

MINISTRY OF AVIATION - D.L.R.D.(T)/RRF

Amend.

Specification MOA/CV4507	<u>SECURITY</u>	
Issue 2 dated 10th May, 1960	<u>Specification</u>	<u>Valve</u>
To be read in conjunction with K.1001, B.S.448 and B.S.1409	UNCLASSIFIED	UNCLASSIFIED

→ Indicates a change

TYPE OF VALVE - Reliable Sub-Miniature Triode with Flying Leads				<u>MARKING</u>		
CATHODE - Indirectly - heated				See K.1001/4		
ENVELOPE - Glass				<u>BASE</u>		
PROTOTYPE - CV468, VX8156				See B.S.448/B8D/F/1.1		
<u>RATINGS</u> (Note A)				<u>CONNECTIONS</u>		
(All limiting values are absolute)						
				Note		
				Lead	Electrode	
Heater Voltage	(V)	6.3	B	1	Grid	g1
Heater Current	(mA)	175		2	Anode	a
Max. Heater - Cathode Voltage, Cathode +ve	(V)	100		3	Heater	h
Cathode -ve	(V)	100		4	Anode	a
Max. Anode Voltage (Ia = 0)	(V)	350	F	5	No connection	N.C.
Max. Negative Grid Voltage	(V)	50		6	Heater	h
Max. Operating Anode Voltage (pa. max)	(V)	190		7	Cathode	k
Max. Anode Dissipation	(W)	2.0		8	Anode	a
Max. Cathode Current	(mA)	20	F F C D	<u>DIMENSIONS</u>		
Max. Grid Circuit Resistance (Fixed Bias)	(M)	0.25		See B.S.448/B8D/F/2.1		
(Auto Bias)	(M)	0.5		Size Ref. No.2		
Max. Vibration (100 Hours duration Max.)	(g)	5				
(10 Minutes duration Max.)	(g)	20				
Max. Shock (short duration)	(g)	500				
Max. Bulb Temperature	(°C)	165				
Min. Operating Pressure	(mm.Hg.)	55				
Max. Ambient Storage Temperature Range	(°C)	-60/+85				
<u>Typical Operating Conditions</u>						
Measured at Va = 100V Vg1 = -3V						
Anode Current	(mA)	8.0				
Mutual Conductance	(mA/V)	4.2				
Amplification Factor		20				
<u>CAPACITANCES</u> (pF)				<u>MOUNTING POSITION</u>		
				Any		
				<u>TYPE APPROVAL</u>		
				See K1001/15		
				Minimum quantity for submission 225		
				See Note G.		
				<u>APPLICATIONS DATA</u>		
				Issue 1 - See section following		
				Page 7.6		
<u>NOTES</u>						
See next page						

NOTES

- A. Caution to Electronic Equipment Design Engineers: Special attention should be given to the temperature of valves to be operated in Guided Weapons and Aircraft. Reliability will be seriously impaired if the maximum bulb temperature is exceeded. The life expectancy may be reduced if conditions other than those specified for life test are imposed on the valve and will be reduced appreciably if absolute maximum ratings are exceeded. Both reliability and performance will be jeopardized if heater voltage ratings are exceeded; life and reliability performance are directly related to the degree that regulation of the heater voltage is maintained at its centre-rated value. Under no circumstances should the heater voltage supply be allowed to deviate more than $\pm 5\%$ from the rated value.
- B. For greater reliability, the potential between heater and cathode, when cathode is negative with respect to heater, should not be allowed to exceed 10 volts.
- C. The maximum peak acceleration under continuous random vibration conditions specified assumes that the vibration frequency components are varying continuously over the band 10 to 1,000 cycles/sec. in a random manner.
- D. The maximum peak acceleration under short term random vibration conditions specified assumes that the vibration frequency components are varying continuously over the band 10 to 1,000 cycles/sec. in a random manner.
- E. Direct soldered connections to the leads must be at least 5 mm. from the seal and any bending of the leads must be at least 1.5 mm. from the seal.
- F. For greater reliability during use, the grid circuit resistance should be kept to a minimum.
- G. When submitting samples for Type Approval the manufacturer must have drawn the samples from a lot which has met the requirements of the specification. The manufacturer shall provide the test results for that particular lot; together with detailed results on the samples, as required by the Type Approval Authority.

TO BE PERFORMED IN ADDITION TO THOSE APPLICABLE IN K.1001

TESTS IN ANY ONE GROUP SHALL BE PERFORMED IN THE SPECIFIED ORDER

TEST CONDITIONS - UNLESS OTHERWISE SPECIFIED												
K1001	TEST	TEST CONDITIONS	AQL %	INSP. LEVEL	SYMBOL	LIMITS						UNITS
						MIN.	LAL	BOGEY	UAL	MAX.	ALD	
		Vh(V) 6.3										
		Va(V) 100										
		Vg1(V) -3										
AIX/2.1	<u>GROUP A</u>											
	Visual Inspection	Notes: 1, 2. No voltages		100%								
5.14	Inoperatives			100%								
	Insulation	Va-all = -300V Vg1-all = -100V	100%		R	200	-	-	-	-	-	M
			100%		R	200	-	-	-	-	-	M
	Reverse Grid Current (1)	Rg1 = 500k max.	100%		Ig1	-	-	-	-	0.3	-	μA
	Vibration Noise (1)	Notes: 2, 3. Acceleration = 15g peak min. Frequency = 50 c/s Rk = 375 Ck = 1000 μF min. Rg1 = 0 Va(b) = 275V Ra = 22k	100%									
					Vout	-	-	-	-	30	-	mV r.m.s.
AIX/2.2		Note: 4										
AIX/2.3												
	<u>GROUP B</u>											
5.3	Heater-Cathode Leakage Current	Vhk = ± 100V	0.4	II V2	Ihk Ihk	- -	- -	- -	- 2	10 -	- -	μA μA
	Anode Current (1)		0.4	II V2	Ia Ia	4.5 -	- 6.75	8.0 -	- 9.25	11.5 -	- 2.8	mA mA
	Mutual Conductance		0.4	II V2	gm gm	3.2 -	- 5.85	4.2 -	- 4.55	5.2 -	- 0.8	mA/V mA/V
	<u>GROUP C</u>											
	Heater Current		1.0	I	Ih	160	-	175	-	190	-	mA
	Anode Current (2)	Va(b) = 100V Vg1 = -10V Ra = 1M max.	1.0	I	Ia	-	-	-	-	50	-	μA
	Change of Mutual Conductance	Vh = 5.7V Note: 5	2.5	I	Δgm	-	-	-	-	15	-	%

K1001	TEST	TEST CONDITIONS	AQL %	INSP. LEVEL	SYMBOL	LIMITS						UNITS
						MIN.	LAL	BOGEY	UAL	MAX.	ALD	
5.9	<u>GROUP D</u>											
	Reverse Grid Current (2)	Vh = 6.9V; Va = 190V Ia = 16 mA; Vg1 or Rk adjust; Rg1 = 500 k max Note: 6.	2.5	Code G	Ig1	-	-	-	-	1.0	-	μA
	Amplification Factor	Max. grid swing = ± 0.5V Note: 7	2.5	Code G	μ	17	-	-	-	23	-	
	Capacitances	Measured on a 1 Mc/s bridge, valve mounted in a fully screened socket. Shielded. Note: 8	2.5	Code G	Cin	1.8	-	-	-	2.6	-	pF
					Cout	2.4	-	-	-	3.2	-	pF
AIX/ 2.4.2.3					Cag1	1.0	-	-	-	1.8	-	pF
	Power Oscillation	Va = 175V Ik = 20 mA Rg1 = 3.3k f = 50 Mc/s.	6.5	Code G	P.O	1.4	-	-	-	-	-	W
AIX/ 2.4.2.1	<u>GROUP E</u>											
	Lead Fragility	No Voltages	1.0	Code I								
	Glass Strain	No Voltages Note: 9	2.5	Code G								
	Vibration Noise (2)	Notes: 3, 10.		Code L	Vout	-	-	-	10	-	-	mV r.m.s.
	Vibration Fatigue	Acceleration = 5g peak min. Time = 200 hours Note: 11		Code L								
AIX/ 2.4.2.4.3.	Vibration Noise (3)	Note: 12 Acceleration = 20g peak min.; Rk = 375 Ck = 1000 μF min.; Rg1 = 0; Ra = 22k; Va(b) = 275V Frequency = (1) 60-120 c/s (2) 120-250 c/s (3) 250-500 c/s (4) 500-1000 c/s (5) 1000-2000 c/s			Vout	-	-	-	150	-	-	mV (pk-pk)
					Vout	-	-	-	150	-	-	mV (pk-pk)
					Vout	-	-	-	150	-	-	mV (pk-pk)
					Vout	-	-	-	150	-	-	mV (pk-pk)
					Vout	-	-	-	200	-	-	mV (pk-pk)
AIX/ 2.4.2.4.3.	<u>Post Vibration Noise (3) Tests:</u>	Combined AQL	2.5									
	Heater-Cathode Leakage Current.	Vhk = ± 100V	1.0		Ihk	-	-	-	-	10	-	μA
	Reverse Grid Current (1)	Rg1 = 500k Max.	0.25		Ig1	-	-	-	-	0.5	-	μA
	Mutual Conductance		1.0		gm	3.0	-	-	-	5.2	-	mA/V
	Vibration Noise (1)	As in group A. Note: 3	1.0		Vout	-	-	-	-	75	-	mV r.m.s.
AIX/ 2.4.2.4.3.	Catastrophics	Note: 13	0.25									
	Shock	Hammer Angle = 30° No Voltages (T/A only)										
AIX/ 2.4.2.4.3.	<u>Post Shock Tests:</u>	As for Post Vibration Noise (3) Tests										

