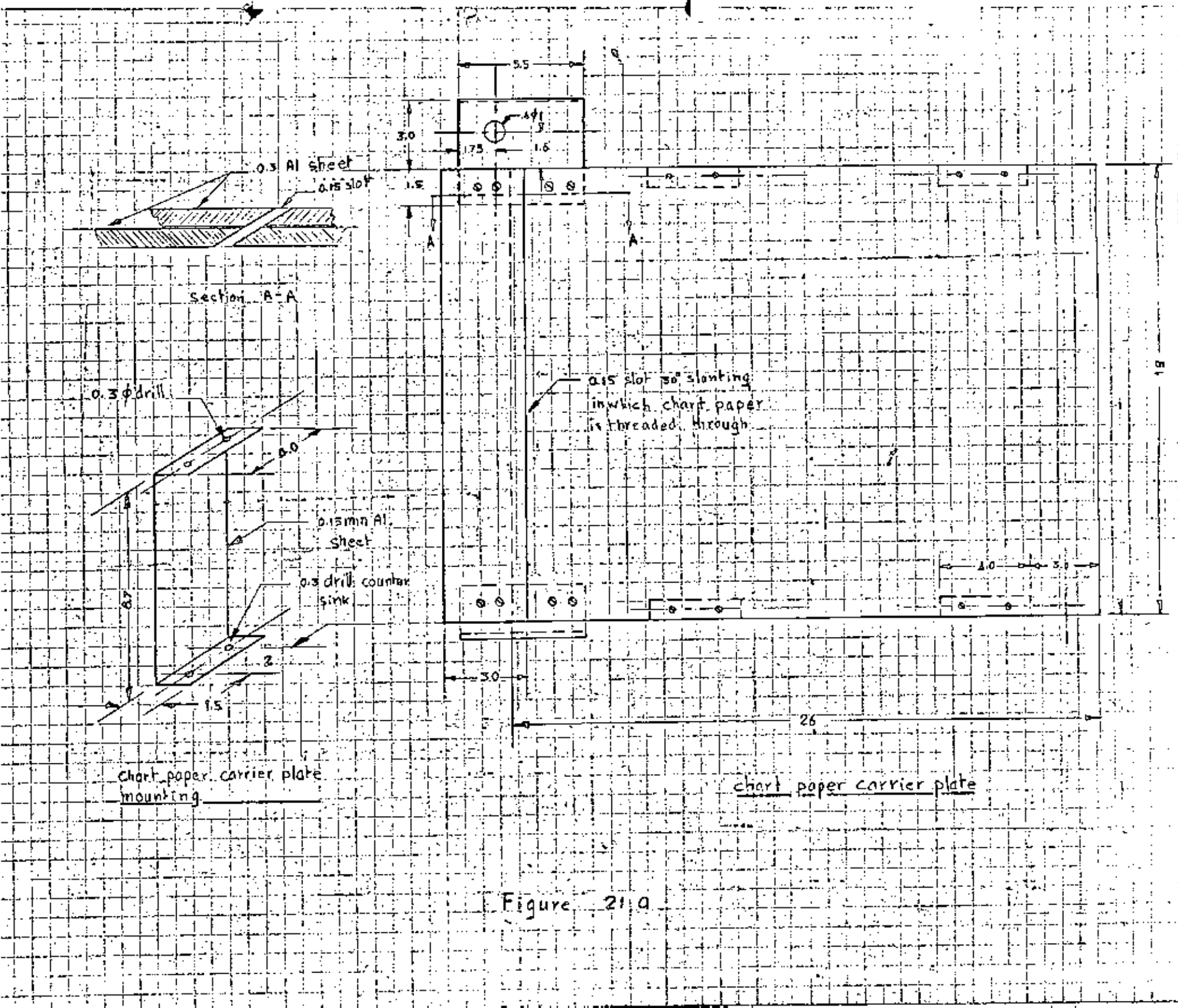

0.3 Al sheet
0.15 slot
Section A-A
0.3 φ drill
0.15mm Al sheet
0.3 drill counter sink
Chart paper carrier plate mounting
0.15 slot 30° slanting in which chart paper is threaded through
chart paper carrier plate
5.5
3.0
1.75
1.6
1.5
8.0
8.7
2
1.5
3.0
26
4.0
3.0
19

Figure 21 a

2.0
0.5
0.5
1.0
1.5
4.5
Belt driving pulley
Brass sleeve
4.6
2
Ball bearing
4
6 mm.φ drill
Idling pulley
1.5
6.0
9.2
5.0
15.2
4.5
Chart paper compartment
Adjustable screw for supporting chart spool
3
4.5
0.3φ drill
counter sink
Chart roll supporter

