

BRIMAR

RECEIVING VALVE

6BS7

APPLICATION REPORT VAD/508.4

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Standard Telephones and Cables Limited

FOOTSCRAY, KENT, ENGLAND

1.0 INTRODUCTION: The Brimar 6BS7 is an indirectly heated screened pentode of miniature construction intended for use where low AF noise, microphony and hum are required, as in early stages of high gain AF amplifiers. The control grid is brought out to a top cap to reduce stray pick-up in the valve. The heater is intended for operation in parallel with those of other valves in AC operated equipment.

Very effective internal screening is employed, but the input and output capacitances are low enough to allow the valve to be used in RF applications up to frequencies of at least 20 Mc/s.

In this report are characteristic curves and details of the performance of the valve as a resistance capacity coupled amplifier. The anticipated levels of hum, hiss and microphony are given and the precautions necessary to ensure the best performance are discussed.

2.0 DESCRIPTION: The valve is a miniature screened pentode with characteristics similar in most ways to those of the 6J7 valve. The structure is mounted in a T6½ bulb and is fitted with a B9A (Noval) base. The whole assembly is designed with a view to obtaining the utmost possible rigidity. The control grid is screened internally from the heater to eliminate hum due to electrostatic pick-up from that source, and being connected to the top cap is well removed from pick-up from wiring to the base connections. The heater is wound in the form of a double spiral to reduce, as far as possible, the magnetic field set up by the heater current.

3.0 CHARACTERISTICS:

3.1 Cathode:	Indirectly heated	
	Voltage	6.3 volts
	Current (Nominal)	0.15 ampere
	Max. DC Heater-Cathode potential	100 volts

3.2 Dimensions:	Max. Overall Length	2-5/8 ins.
	Max. Diameter	7/8 in.
	Max. Seated Height	2-3/8 ins.

3.3 Base: Type B9A (Noval)	Pin 1	No Connection NC
	Pin 2	Internal Connection IC
	Pin 3	Cathode k
	Pin 4	Heater h
	Pin 5	Heater h
	Pin 6	Internal Shield s
	Pin 7	Anode a
	Pin 8	Screen Grid g ₂
	Pin 9	Suppressor Grid g ₃
	Top Cap	Control Grid g ₁

3.4 Ratings (Design centre):

PENTODE CONNECTED:

Max. Anode Voltage	300 volts
Max. Screen Voltage	125 volts
Max. Anode Dissipation	0.75 watts
Max. Screen Dissipation	0.3 watts

TRIODE CONNECTED (g₂ connected to anode, g₃ connected to cathode):

Max. Anode Voltage	250 volts
Max. Anode Dissipation	1.75 watts

3.5 Inter-electrode Capacitances (measured with no external shield):

PENTODE CONNECTED:

C _{in}	4.0 pF
C _{out}	4.0 pF
C _{g1, a}	0.01 pF

TRIODE CONNECTED:

C _{in}	3.0 pF
C _{out}	6.7 pF
C _{g, a}	1.1 pF

3.6 Characteristic Curves: Curves are included in this report which show:—

Anode current versus anode voltage (I_a/V_a) at various values of control grid voltage with a screen voltage (V_{g2}) of 125 volts, No. 308-237. Similar curves for a screen voltage of 100 volts are shown on No. 308-238, for V_{g2} 75 volts, No. 308-239, and for V_{g2} 50 volts, No. 308-240.

Anode current versus control grid voltage at various values of screen grid voltage, No. 308-242.

Anode current versus anode voltage with the valve connected as a triode, No. 308-241.

Mutual conductance and impedance versus control grid voltage for the valve connected as a pentode, No. 308-243.

Mutual conductance, impedance and amplification factor versus grid voltage for the valve connected as a triode, No. 308-244.

4.0 TYPICAL OPERATION:

4.1 PENTODE CONNECTED (g_3 connected to cathode):

Heater Voltage	6.3	6.3	volts
Anode Voltage	100	250	volts
Screen Voltage	100	100	volts
Grid Voltage	—3	—3	volts
Cathode Bias Resistor	1100	1100	ohms
Anode Current	2.0	2.1	mA
Screen Current	0.7	0.6	mA
Anode Impedance	1.5	2.4	MΩ
Mutual Conductance	1.1	1.25	mA/V
Inner Amplification Factor	20	20	
Grid Voltage for 1/100 g_m at V_{g1} — —3	—8	—9	volts

4.2 TRIODE CONNECTED (g_2 connected to anode, g_3 connected to cathode):

Heater Voltage	6.3	volts
Anode Voltage	250	volts
Grid Voltage	—8	volts
Anode Current	6.5	mA
Mutual Conductance	1.72	mA/V
Anode Impedance	11,600	ohms
Amplification Factor	20	

5.0 OPERATION AS A RESISTANCE CAPACITY COUPLED AF AMPLIFIER:

5.1 Pentode Connected: In the table below are given typical operating conditions under various conditions of anode load and supply voltage which yield an output with approximately 5% distortion.

Anode Supply Voltage		100		300		volts
Anode Load Resistor	100	220	470	100	220	470 kΩ
Cathode Bias Resistor	1.3	3.3	5.6	0.56	1.5	2.2 kΩ
Series Screen Resistor	0.47	1.5	2.8	0.47	1.5	2.8 MΩ
Succeeding Stage Grid Resistor	1.0	1.0	1.0	1.0	1.0	1.0 MΩ
Peak Output Voltage	21	28	31	70	92	100 volts
Voltage Gain	65	80	140	104	124	185

Included in this report are curves of anode and screen current versus control grid voltage taken with a supply voltage of 250 volts and various values of anode load resistor. The characteristics for an anode load of 100 kΩ are given on No. 308-247, for 220 kΩ on No. 308-246 and for 470 kΩ on No. 308-245. The method of using these curves for calculating the resistance capacity coupled amplifier performance is as follows:

As an example, assume it is desired to operate with a load resistor of 220 kΩ and a succeeding valve grid leak of 1 MΩ. It can be seen from the curve that control grid current sets in at about -0.5 volts, so that the bias should be chosen to prevent excursion into voltages lower than this. If a value of -2.0 volts is selected, a reasonably linear I_a/V_{g1} characteristic is obtained with the screen grid operating at 50 volts. With such an operating point the anode current is 0.48 mA, and the screen current 0.23 mA. The cathode bias

resistor will be $\frac{2.0 \times 1000}{0.48 + 0.23}$ or 2800 ohms.

The series screen resistor will be $\frac{200 \times 1000}{0.23}$ or 0.87 MΩ.

Allowing a peak input voltage of 0.3 volt, the grid will swing from -2.3 to -1.7 volts, giving an anode current swing of 0.32 mA to 0.68 mA, or 0.36 mA peak to peak. In a 220 kΩ load this corresponds to an output voltage of 79 volts peak to peak or 39.5 volts peak. The voltage gain is then 131 times.

As allowance must be made for the following grid leak of 1 MΩ, these figures must be reduced by a factor of $\frac{10^6}{10^6 + 0.22 \times 10^6}$ or 0.82. The stage gain is then 108 times and the output voltage 32.5 volts peak.

The distortion may be estimated by inspection of the relative stage gains at the positive and negative peaks of the signal. The gain at -2.3 volts is

$$\frac{(0.48 - 0.32) \times 220 \times 0.82}{0.3} \text{ or } 96.5 \text{ times.}$$

The gain at -1.7 volts is $\frac{(0.68 - 0.48) \times 220 \times 0.82}{0.3}$ or 120 times.