K1001	TEST	TEST CONDITIONS	AQL %	INSP. LEVEL	SYMBOL	LIMITS						UNITS
						MIN.	LAL	BOGEY	UAL	MAX.	ALD	
	<u>GROUP F</u>											
AVI/5	Life	Vg1 = 0V Vhk = 135V heater positive Rg1 = 470k Rk = 375										
AVI/5.1	Stability Life											
	Change in Mutual Conductance		1.0	I	Δgm	-	-	-	-	10	-	%
AVI/5.3	Intermittent Life											
	Test Point 200 hours	Combined AQL	4.0	Code I								
5.14	Inoperatives	Note: 14	0.25									
	Heater-Cathode Leakage Current	Vhk = \pm 100V	1.5		Ihk	-	-	-	-	10	-	μA
	Reverse Grid Current (1)	Rg1 = 500k max.	1.0		Ig1	-	-	-	-	0.3	-	μA
	Mutual Conductance		1.0		gm	3.2	-	-	-	5.2	-	mA/V
	Average Change of Mutual Conductance				Δgm	-	-	-	-	10	-	%
	Insulation		2.5									
		Va - all = -300V Vg1 - all = -100V			R	100	-	-	-	-	-	M
					R	100	-	-	-	-	-	M
	Test Point 1000 hours	Combined AQL	6.5	Code H								
5.14	Inoperatives		1.5									
	Heater-Cathode Leakage Current	Vhk = \pm 100V	4.0		Ihk	-	-	-	-	10	-	μA
	Reverse Grid Current (1)	Rg1 = 500k max.	1.5		Ig1	-	-	-	-	1.0	-	μA
	Mutual Conductance		1.5		gm	2.8	-	-	-	5.2	-	mA/V
	Insulation		4.0									
		Va - all = -300V Vg1-all = -100V			R	50	-	-	-	-	-	M
					R	50	-	-	-	-	-	M
	<u>GROUP G</u>											
AIX/2.5	Electrical Re-Test after 28 days holding period			100%								
5.14	Inoperatives		0.5									
	Reverse Grid Current (1)	Rg1 = 500k max.	0.5		Ig1	-	-	-	-	0.3	-	μA
	Mutual Conductance				gm	3.2	-	-	-	5.2	-	mA/V

NOTES

- 1 The valve shall be visually inspected for good workmanship, using a visual aid having a X10 magnification. Particular attention shall be paid to the following:-
Structure quality, quality of welds, quality of lead tinning, external dimensions and shape, and freedom from harmful loose particles.
2. This test may be done alternatively in Group G, at the discretion of the manufacturer.
3. The valve shall be mounted so that the direction of vibration is parallel to the minor axis of the electrode structure. The test shall be of sufficient duration to obtain a steady reading of noise output.
4. At this stage the lot shall be formed. It shall be an identifiable lot not exceeding 5,000 valves, manufactured in a period not exceeding 20 consecutive Working days. Normal Sampling (Single) shall apply.
5. The change in mutual conductance is expressed:

$$\frac{(\text{gm at } 6.3\text{V}) - (\text{gm at } 5.7\text{V})}{(\text{gm at } 6.3\text{V})} \times 100\%$$

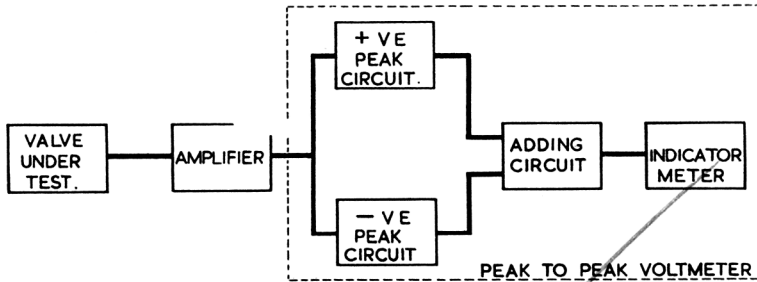
6. For this test, the valve shall be pre-heated for 5 minutes under the test conditions. Ig1 shall not be rising or out of limit after a total of 5 minutes.
7. Va adjusted to maintain a constant Ia of 8mA.
8. The capacitance Test Jig connections shall be as follows:-

Test	Links to H.P	Links to L.P.	Links to E.
Cin	1	3, 5, 6, 7 Sh.	2, 4, 8
Cout	2, 4, 8	3, 5, 6, 7 Sh.	1
Cag1	1	2, 4, 8	3, 5, 6, 7 Sh.

9. This is a destructive test and valves used for this test will not be accepted for delivery.
10. Test conditions as for Vibration Noise (1) in Group A.
11. The valves shall be randomly mounted on the vibrator mount in such a manner that each valve experiences an acceleration of at least 5g peak.
The frequency of vibration shall be swept continuously over the range 60-1000 c/s at a rate of change of frequency not greater than 1 octave per minute.
The heater supply shall be 6.6 V and switched approximately 8 minutes on 16 minutes off throughout the duration of the test.
No other voltages are to be applied.
12. This test to be applied to the total sample previously subjected to the Vibration Fatigue test. Each valve shall be mounted so that the direction of vibration is parallel to the minor axis of the electrode structure and shall be vibrated over the frequency range 60-2000 c/s swept once only at a rate of change of frequency not greater than 1 octave per 30 secs. The voltages to be recorded shall be the values of noise output at the maximum resonance in each of the specified frequency bands, as measured in terms of peak to peak voltage using an approved equipment. See Page 7 & 8 of CV4507 *Amade 1*
13. A valve shall be deemed to be catastrophic if it is either an inoperative as defined in K1001 Section 5.14, or has either or both the following defects:
 - (i) Anode current outside the range $\pm 75\%$ of the bogey in Group B.
 - (ii) Vibration noise output, as measured in Group A, greater than 300 mV.
14. Accept lot if 0 inoperatives in sample, reject lot if 2 or more inoperatives. If 1 inoperative, take further sample of 50 and accept if no further inoperatives.

Test Circuit for Measurement of Peak-to-Peak Noise Output

1. Basic Circuit



ARRANGEMENT OF APPARATUS.

FIG. 1.

2. **Amplifier.** The Input Impedance shall be 1M coupled through a 0.1 μ F capacitor to the valve under test. From 60c/s to 50Kc/s the frequency response shall be within ± 1 dB. of the reference voltage at 1000 c/s. At 60Kc/s it shall be -3dB. ± 0.5 dB, and at 100Kc/s it shall be -15dB ± 1 dB.
3. **Peak-to-Peak Voltmeter.** This shall comprise of the Charging Circuits, Adding Circuit and an Indicator Meter. Its sensitivity shall be such that a signal of 25V R.M.S. applied to its input terminals shall produce full-scale deflection on the Indicator Meter. An approved circuit for the peak-to-peak Voltmeter is given in Fig. 2.
- 3.1 **Charging Circuits.** The positive peak and negative peak charging circuits shall each consist of a diode in series with the capacitor to be charged, or alternatively be such that the combined circuit will develop a peak-to-peak charge equal to that which would have been indicated had these specified circuits been employed. The two time constants shall be the same and shall be such that a single pulse of 25 micro-seconds duration, applied to the input of the amplifier, will result in an indicated reading of not less than 65% of the pulse amplitude. This is equivalent to saying that a 100 micro-second pulse will give a reading of not less than 98% of the pulse amplitude. The leakage rate shall not exceed that which would cause the meter reading at full scale deflection to decay by more than 1% per minute.
- 3.2 **Adding Circuit.** The adding circuit shall be capable of summing accurately the voltages developed across the respective charging circuit capacitors.
- 3.3 **Indicator Meter.** The Indicator Meter shall be such that it will show the magnitude of the total voltage developed in the adding circuit and shall be calibrated to give the peak-to-peak voltage value of the microphony developed at the anode of the valve under test.
4. **Calibration.** Overall calibration of the test circuit shall be effected by applying a 1000 c/s sinusoidal waveform of known amplitude to the input of the amplifier. The overall sensitivity shall be controlled by varying the Amplifier gain.

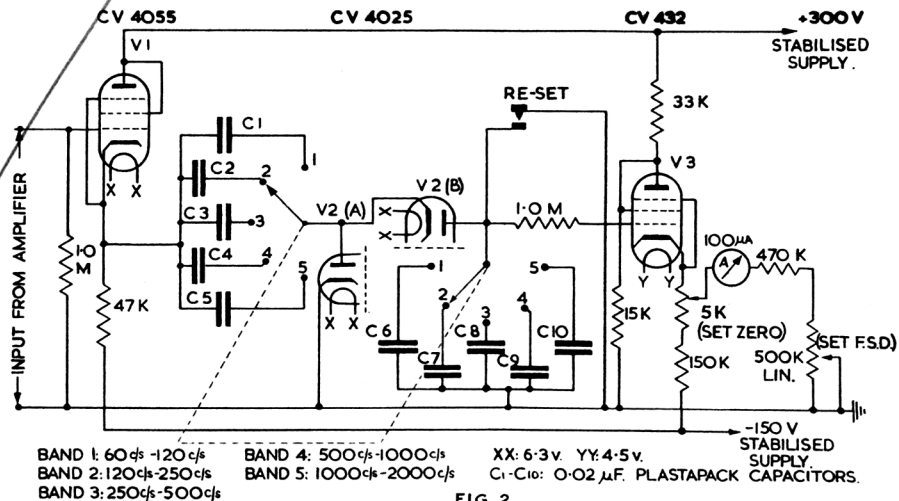


FIG. 2.

ELECTRONIC VALVE SPECIFICATIONS

SPECIFICATION MOA/CV4507

ISSUE 2 DATED 10TH MAY 1960

AMENDMENT NO. 1

- Page 1 Amend 'No. of Pages' to read '6'
Amend Specification Authority to read 'D.L.R.D.(T)/R.R.E.
In 'Application Data' box amend 'Page 7' to read 'Page 6'
- Page 4 Group E Vibration Noise (2) Amend 'Inspection Level' column
to read 'Code L'
- Page 6 Note 12 Amend last sentence to read 'See pages 7 and 8 of CV4504
- Page 7 Remove and destroy page 7

May 1962

N.40490

ARS
13^{9/62}
D.L.R.D.(T)

CV4507

APPLICATIONS DATA

FOR

VALVE TYPE

CV4507

This information is intended for the guidance of users and
does not form part of the procurement specification

ISSUE 1 AUGUST 1960

ISSUED BY:-

MINISTRY OF AVIATION T.L.5. (B)

CASTLEWOOD HOUSE,

77-91 NEW OXFORD STREET,

LONDON, W.C.1.

AMENDMENTS

No:	Date	Page

CONTENTS.

<u>Statistical Sampling.</u>	<u>Page</u>
Statistical Aspects of CV4500 Specifications	4
Typical Operating Characteristic	5
Limiting Distributions of Major Characteristics	6
Maximum Range Distributions centred on Bogey	7
 <u>Grid Characteristics.</u>	
Ia : Vg1 Va=50V, 100V, 150V, 200V	8
gm : Vg1 Va=50V, 100V, 150V, 200V	9
ra : Vg1 Va=50V, 100V, 150V, 200V	10
 <u>Anode Characteristics.</u>	
Ia : Va Vg1= -20V to +2V For nominal valve	11
Ia : Va Vg1= -20V to +2V For top lmt. valve	12
Ia : Va Vg1= -20V to +2V For bottom lmt. valve	13
Ia : Va Vg1= -3V Upper and lower lmt.	14
μ , gm, ra, Vg1 : Ia Va=50V	15
μ , gm, ra, Vg1 : Ia Va=100V	16
μ , gm, ra, Vg1 : Ia Va=150V	17
μ , gm, ra, Vg1 : Ia Va=200V	18
 <u>Miscellaneous.</u>	
Cathode warm-up time curve	19
Maximum permissible value of Grid to Cathode Resistor	20
" " " " " "	21

STATISTICAL ASPECTS OF CV4500 SPECIFICATIONS

These test specifications have been drawn up on a statistical basis involving the following considerations:-

1. The use of 100% testing on its own does not, with presently known methods, and with reasonable economy, result in 100% perfect items reaching the customer, because reliability cannot be tested into a product.
2. To control the average and spread of the characteristics of a batch of valves is a better guarantee that the product is under control, than to accept all of a product solely on the basis that the characteristics lie within certain limits. In general it is true to say that a valve which is just inside a limit is neither better nor more reliable than one which is just outside that limit.
3. It may be demonstrated that the main characteristics of valves fairly closely follow normal or log-normal Gaussian distributions.