Figure 21b

1.0
0.3
1.25
1.60
0.2
0.2
Cross section of stylus guide block showing groove dimensions
stylus trolley
0.6
0.3
Position of stylus
Lower stylus guide plate
0.2
cross section of stylus guide block
3.0
3.0
0.5
0.8
2.5
1.5
18.5
Plexiglass
Aluminium angle 0.3 mm thick
Stylus track assembly
Detail drawing of stylus track assembly

Figgure 21 C

Effective chart length, L $= \frac{5.85 \text{ ft} \times 318}{360}$

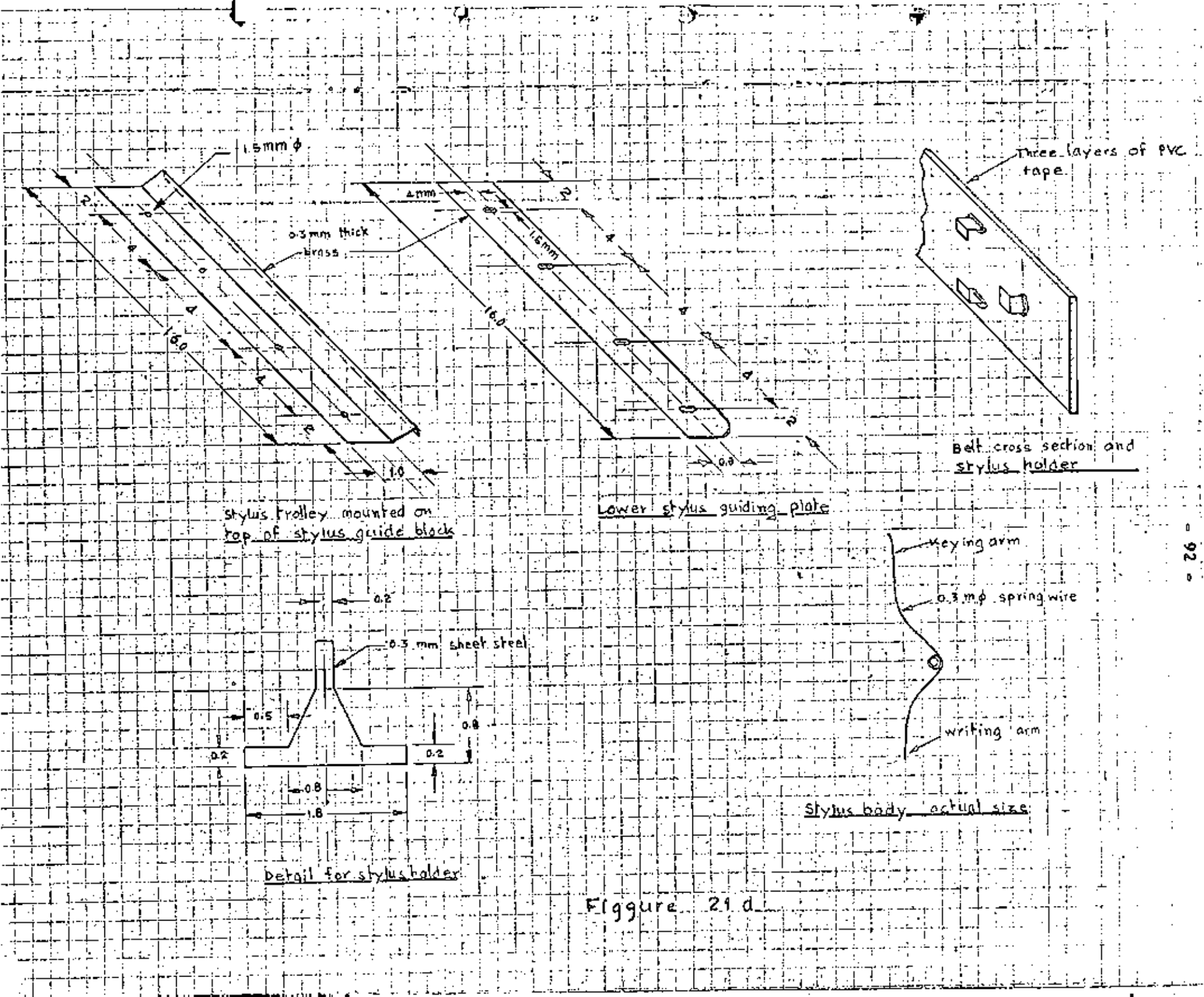
$= 16.25 \text{ cm}$

The printed y scales as measured are 1 inch apart. Let the rate of increasing of voltage scale be 40 Volt/in.