The distortion is then:

$$\frac{120 \left(\frac{120 + 96.5}{2} \right)}{120 + 96.5} \times 100 = 5.3\%$$

5.2 Triode Connected: The valve may be used as a low μ triode resistance capacity coupled amplifier where the requirements for low hum and noise outweigh these for high gain. In the table below are given typical operating conditions under various conditions of anode load and supply voltage which yield an output with approximately 5% distortion.

Anode Voltage	100			300			volts
Anode Load Resistance	100	220	470	100	220	470	k Ω
Cathode Bias Resistor	7.5	14.5	20.0	6.0	14.0	18.6	k Ω
Succeeding Stage Grid Resistor	0.5	1.0	1.0	0.5	1.0	1.0	M Ω
Peak Output Voltage	22	26	28	88	96	105	volts
Stage Gain	12	13	14	13	14	14	times

A curve, No. 308-248, is included in the report, which shows the relation between the various valve parameters and control grid voltage under conditions of RC coupled operation with various values of anode load resistance.

A method of using this curve for calculating performance is as follows. If it is desired to use an anode load of 220 k Ω with a supply of 250 volts, inspection of the curves indicates a reasonably linear portion over the region of grid voltage -2 to -8 volts. Assuming an operating point at -5 volts the anode impedance and amplification factor are shown as 27.2 k Ω and 17 respectively. The anode load is effectively in parallel with the following

valve grid leak, and if this is 1 M Ω the effective load is $\frac{220 \times 1000}{1220}$ or 180 k Ω .

The stage gain is then $\frac{\mu R_a}{R_a + r_a} = \frac{17 \times 180}{207.2}$ or 14 times.

The distortion may be estimated in the same way as for pentode operation by calculating the stage gain at the extremes of the input signal.

6.0 LOW HUM APPLICATIONS:

6.1 Pentode Connected: Due to the extensive internal screening very little magnetic and electrostatic hum pick-up occur in the electrode structure. The double ended construction with the grid connection well separated from the heater wiring enables the grid to heater capacity to be reduced to a negligible value, with the result that hum levels below 1 μ V referred to the grid are obtainable.

Curve No. 308-249 shows the maximum hum level referred to the grid plotted against the percentage of valves giving this level, or less, with a grid circuit impedance of 100 k Ω . A hum balancing resistor with its slider connected to earth was connected across the heater. From this curve it can be estimated how many samples from a large batch will have a hum level below a certain value. It will be seen that to expect a hum level of the order of 2 μ V is reasonable as 90% of the valves would be better than this.

In order to achieve low hum levels from this valve in the first stage of a high gain amplifier, precautions must be taken to see that the valve is not situated in any AC fields from chokes, transformers or heater wiring. Similar precautions must also be taken with the input wiring, and decoupling earth returns pertaining to the stage should be connected to a single point and not distributed around the chassis forming closed loops liable to couple with AC magnetic fields.

A screened top cap connector is necessary to obtain the full low hum advantages from the 6BS7. An external screen around the bulb is desirable, as although an internal screen is provided, the effect of electrostatic charges on the glass envelope is not entirely eliminated, nor can a single screen give complete protection from strong magnetic fields. If the valve is not being used at very low input levels the external screen will not be required.

Although the figures shown on Curve No. 308-249 were measured with a hum balancing resistor across the heater, in general, direct earthing of one heater pin will result in only slightly increased hum from valves otherwise exhibiting the lowest hum levels.

The figures quoted for hum were obtained with a grid leak of 100 k Ω . Wherever possible the grid circuit impedance should be limited to this figure. A higher value is permissible, but the danger of electrostatic pick-up is increased.

6.2 Triode Connected: The same considerations apply as in paragraph 6.1 with regard to precautions to ensure low hum. Triode connection yields even lower hum levels than pentode connection. No curve of expected hum level is given as it was found impossible to obtain reliable measurements at such low levels.

Both pentode and triode connection hum levels are affected by the anode current. All the figures quoted are for RC coupled amplifiers, where the anode current is less than 1 mA. If the valve is operated with a choke or transformer load the anode current should be held below 1.5 mA to maintain low hum level.

7.0 Microphony: It is not possible to specify the microphony level because this is so much dependent on the circumstances of the application. The valve has been designed with a very rigid structure to minimise the effect of vibration, but there will always be some movement of individual grid wires when vibrated at their resonant frequency. By careful design, all low frequency resonances due to loose electrodes have been removed, so that there are no internal resonances below 1000c/s. This is shown on the curves No. 308-252 and 308-253, which indicate the amplitude of the resonances when the valve is vibrated across the major and minor axes respectively. The frequency of vibration was varied from 10 to 3000 c/s with a constant acceleration of 2.5g.

It is interesting to note that the amplitude of vibration to produce an acceleration of 2.5g varies from 0.25 in. at 10 c/s to approximately 0.001 in. at 150 c/s, while at 5000 c/s the peak amplitude is only two millionths of an inch. Most of the higher frequency vibrations are heavily damped by the chassis and valve holder mounting. The use of an antimicrophonic type of valve-holder usually eliminates vibration effects at these frequencies.

Where the valve is being used at the limit of its sensitivity it is important to minimise as far as possible by flexible valve holder mountings all mechanical and acoustical vibrations. This is particularly important where the valve is included in the same cabinet as the loudspeaker, or a motor, such as in magnetic tape recorders and sound film projectors.

8.0 Valve Shot Noise (Hiss): A certain amount of random noise will be generated in the valve by the random arrival of electrons at the anode, and this is further increased by the partition of the cathode current between anode and screen, as the random collection of electrons by the screen must have its effect as an increased variation in the number of electrons arriving at the anode. This is inherent in the valve and cannot be entirely eliminated. A major contribution to valve noise, however, is noise produced by leakage between electrodes over the mica insulators and stray fibres or "lint" between electrodes. Also a poorly activated cathode can produce a noise voltage swamping the normal valve noise.

The shot noise in the 6BS7 has been reduced to a minimum by careful design, and the noise due to leakage controlled by careful assembly and inspection. A certain amount of leakage noise is unavoidable in a mass produced valve, and this reveals itself as a small variation in noise level from valve to valve.

The Curve No. 308·250 shows the maximum hiss voltage plotted against the percentage of valves, using a grid resistor of 100 k Ω and a bandwidth of 10 kc/s. The curve is very steep, and indicates that a hiss level on the grid always lower than 7 μ V is to be expected.

The Curve No. 308·251 shows the same parameters with the valve triode connected. Here partition noise has been eliminated. As would be expected the higher noise levels are unaltered because they are due mainly to leakage which is not greatly affected by whether the valve is triode or pentode connected. The lower noise level is reduced, and in fact falls below the thermal agitation noise generated by the 100 k Ω grid resistor, which in a 10 kc/s bandwidth at 20° C is about 4 μ V.