The inspection of these valves when submitted for acceptance is therefore carried out in two complementary stages.

Acceptance Sampling by Attributes.

Each Attribute sampling test in the specification has two conditions which define the inspection which must be made in order to ensure that the corresponding characteristic meets the required standard. The conditions are:-

- (a) The Inspection Level, which defines, directly or indirectly, the size of the sample which must be taken.
- (b) The Acceptance Quality Level (AQL), which defines, indirectly, the number of rejects which can be tolerated in the sample.

These conditions also define the Operating Characteristic of the sampling scheme (Page 5), which gives the relationship between the quality of the submitted lot and the probability of its acceptance. In general the levels are so calculated that if lots containing a percentage of rejects equal to the AQL were constantly submitted, then approximately 95% of the lots would be accepted.

It can be seen that the above scheme only defines the permissible percentage of valves outside the specified test limits, and not the distribution of the values of the characteristic within those limits. Theoretically therefore, it would be possible for all the values to lie just within a limit and the product would still be accepted.

To ensure that this situation does not occur on the major electrical characteristics, Variables sampling is introduced.

Acceptance Sampling by Variables

Each Variables sampling test in the specification has one condition which defines the inspection which must be made in order to ensure that the corresponding characteristic meets the required standard. This condition is the Inspection Level, which defines the size of the sample which must be taken.

The sample is divided into groups of five and the required characteristics are recorded. From these results the average value of each characteristic for the whole sample, and the average of the individual ranges for each group of five, are calculated. These values define the location and the dispersion of the characteristic distribution, respectively. The average must lie between the Lower Acceptance Limit (LAL) and the Upper Acceptance Limit (UAL), and the average range must not exceed the Acceptance Limit for Dispersion (ALD)

/Illustrations

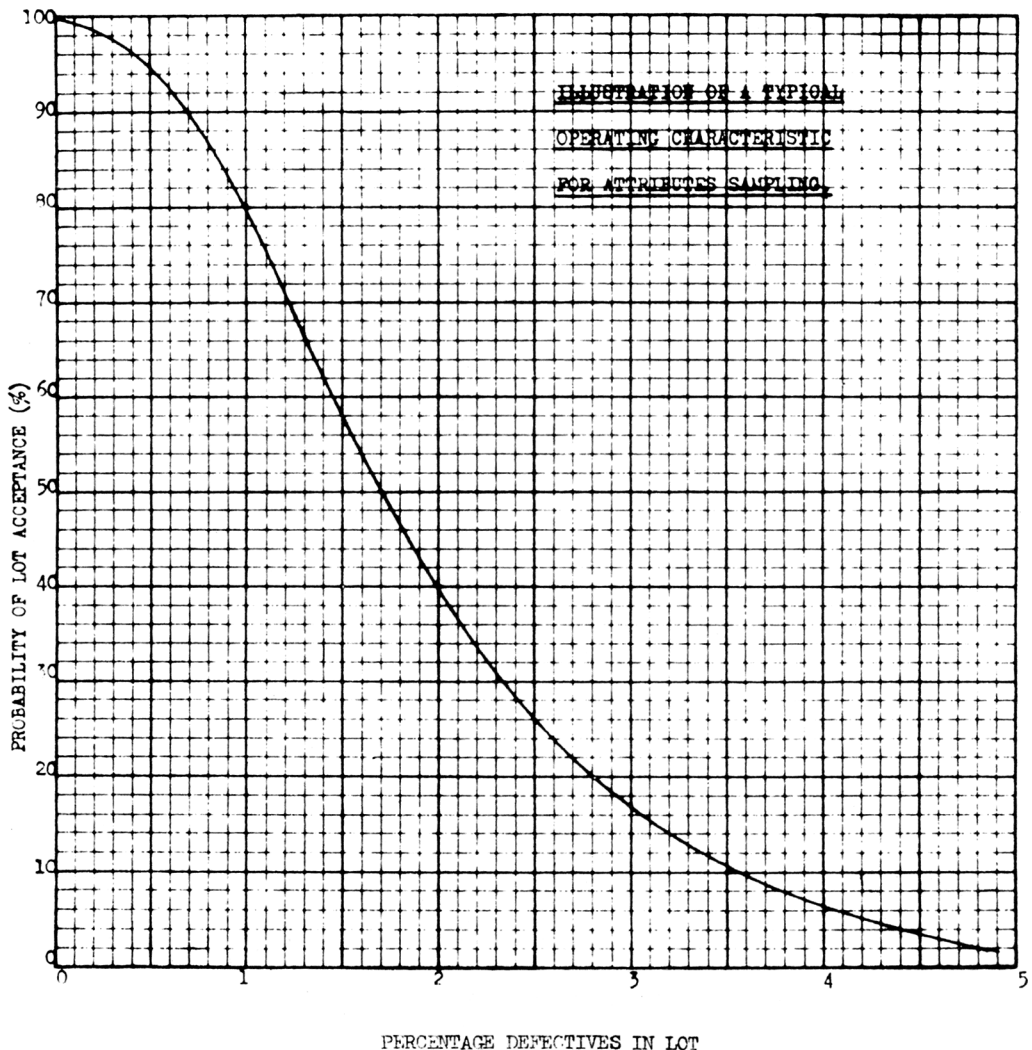
Illustrations of the limiting distributions for this valve, which would be just accepted by the above controls, are given on Pages 6 and 7. These show normal curves with the maximum permissible spread allowed by the ALD, centered on the LAL and UAL, respectively, and the maximum spread distributions, centered on the bogey value.

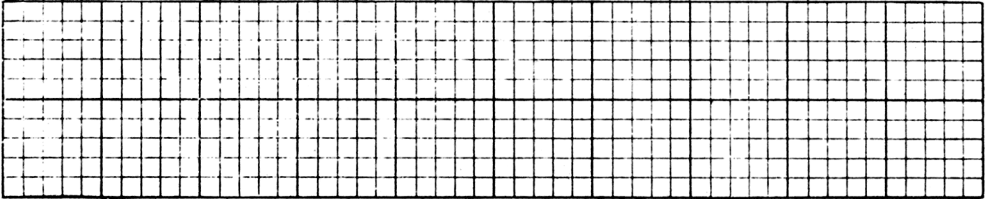
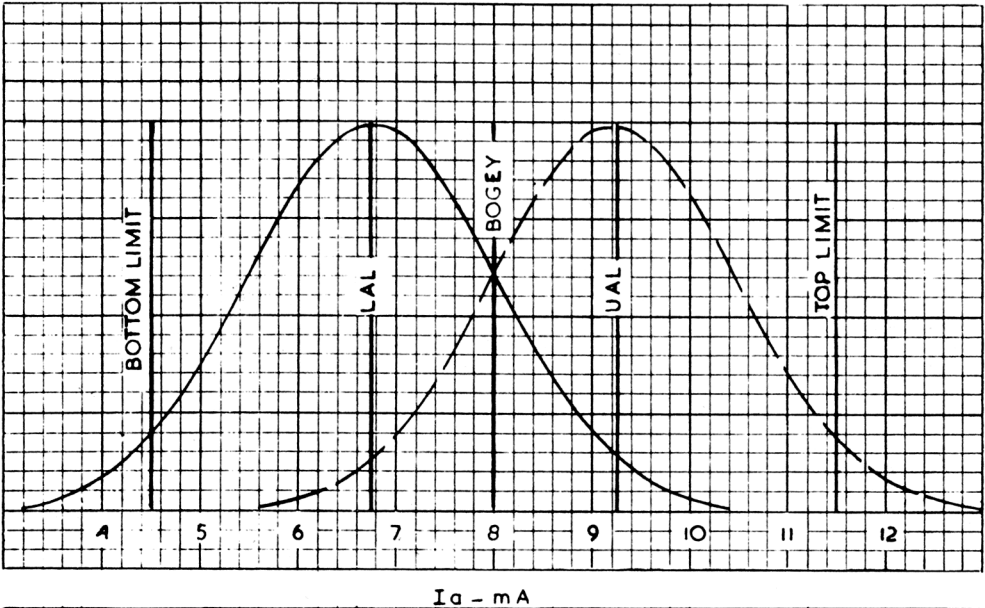
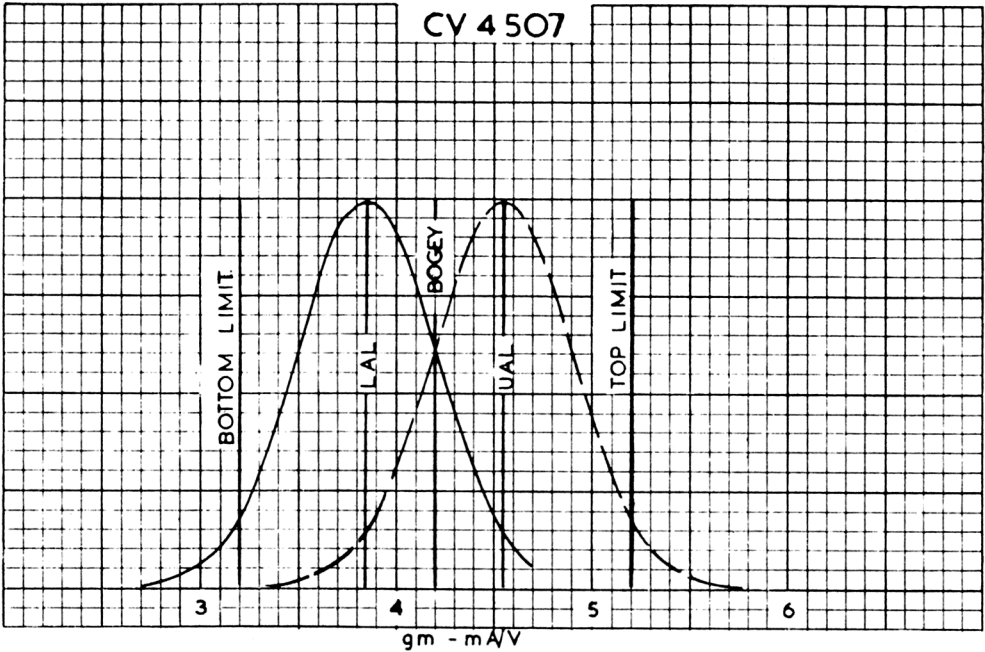
For further details of sampling inspection procedures for Attributes and Variables, reference should be made to K1001, Appendix XI, and MIL Standard 105A, Sampling Procedures and Tables for Inspection by Attributes.