So the range of voltage scale $= \frac{16.25 \times 40}{2.54}$

$= 256$ Volts

The final setting of the voltage range is from 20 to 256 + 20 = 276 V


1.5mm ϕ
0.3mm thick brass
4mm
1.6mm
16.0
16.0
1.0
0.8
Stylus trolley mounted on top of stylus guide block
Lower stylus guiding plate
Three layers of PVC tape
Belt cross section and stylus holder
keying arm
0.3 mϕ spring wire
writing arm
Stylus body actual size
0.2
0.3 mm sheet steel
0.5
0.8
0.2
0.2
0.8
1.8
Detail for stylus holder

Figgure 21 d

A P P E N D I X

A-1 Calculation of Operating Speeds of the Display Unit

Data for Calculation

Motor speed from measurement at normal operating condition	258.0	rpm
Diameter of driving pulley	4.4	cm
Diameter of idling pulley	4.7	cm
Distance from center to center of pulleys	21.7	cm
Effective chart width	16.0	cm
Required trace width	1.2	cm

Length of belt $= 2 \times 21.7 + \pi \left(\frac{4.4 + 4.7}{2}\right)$

$= 55.8$ cm

Stylus linear speed $= \frac{2580 \times \pi \times 4.4}{60}$

$= 595$ cm/sec

Stylus sweep time for 16 cm effective chart width $= \frac{16}{595} \times 1000$

$= 26.9$ ms

Period of sweep $= \frac{55.8}{595}$

$= .0945$ sec

Sweep rate $= \frac{595}{55.8} \times 60$

$= 592$ cycle/min

Marking pulse width for 1.2 mm trace width $= \frac{0.12 \times 1000}{595}$

$= 202$ μs

A-2 Relation between output voltage and position of the potentiometer (fig. 14)

In normal operating condition, the voltage between grid to cathode of the 6AU6 tube Eg is low and nearly constant. And cathode of the 6AU6 tube is kept constant by the voltage devider resistor R3, R4, R5.

So it is assumed that Eg = constant

From the equation of the output voltage

$$V = I\,(2.2 + 0.5 + .22)$$

$$= I \times 2.92 \times 10^{-3} \text{ Volts}$$

and

$$I = \frac{Eg}{0.5 - R + 0.22}$$

$$= \frac{Eg}{0.72 - R} \times 10^{-3}$$

$$V = \frac{Eg}{0.72 - R} \times 2.92 \times 10^{-3}$$

It is seen that the relation between the output voltage and position of the potentiometer is not linear.

A-3 Calculation of difference amplifier for voltage control circuit (fig. 15)

Design data

Cathode voltage of 6AU6	=	-149 V	regulated
Grid voltage of 6AU6	≅	-146 V	constant
Control potentiometer	=	30	k-ohm, Linear

Assume that voltage at cathode of the 12AX7 tube changes from 50 to 100 V as the output voltage varies from 0 to +300 V. Consequently, voltage between plate to cathode of V1 varies from

$$146 - 50 \text{ V} = 96 \text{ V}$$

to

$$146 - 100 \text{ V} = 46 \text{ V}$$

Resistance ratio of the output voltage devider net work

$$= \frac{R2}{R3} = \frac{50}{250} = \frac{100}{500}$$
$$= 1 : 5$$

Standard resistance value of 47 k-ohm and 220 k-ohm are used.

Actual grid voltage of V2

at output voltage = 0 V $Eg_2 = \frac{300}{47 + 220} \times 47 = 52.8 \text{ V}$ .... (1)

at output voltage = 300V $Eg_2 = \frac{600 \times 47}{47 + 220} = 106 \text{ V}$ ..... (2)

It is assumed that the difference between voltage Eg_2 and Eg_1 is constant and very small.

Thus the voltage drop across control potentiometer

must be $106 - 53 = 54 \text{ V}$

Therefore resistance of the reference voltage devider net work

$$R4 + R5 = \frac{53}{53} \times 30 = 30 \text{ k-ohm}$$

$$R6 = \frac{(150 - 106)}{53} \times 30 = 24.9 \text{ k-ohm}$$

A-4 Effect of non-constant difference of grid voltages to output voltage linearity (fig. 15)

Considering the output voltage equation

$$V_{out} = (Eg_2 \times k_1 - 300) \quad \ldots\ldots (1)$$

where k_1 = Ratio of the voltage devider

and from $Eg_2 = (Eg_1 - \Delta e)$

$$= (V_1 + k_2 R - \Delta e) \quad \ldots\ldots (2)$$

where e = voltage difference between Eg_1 and Eg_2

V_1 = minimum voltage from voltage control potentiometer

k_2 = constant of the potentiometer

from (1) and (2)

$$V_{out} = k_1 (V_1 + k_2 R - \Delta e) - 300$$

$$= k_1 R \left(\frac{V_1 - \Delta e}{R} + k_2 \right) - 300$$

Thus from eq. (3), it is obvious that the relation between the output and resistance of the potentiometer (angular displacement of the paper drum) is linear only when Δe is constant.

A-5 Effect of the potentiometer end effect to voltage scale.

It is found that the effective angular displacement of voltage control potentiometers is 318 degree. Since the diameter of the paper driving drum is 5.85 cm. So, the effective chart displacement per one revolution of the driving drum.