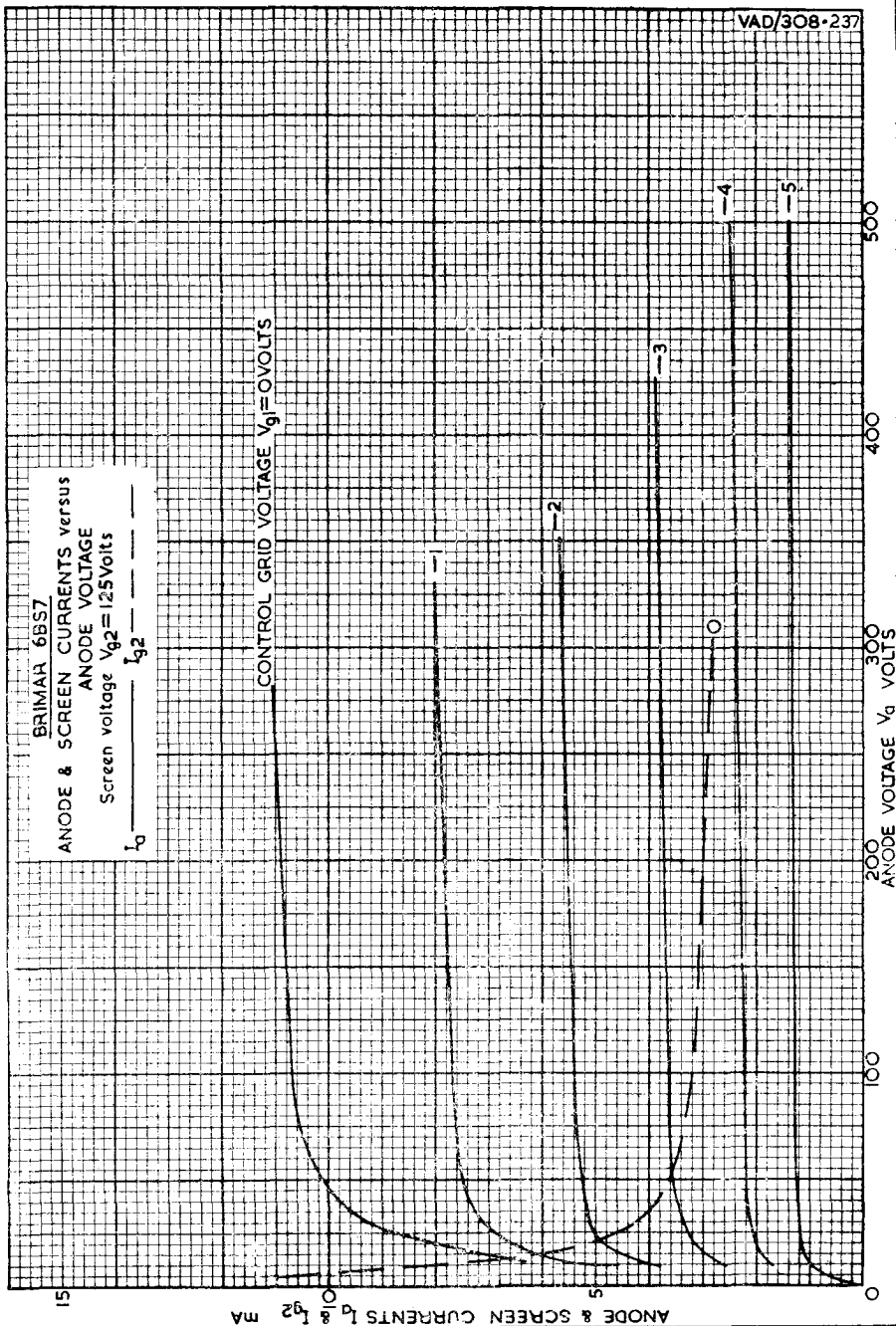
9.0 Other Applications: By virtue of the precautions taken to ensure low grid leakage, the 6BS7 may be of use where a valve with exceptionally low control grid current is required and the use of a special electrometer valve is not warranted. Curve No. 308·254 shows the maximum control grid current plotted against the number of valves giving this value or less. This is for the valve connected as a triode with an anode voltage of 100 volts and grid bias of —3 volts. 50% of the valves show a grid current of less than 10⁻³ μ A.

The value of grid current is affected, in the case of valves with lowest leakage, by incident light due to stray photo-emission. The figures quoted are for normal room daylight, and some improvement may be obtained by shielding the valve from incident light.