Typical Operating Characteristic

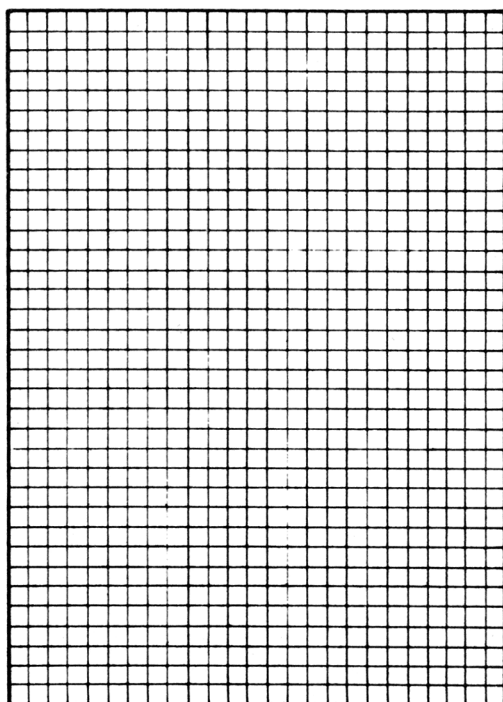
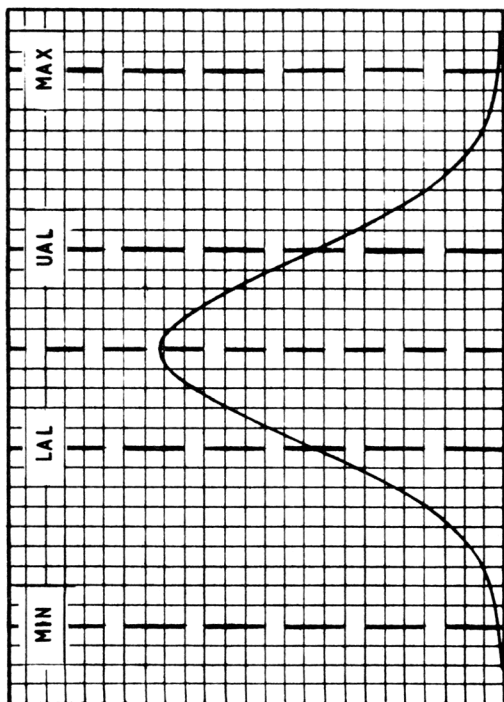
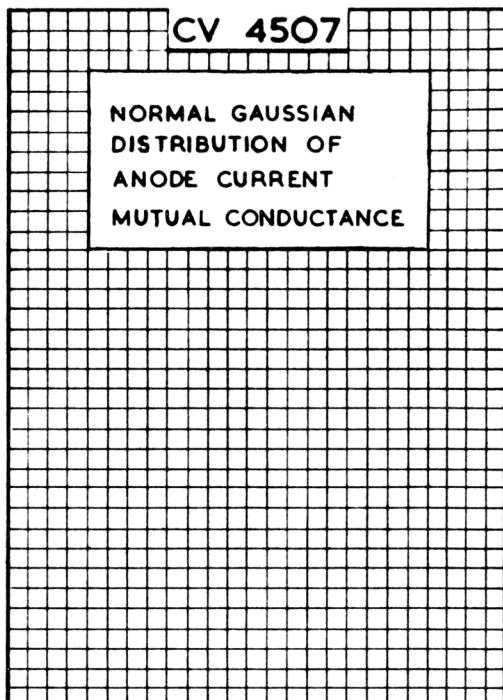
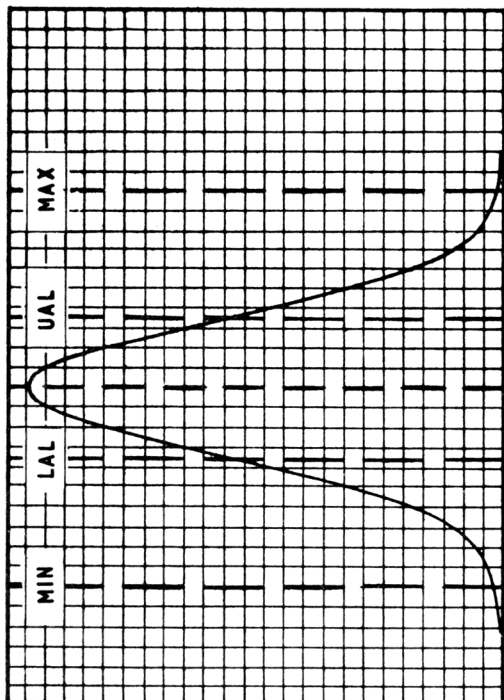
The following curve gives a typical Operating Characteristic for:-

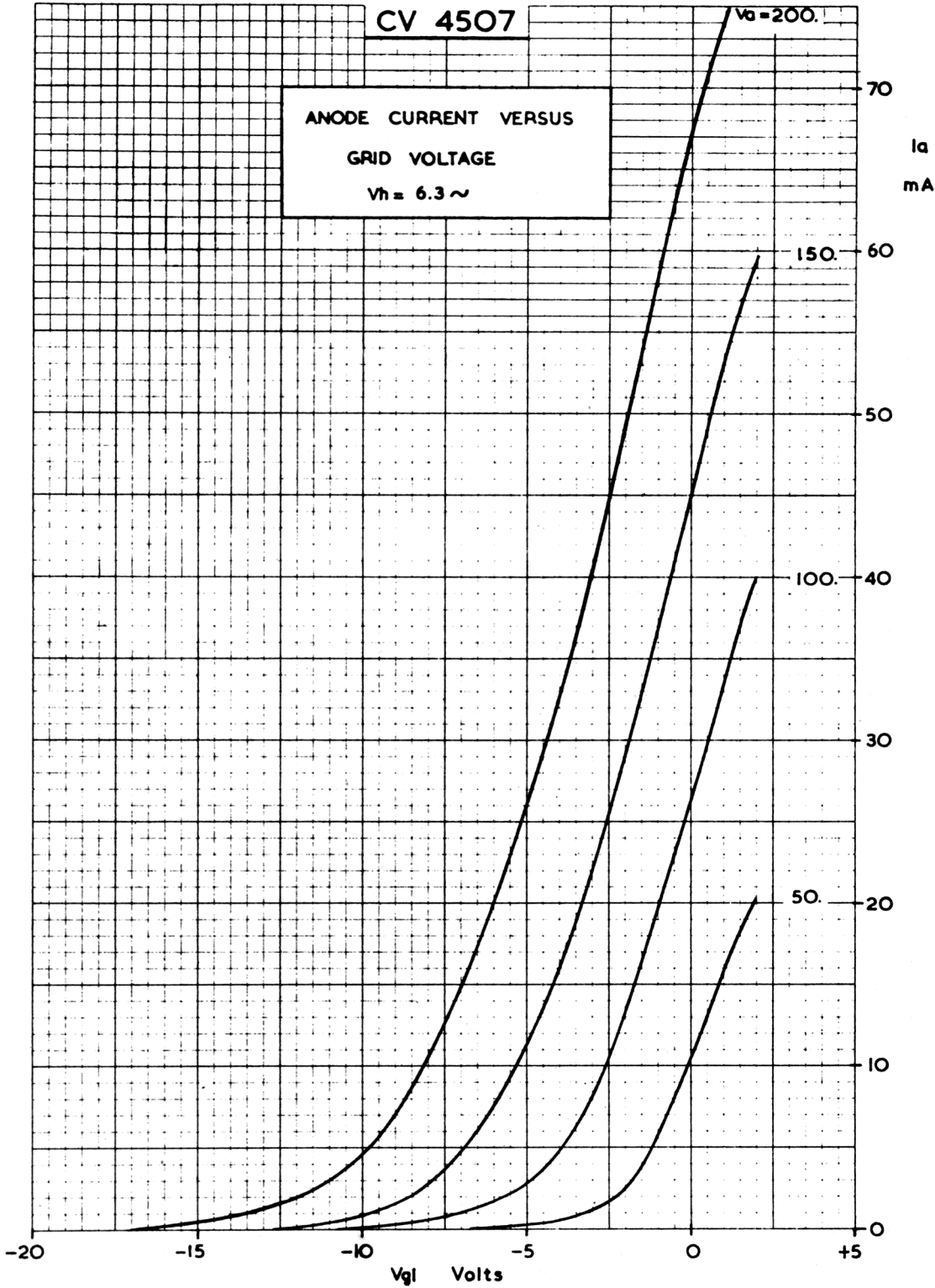
Lot Size of between 1301 and 3200
Inspection Level II (Code Letter L, Sample size 150)
An AQL of 0.4% (Accept on 2, reject on 3).

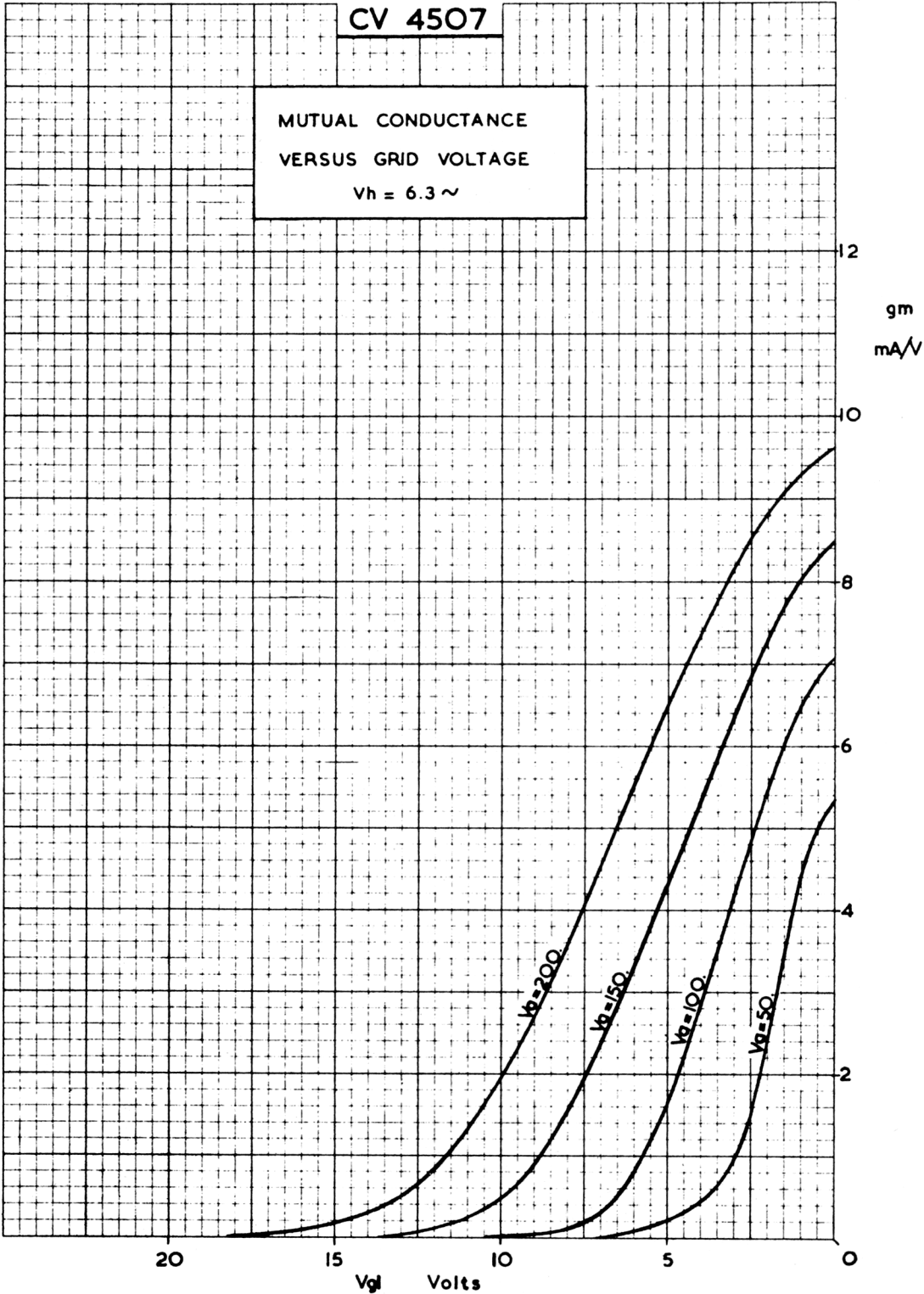


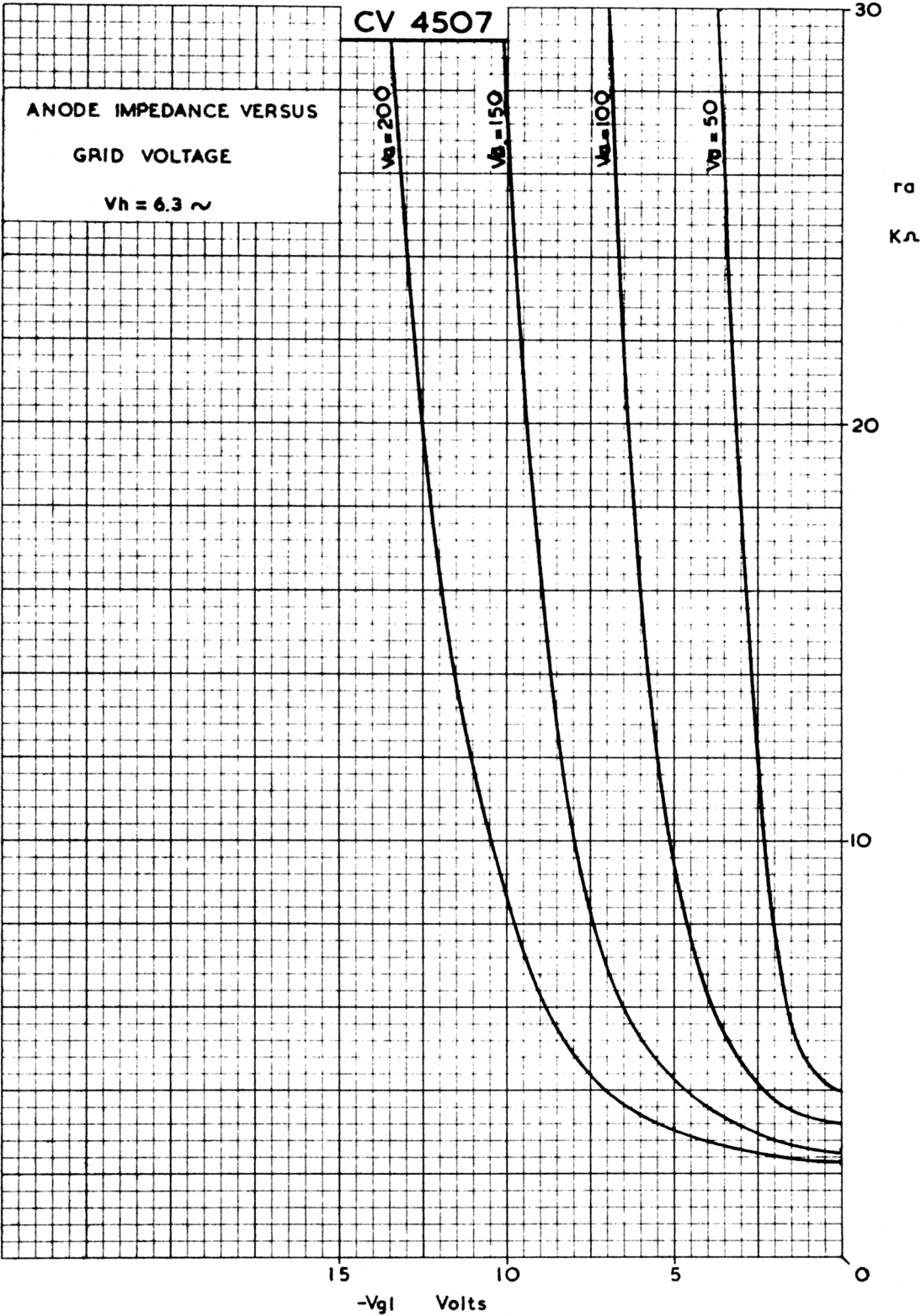


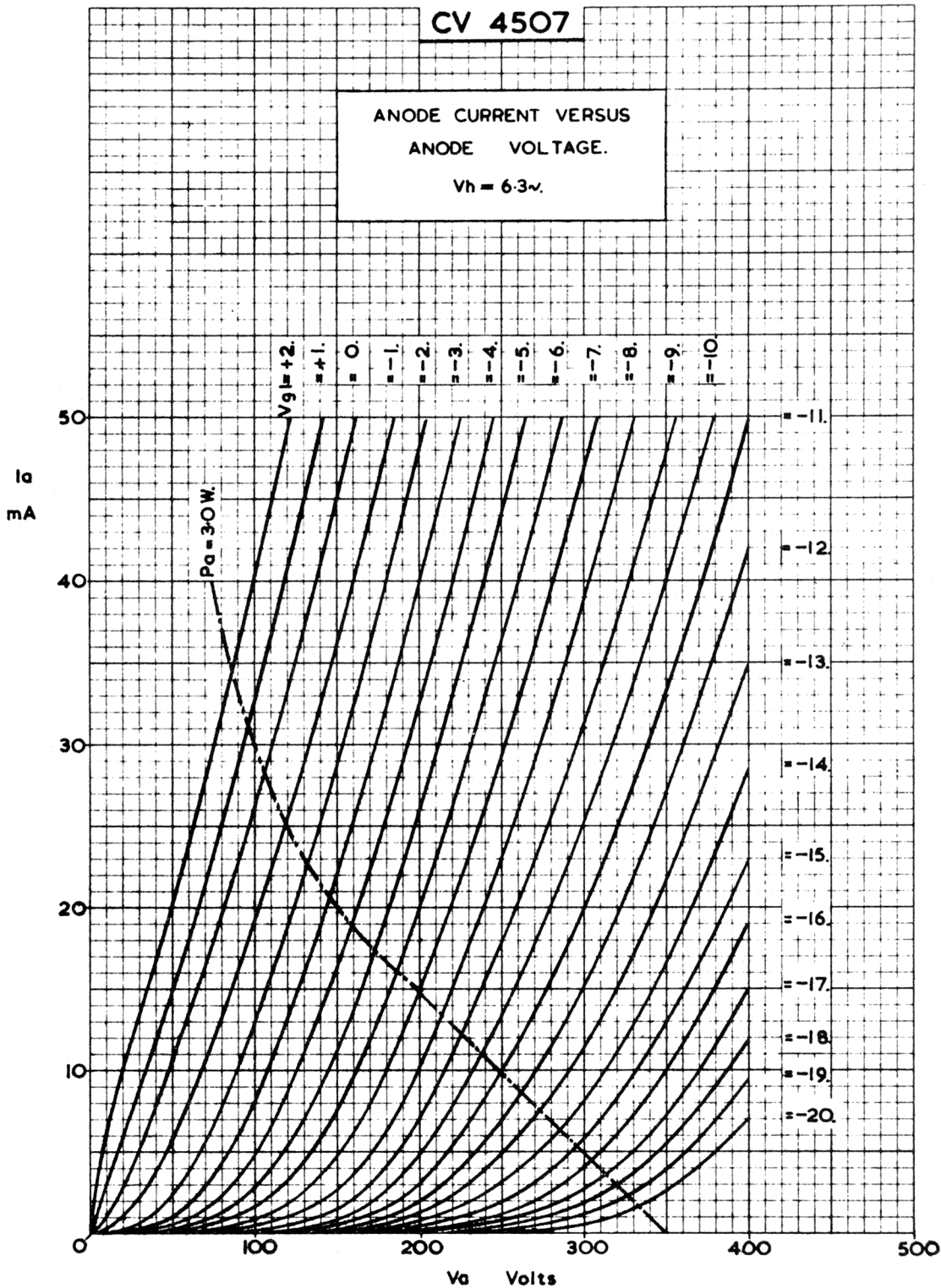
LIMITING DISTRIBUTIONS OF MAJOR CHARACTERISTICS