BRIMAR 6BS7

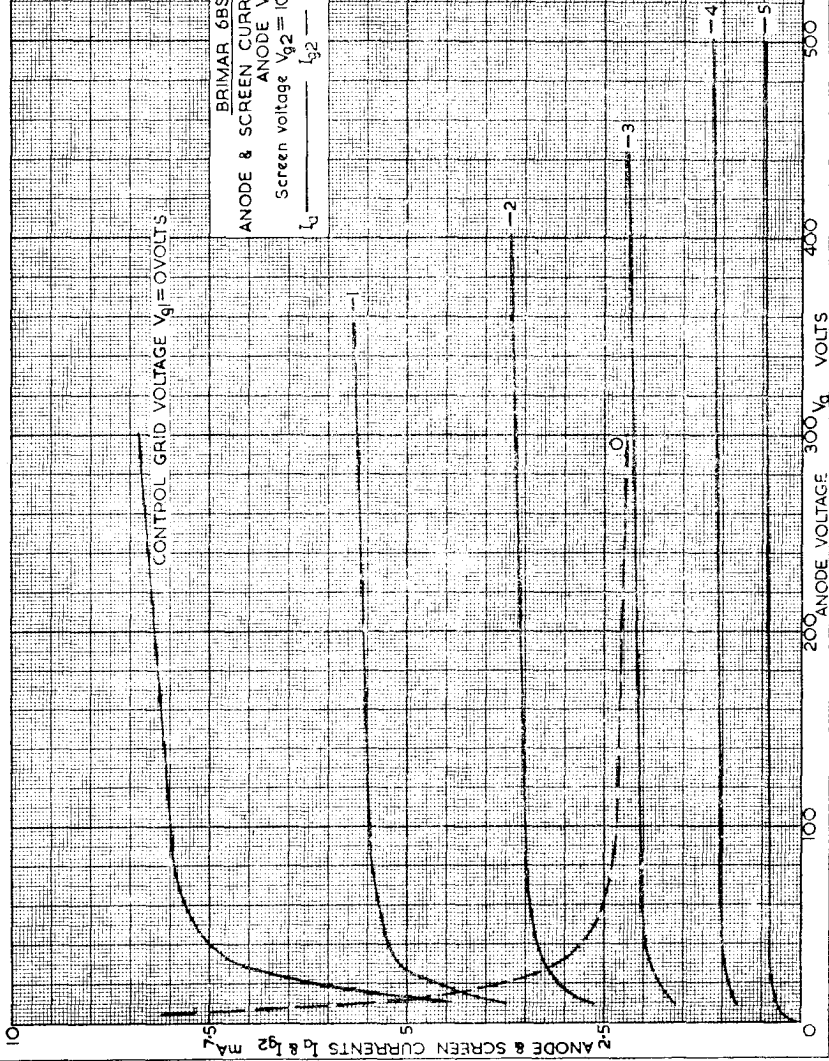
ANODE & SCREEN CURRENTS versus

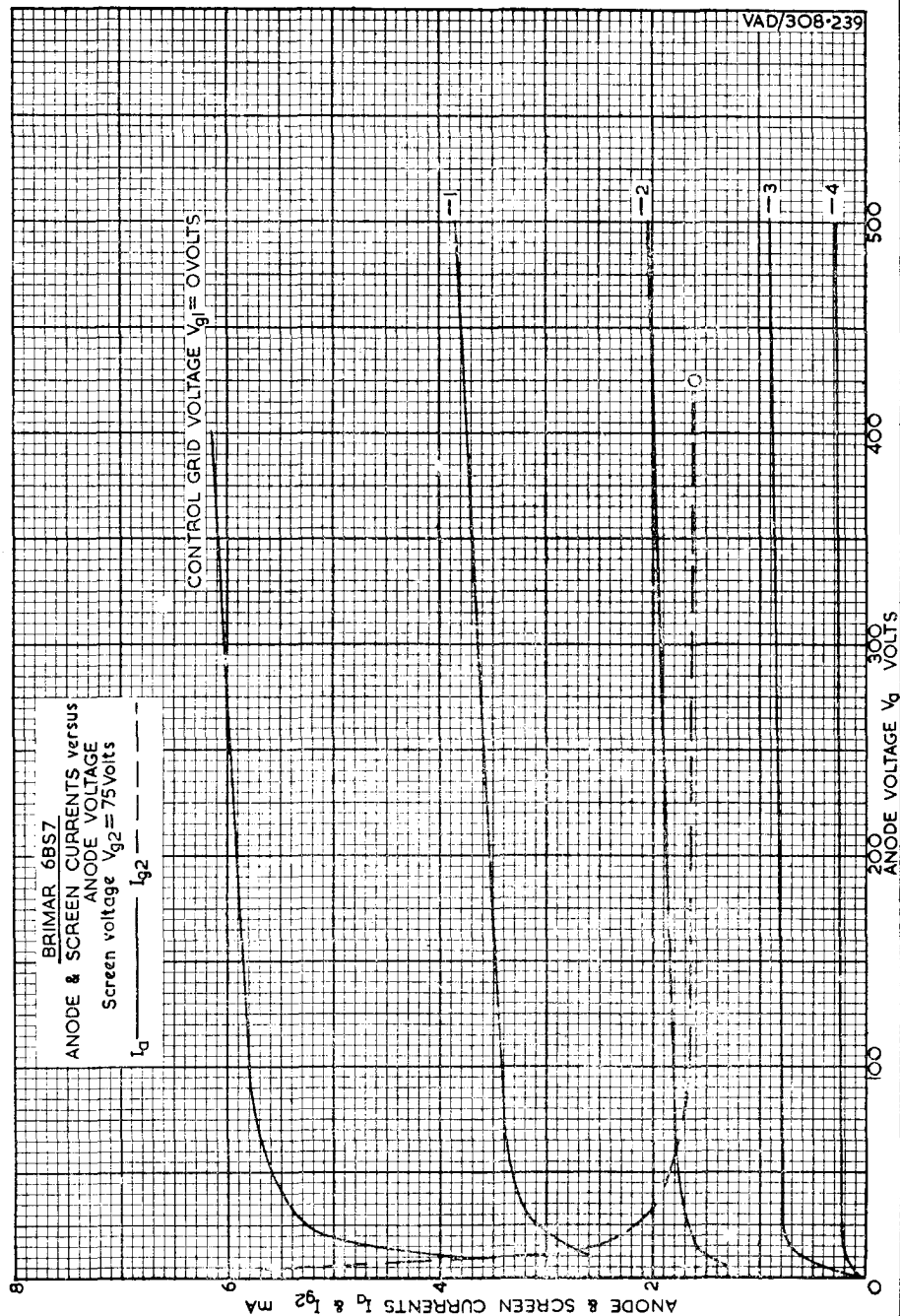
ANODE VOLTAGE

Screen voltage $V_{g2} = 125$ Volts I_0 ——— I_{g2} ——— ———CONTROL GRID VOLTAGE $V_{g1} = 0$ VOLTS

BRIMAR 6BS7
 ANODE & SCREEN CURRENTS versus
 ANODE VOLTAGE
 Screen voltage $V_{g2} = 100$ Volts
 I_b ——— I_{g2} ——— ——— ———

CONTROL GRID VOLTAGE $V_{g1} = 0$ VOLTS





BRIMAR 6BS7

ANODE & SCREEN CURRENTS versus

ANODE VOLTAGE

Screen voltage $V_{a2} = 50 \text{ Volts}$

—Dr.

ANODE & SCREEN CURRENTS I_d & I_{g2} mA

MA 92

ANODE VOLTAGE	V_a	VOLTS
200		

505

400

1007

00 V

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466
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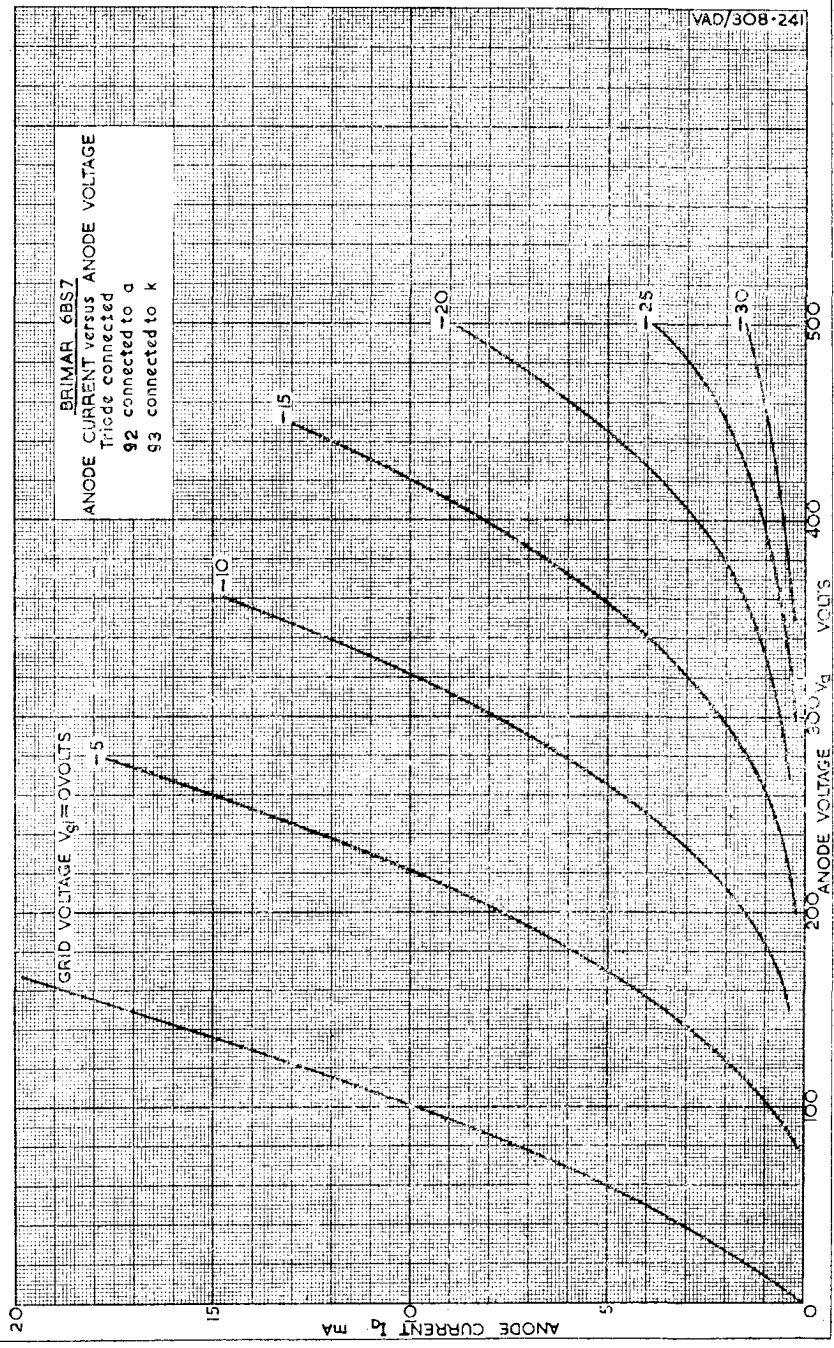
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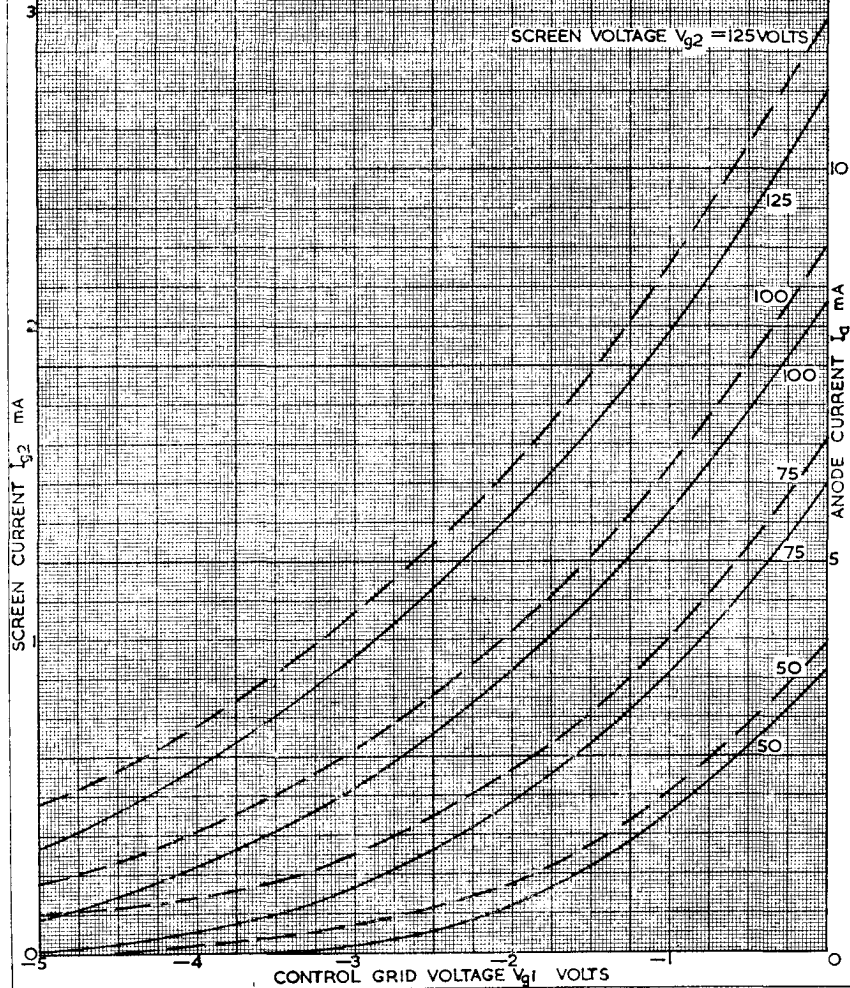
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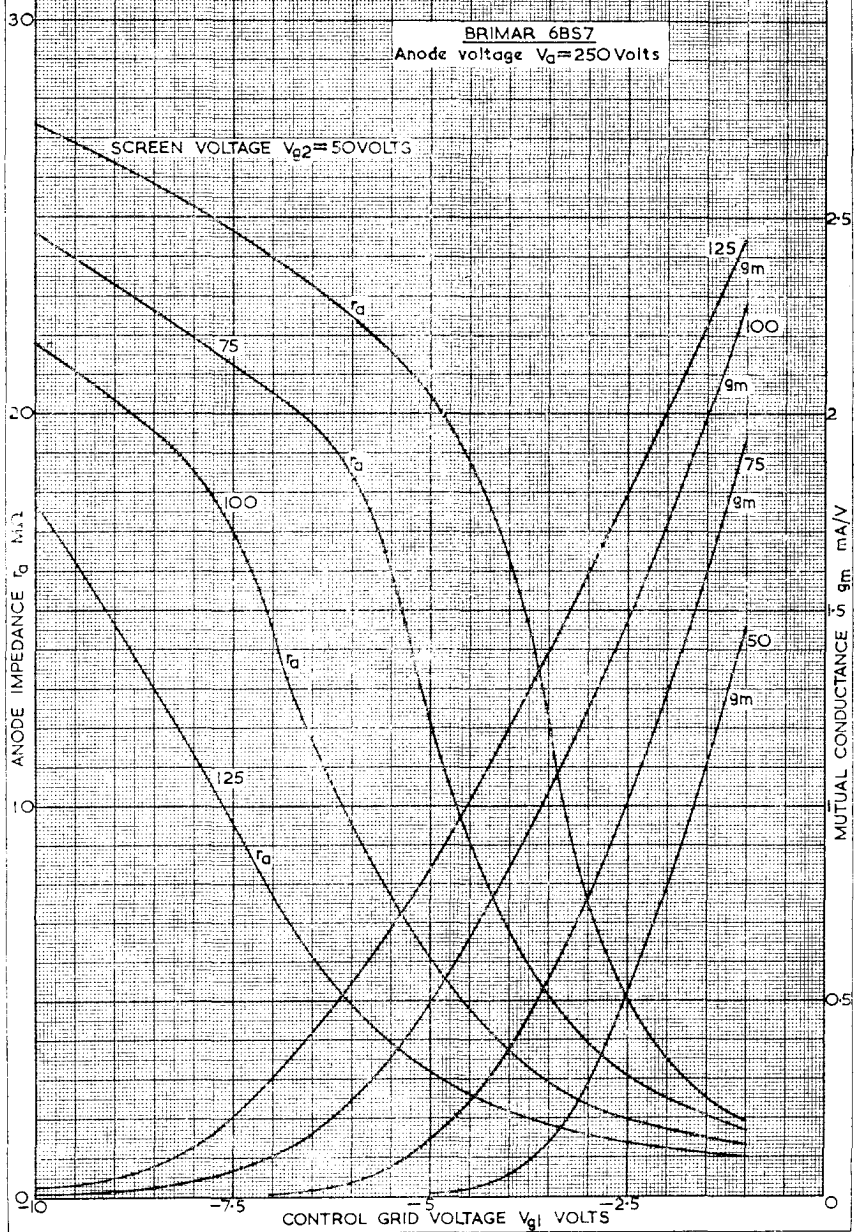
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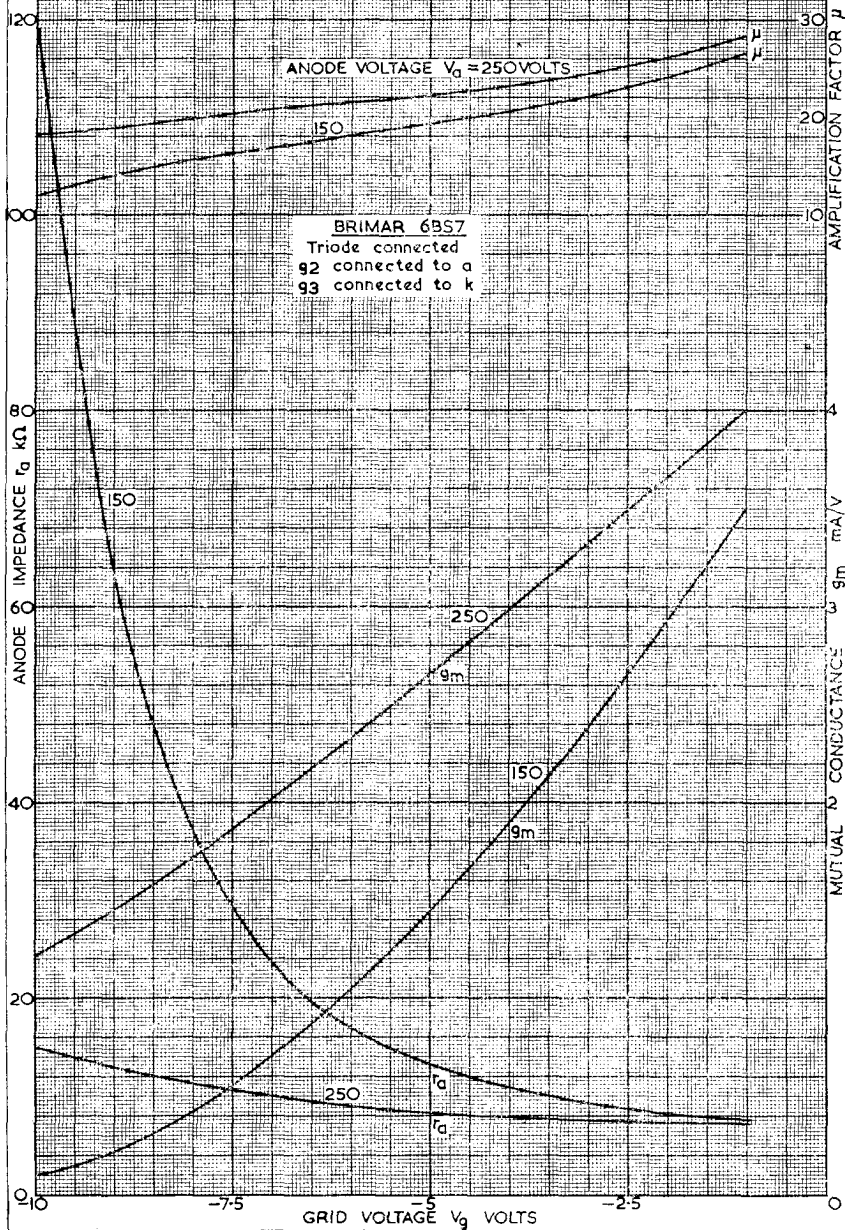