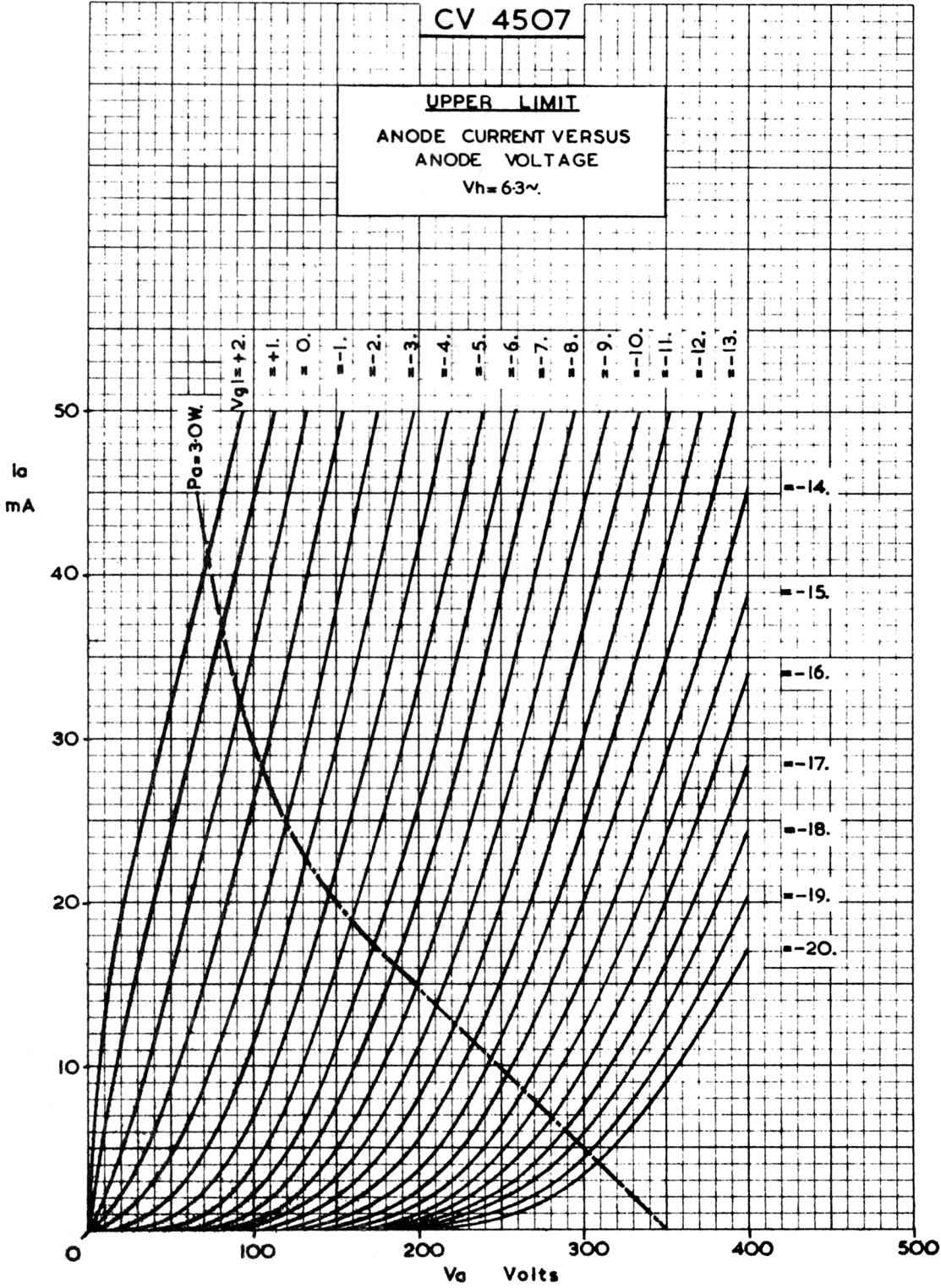


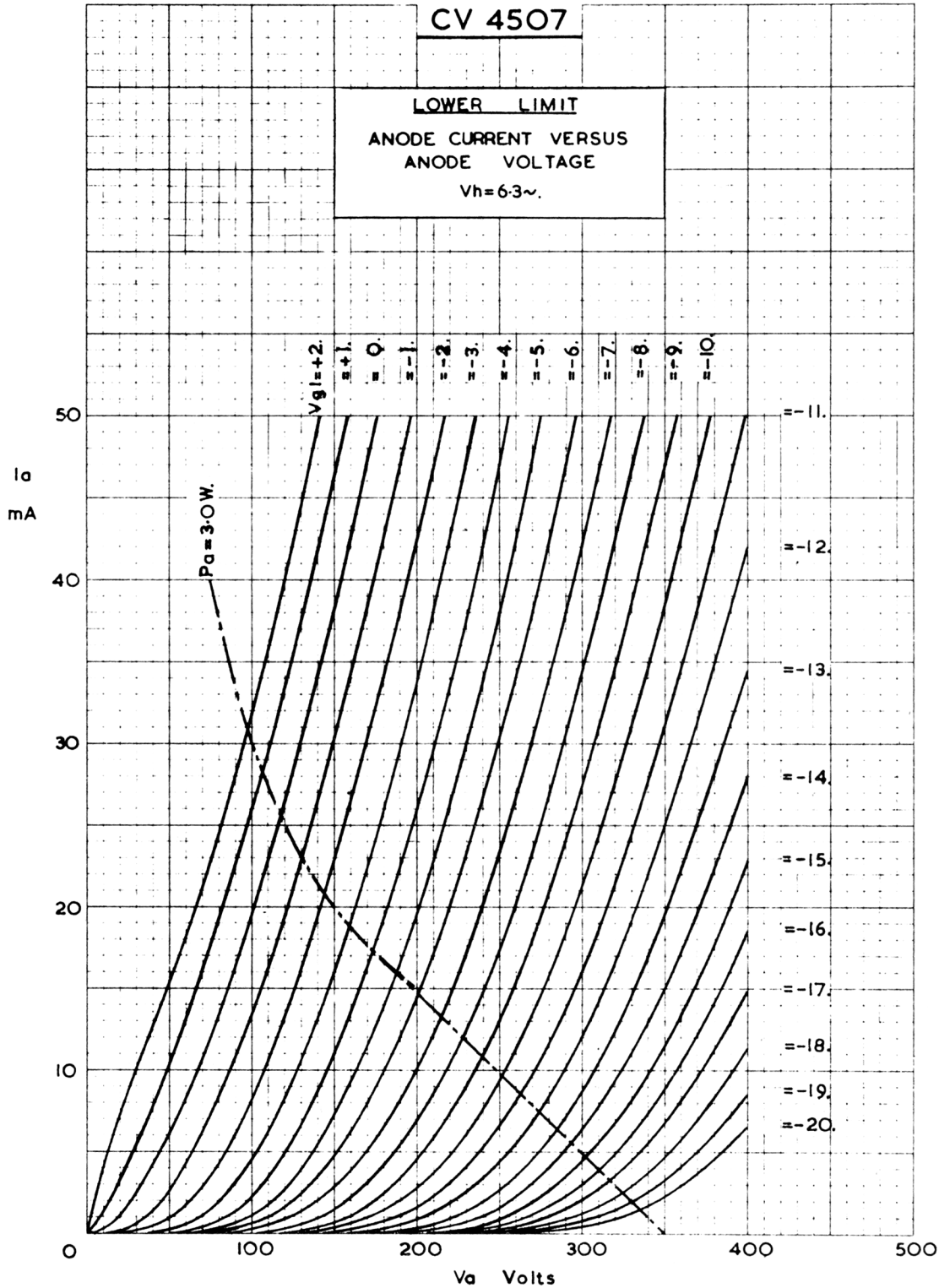


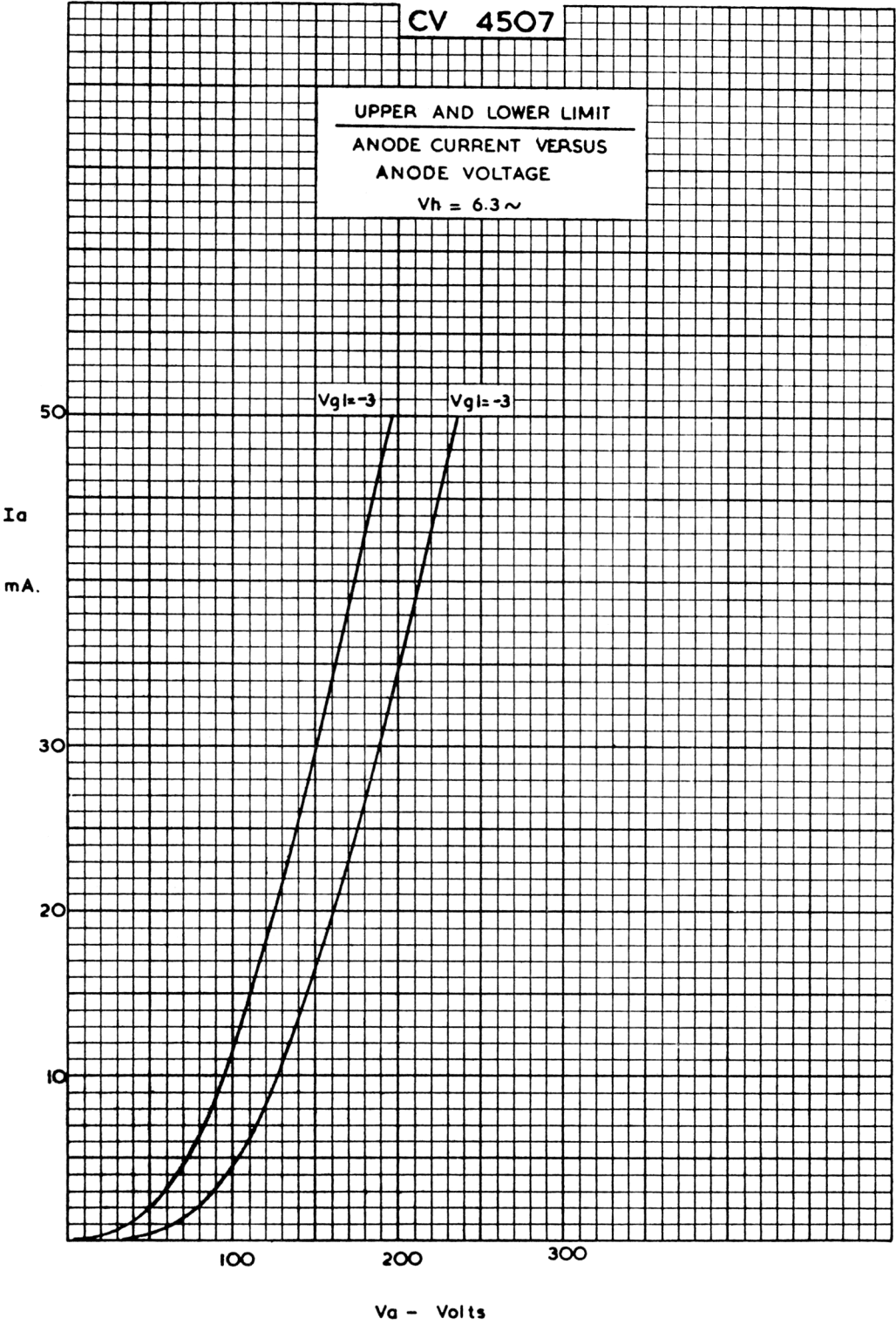


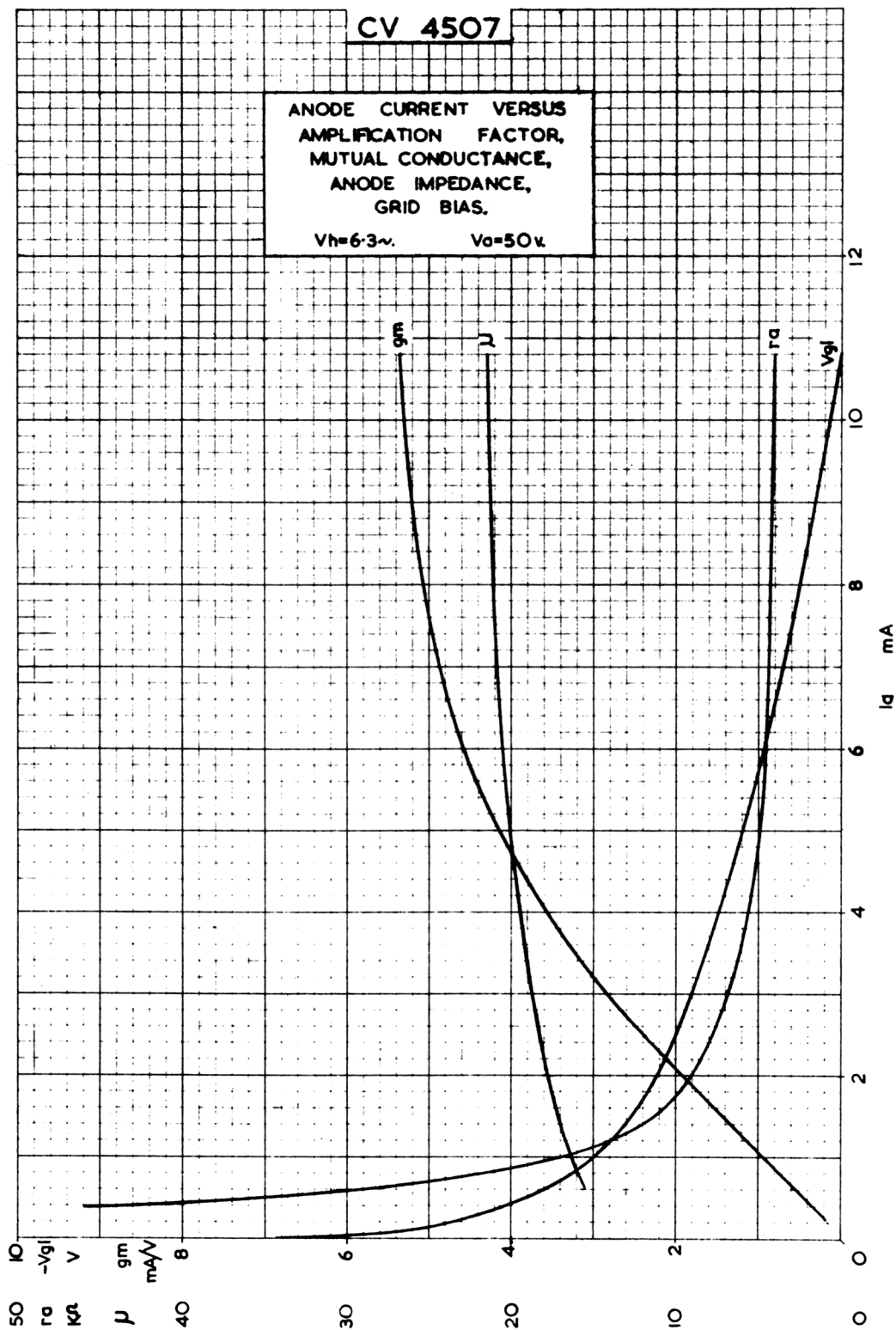


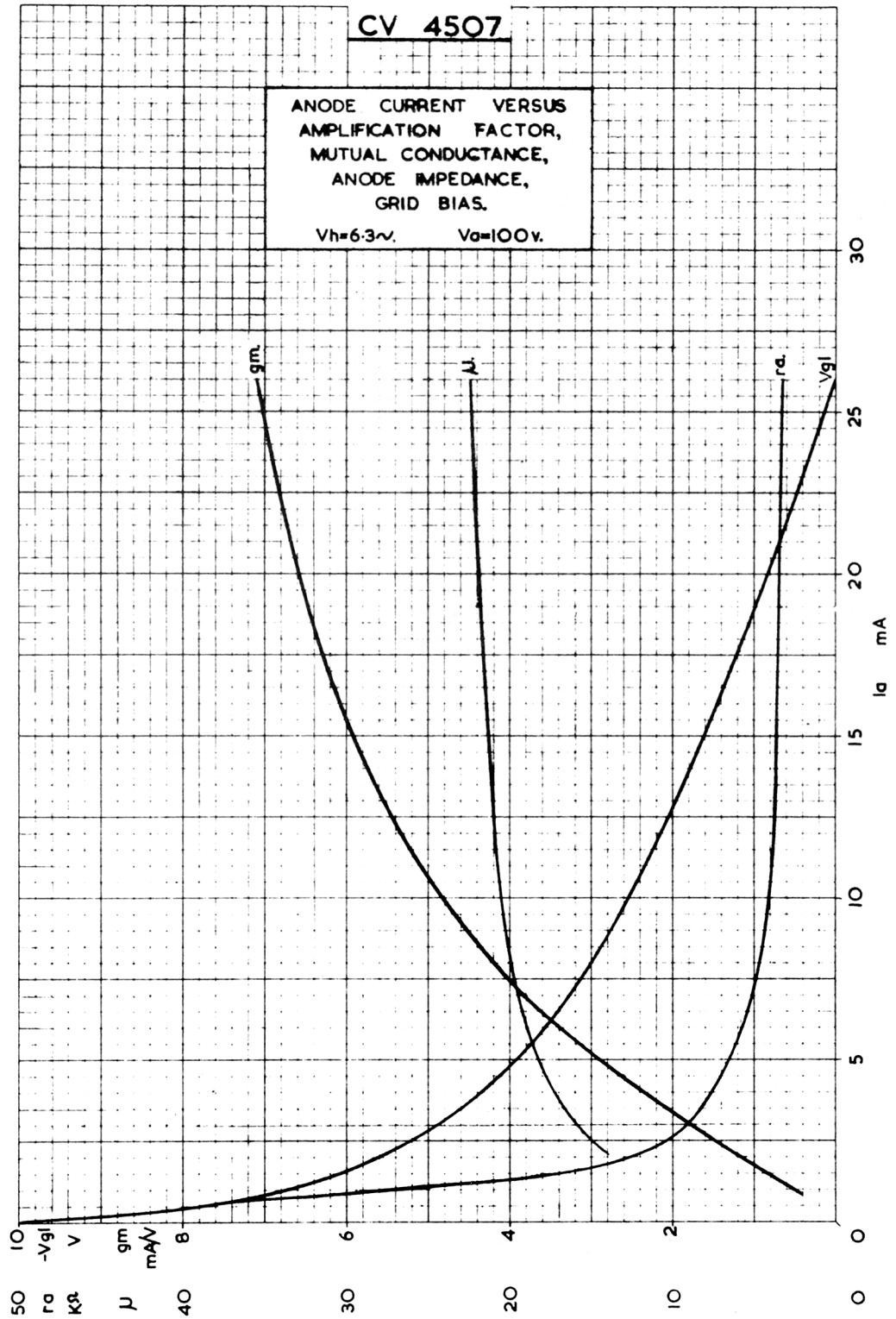


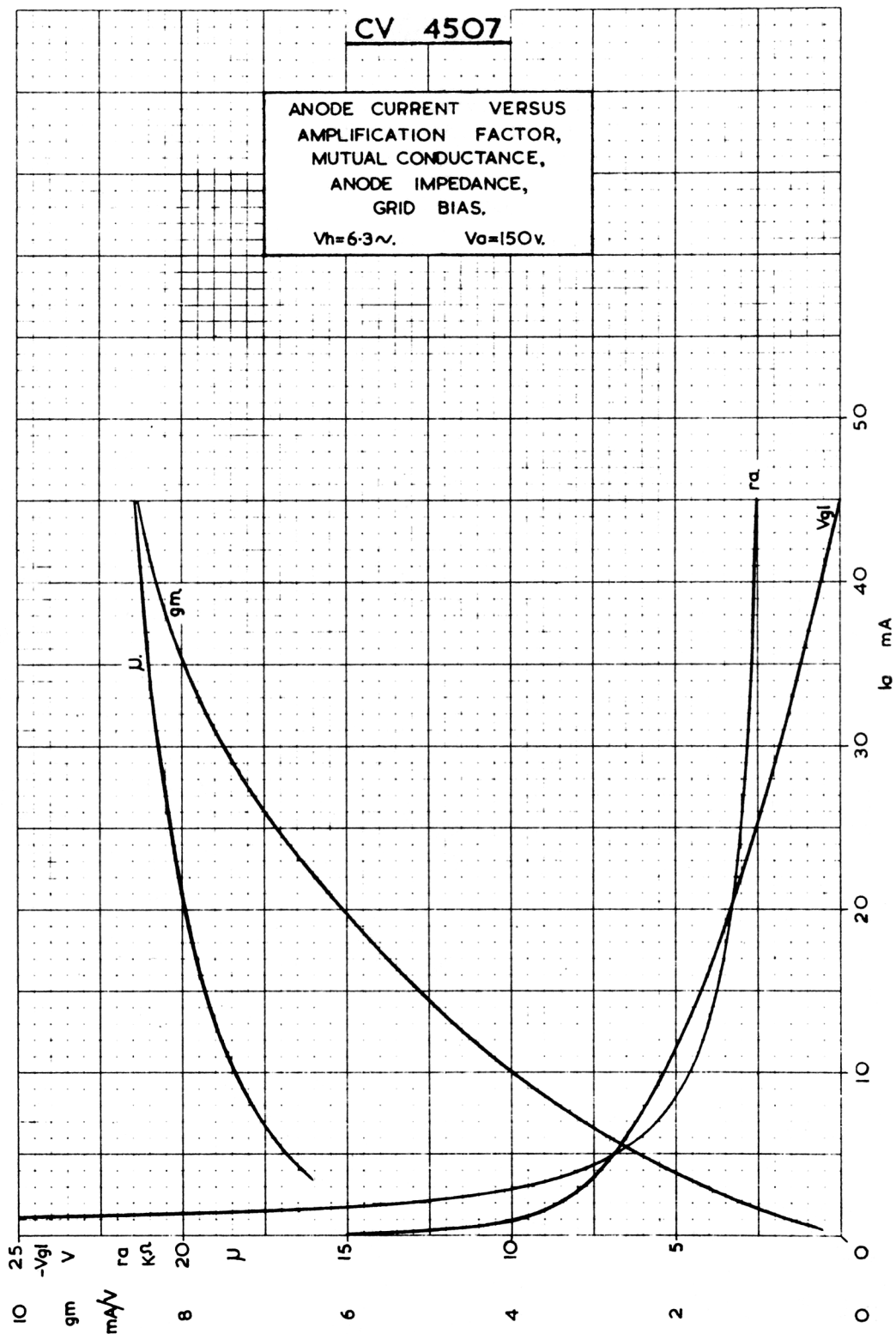


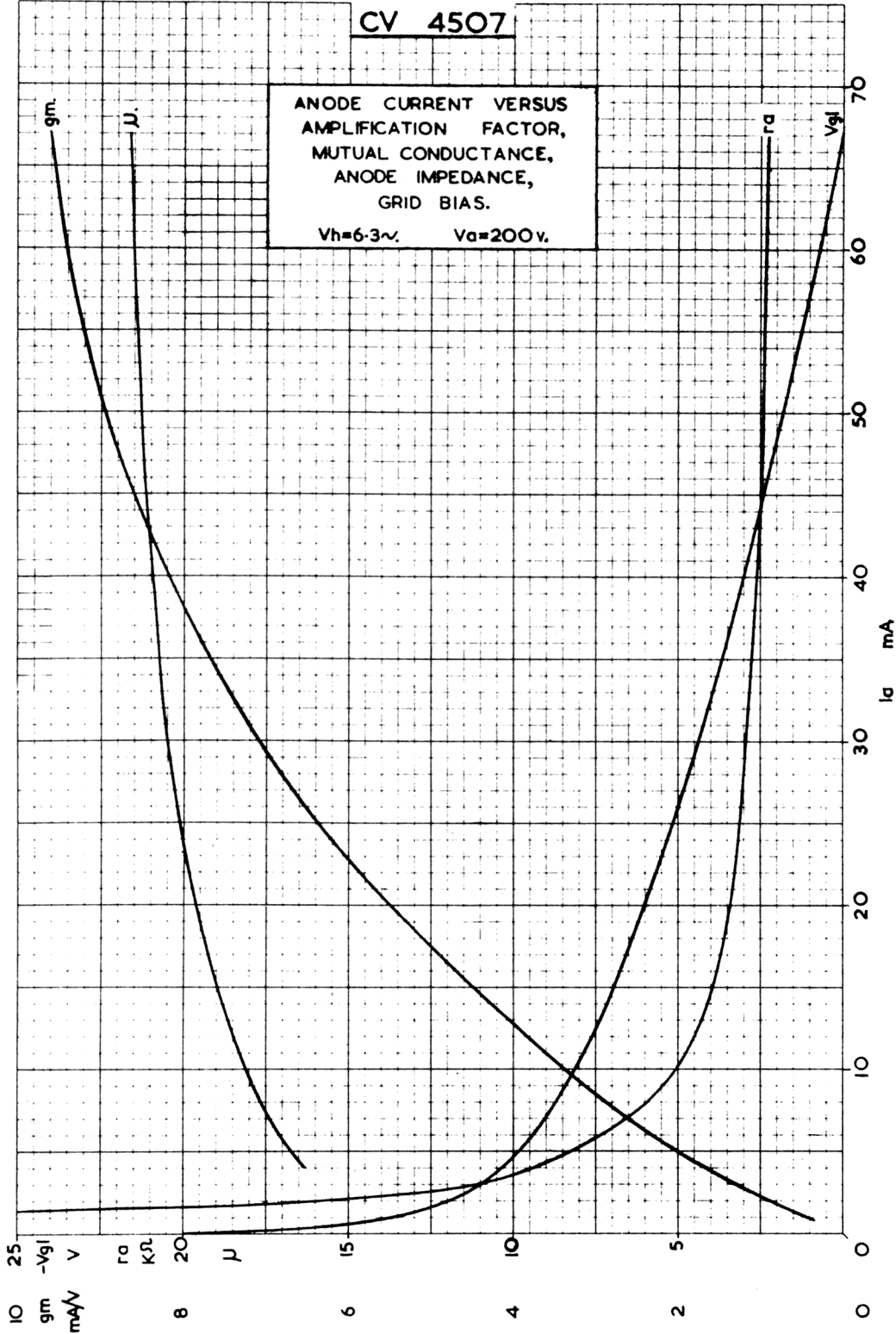


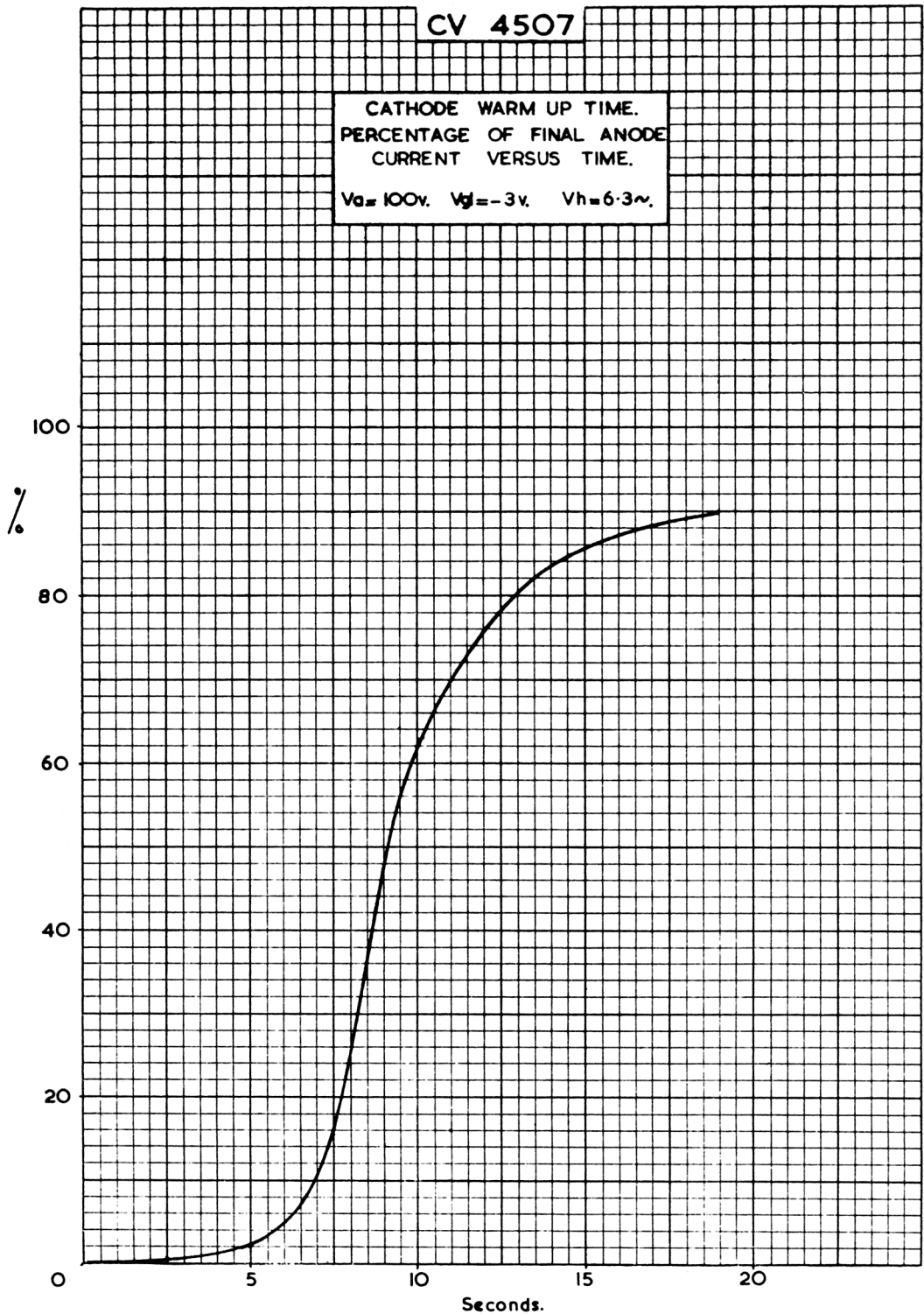












MAXIMUM VALUE OF GRID-TO-CATHODE RESISTOR

The value of the external grid to cathode resistor which can be used with a valve in circuit is limited by the negative grid current of the valve and the D.C. effective mutual conductance of the valve in the circuit.

In simple circuits, the maximum safe value of grid to cathode resistor can be obtained with the aid of the curves given on the next page, by taking the working slope from characteristic curves and calculating the value of the effective cathode resistor from the following equations:-