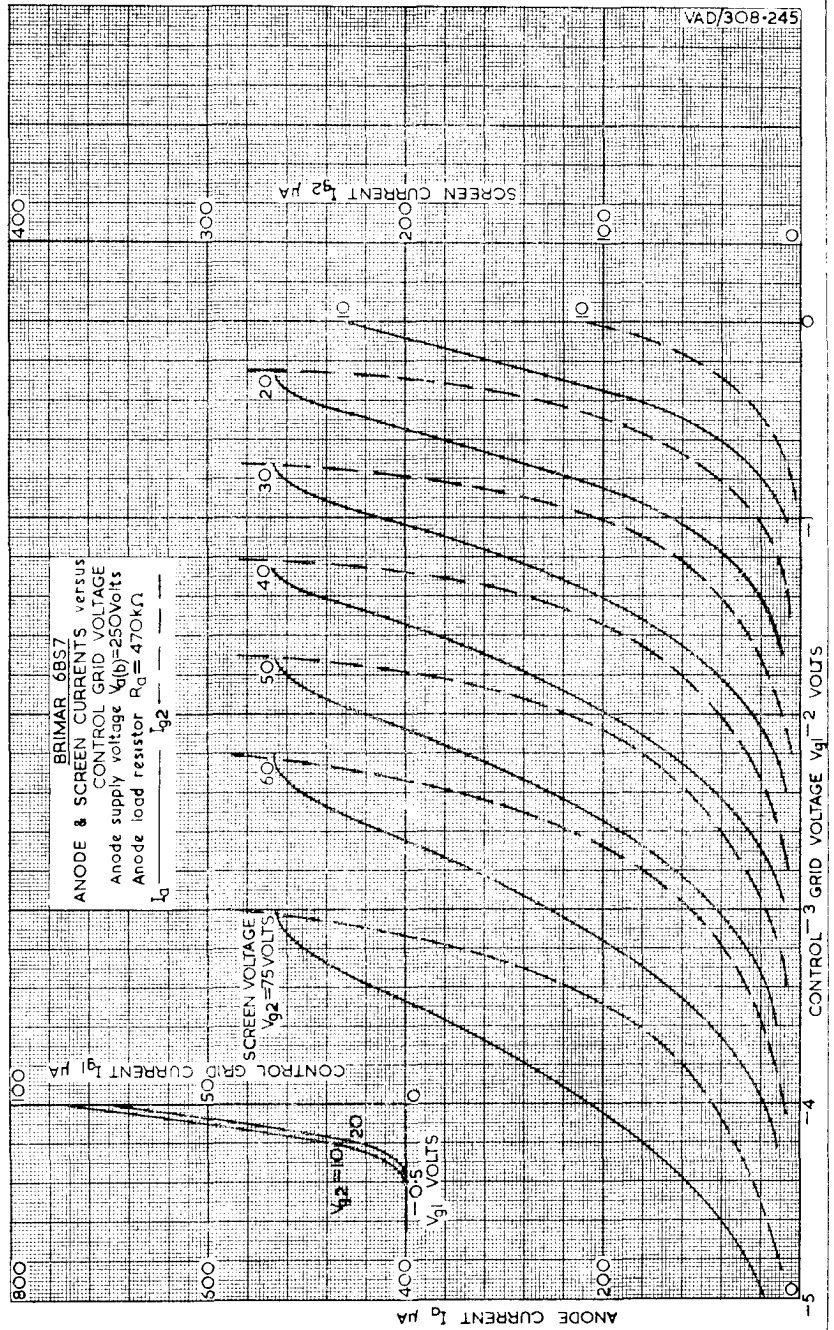
BRIMAR 6BS7
ANODE & SCREEN CURRENTS versus
CONTROL GRID VOLTAGE
Anode voltage $V_a = 250$ Volts
 I_a ——— I_{g2} - - - - -

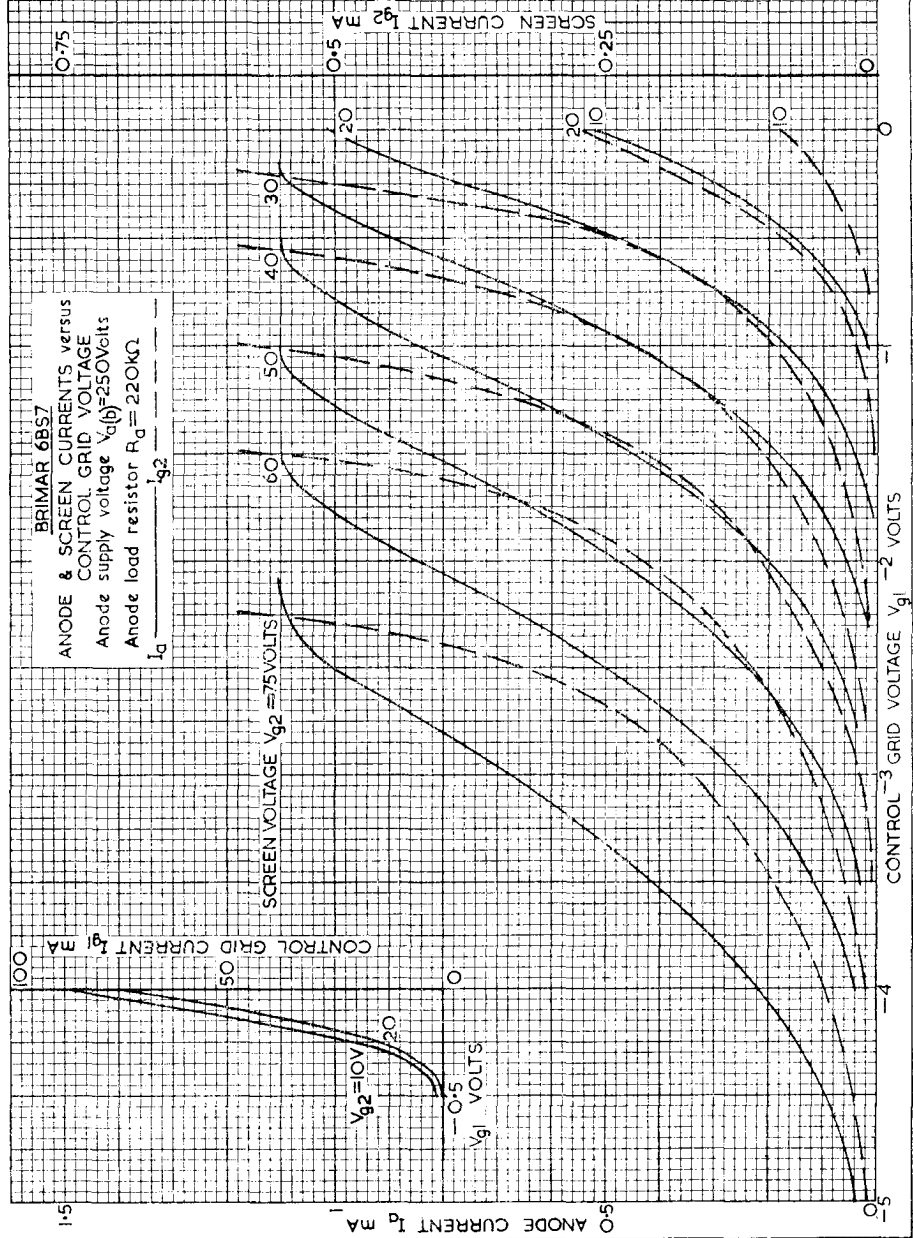


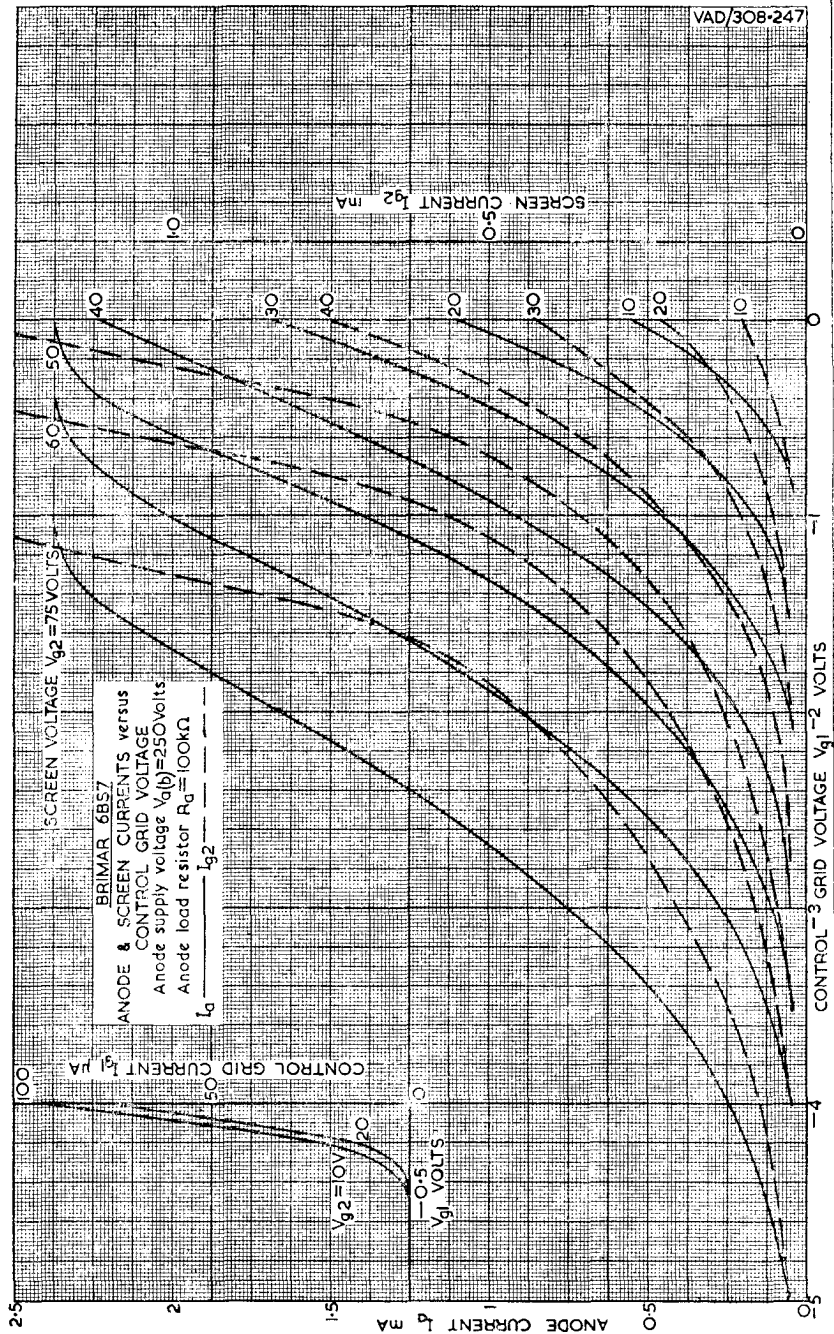
BRIMAR 6BS7

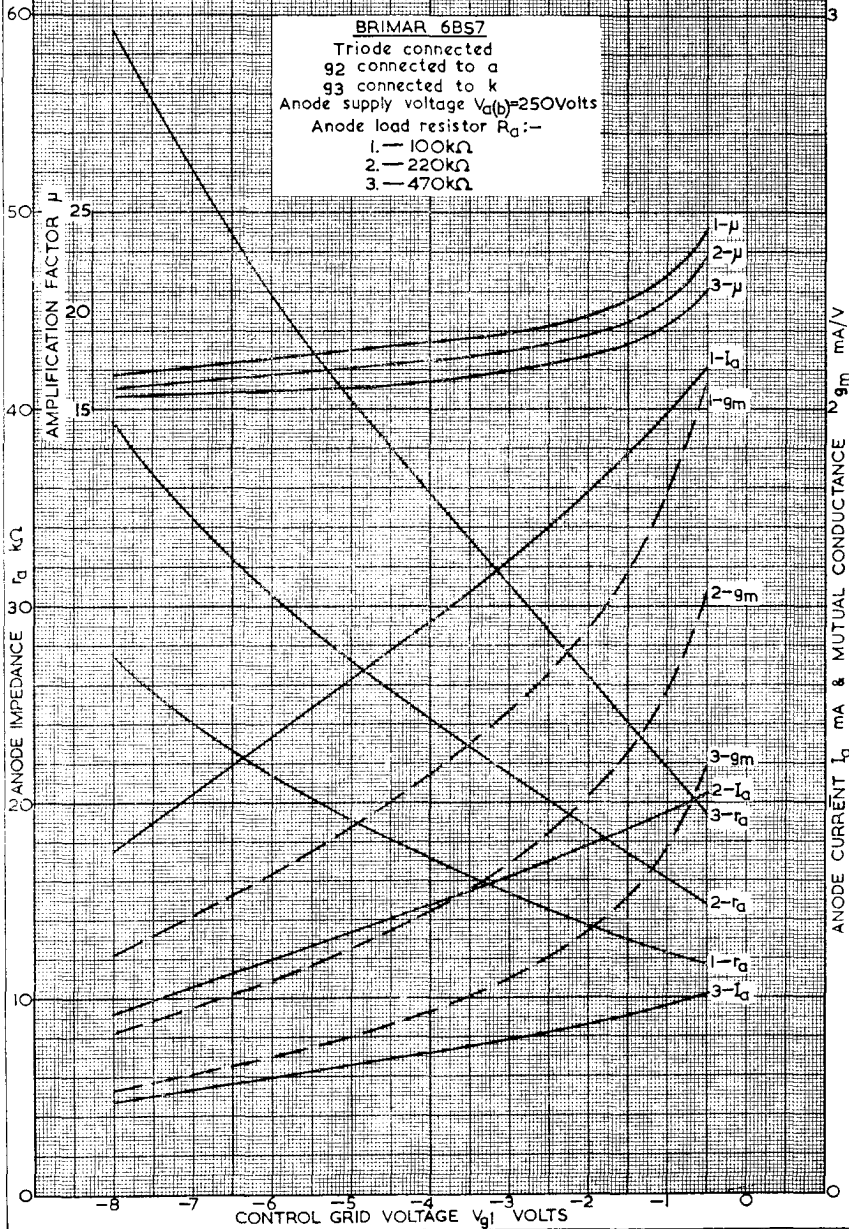
Anode voltage $V_a = 250$ Volts



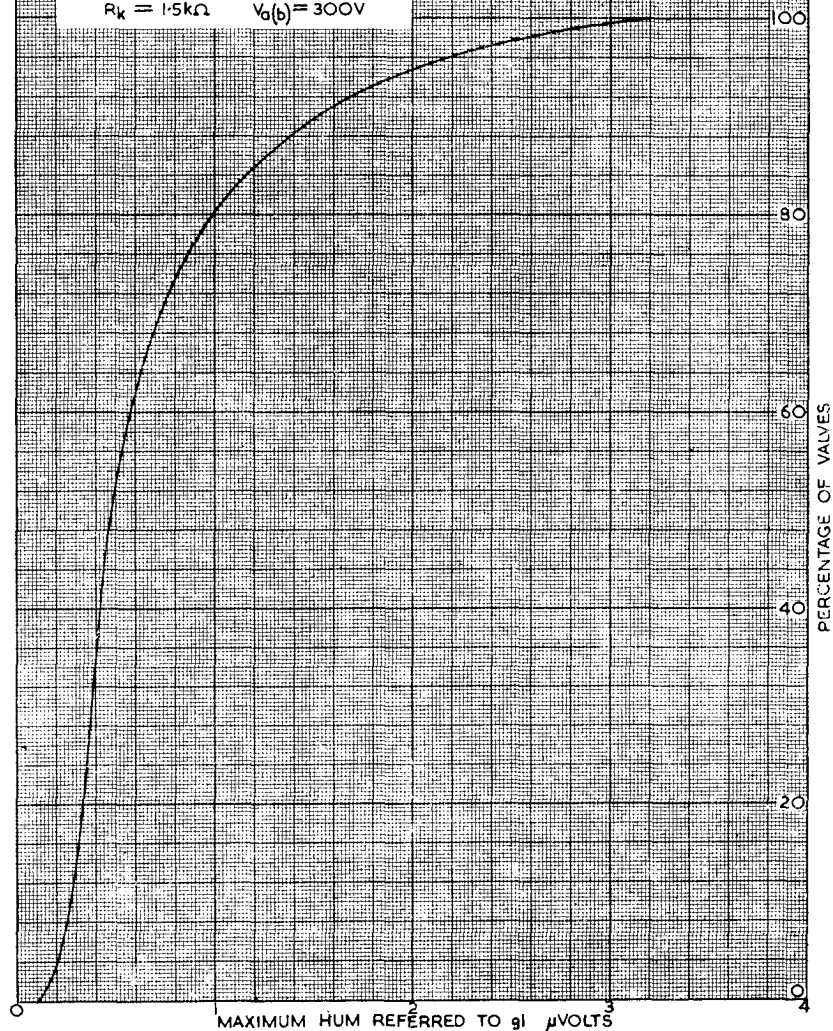




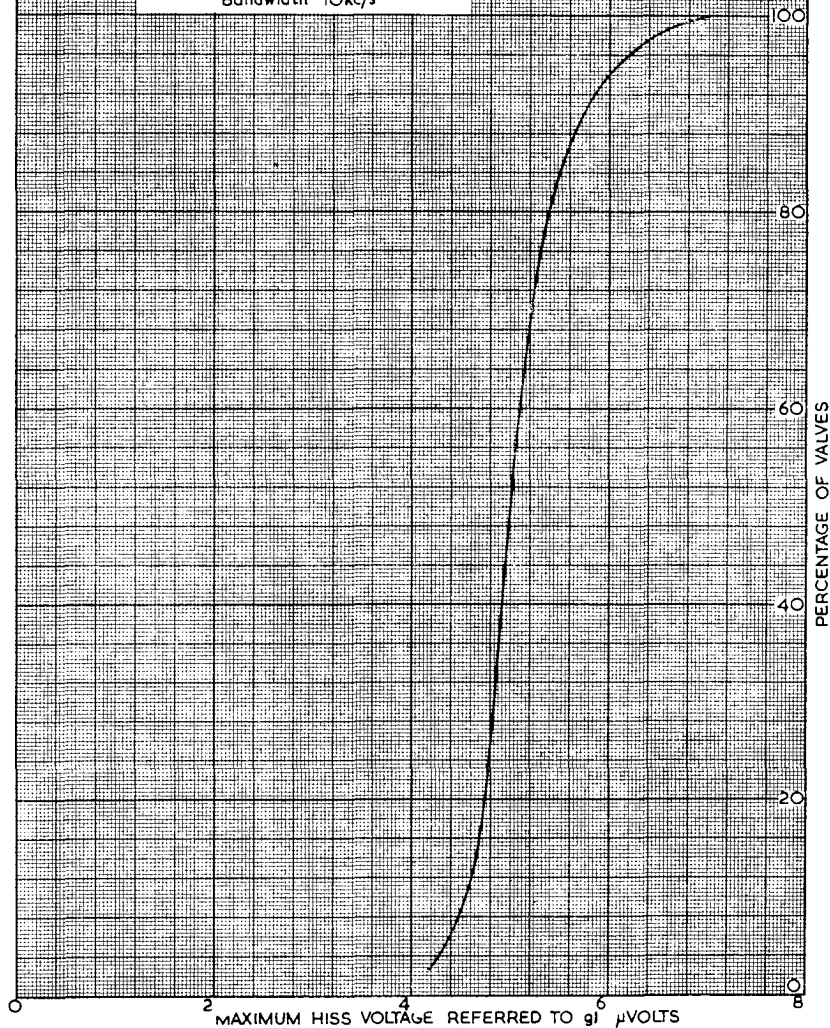




BRIMAR 6BS7
PENTODE CONNECTED
DISTRIBUTION OF HUM AS AN R.C.
COUPLED AMPLIFIER.
Control grid resistor $R_{g1} = 100k\Omega$
Cathode by pass condenser $= 50\mu F$
Bandwidth $= 340c/s$
Hum bucking adjusted for minimum hum
 $R_a = 220k\Omega$ $R_{g2} = 1.5M\Omega$
 $R_k = 1.5k\Omega$ $V_a(b) = 300V$



BRIMAR 6BS7
PENTODE CONNECTED
DISTRIBUTION OF HISS AS AN R.C.
COUPLED AMPLIFIER
Control grid resistor $R_{g1} = 100k\Omega$
Cathode by pass condenser $\approx 50\mu F$
 $R_a = 220k\Omega$ $R_{g2} = 1.5M\Omega$
 $R_k = 1.5k\Omega$ $V_{a(b)} = 300V$
Bandwidth 10kc/s



BRIMAR 6BS7
TRIODE CONNECTED
DISTRIBUTION OF HISS AS AN R.C.
COUPLED AMPLIFIER.
Control grid resistor = $100k\Omega$
Cathode by-pass condenser = $50\mu F$
 $R_a = 220k\Omega$. $R_k = 14k\Omega$
 $V_a(b) = 300V$
Bandwidth = $10kc/s$