$$\text{For Triodes:-} \quad R_{k \text{ eff.}} = R_k + \frac{R_a}{\mu}$$

$$\text{For Pentodes:-} \quad R_{k \text{ eff.}} = \frac{I_{k1} \times R_k}{I_a} + \frac{I_{g2} \times R_{g2}}{I_a \times \mu(g_1 - g_2)}$$

Example

CV4502 operating as a voltage amplifier with $V_a(b)=250V$, $R_a=100K$, $R_{g2}=330K$, $R_k=560$. $I_a=2.0mA$, $I_{g2}=0.67mA$, $g_m \text{ working}=3.5mA/V$.

$$\begin{aligned} \text{Then } R_{k \text{ eff.}} &= \frac{2.67 \times 560}{2.0} + \left(\frac{0.67}{2.0} \times \frac{330,000}{28} \right) \\ &= 4715 \text{ ohms.} \end{aligned}$$

From the curves for these values of $R_{k \text{ eff.}}$ and $g_m \text{ working}$:-

$$\frac{R_{g1} \text{ (maximum)}}{R_{g1} \text{ (max) (Fixed bias published)}} \times \frac{g_m \text{ (working)}}{g_m \text{ (published)}} = 16$$

$$\text{Therefore } R_{g1} \text{ maximum} = 16 \times 0.25 \times 10^6 \times \frac{5.2}{3.5} = 6M.$$

In more complex circuits, for example, those employing feedback additional to that given by a cathode, anode or screen grid resistor, or those having large signals and driven into positive grid current, the working slope and effective cathode resistor are difficult to assess. For these cases the maximum value of grid to cathode resistor in circuit is given by the following relationship:-

$$\frac{R_{g1} \text{ (maximum)}}{R_{g1} \text{ (max) (Fixed bias published)}} = \frac{g_m \text{ (published)}}{g_m \text{ (w: eff.)}}$$

where the effective working mutual conductance $g_m \text{ (w: eff.)}$ is obtained by measurement in the circuit and is the change of anode current that would occur in that circuit for unit change of grid voltage, where this change of voltage is that which would be caused by a change of negative grid current within the valve.

