Power output valves

and

Microphone pre-amplifier pentode

Power output valves

In the following, details are given of a number of directly and indirectly-heated power output valves for use in small, medium and large amplifier equipment. Some of these valves, when employed in a balanced output stage, are capable of delivering up to 55 or even 133 W. The mutual conductance of all these types is very high, necessitating only a low grid input to load them fully.

The valves concerned are the following:

4641 directly-heated 25 W triode; V_a = max. 1,500 V, V_f = 4 V.

4654 indirectly-heated 18 W pentode; V_a = max. 600 V, V_{g2} = max. 425 V, V_f = 6.3 V.

4683 directly-heated 15 W triode; V_a = max. 350 V, V_f = 4 V.

4689 indirectly-heated steep-slope 18 W pentode; V_a = max. 375 V, V_{g2} = max. 275 V, V_f = 6.3 V.

4694 indirectly-heated steep-slope 9 W pentode; V_a = max. 400 V, V_{g2} = max. 425 V, V_f = 6.3 V.

4699 indirectly-heated steep-slope 18 W pentode; V_a = max. 425 V, V_{g2} = max. 425 V, V_f = 6.3 V.

EL 51 indirectly-heated steep-slope 45 W pentode; V_a = max. 750 V. V_{g2} = max. 750 V, V_f = 6.3 V.

F 443 N directly-heated 25 W pentode; V_a = max. 550 V, V_{g2} = max. 300 V. V_f = 4 V.

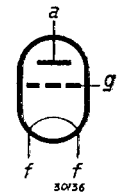
Besides these, Philips are marketing ranges of smaller and also considerably larger valves, particulars of which will be gladly given on application.

With the exception of types 4641 and F443 N, the amplifier valves in question are all fitted with the P-type, or side-contact, base. The small dimensions of these valves permit the design of small, compact amplifiers of outstanding efficiency, delivering high power with only slight distortion. The ranges include low and high power triodes for low-impedance output stages, as well as normal and steep-slope pentodes for high-impedance stages. The high working voltages of the new steep-slope pentodes, amongst other features, make it possible to design highly sensitive amplifiers incorporating a minimum number of valves.

The data reproduced in the following pages relate only to valves in output stages operating without grid current; if a valve is run in the grid-current zone it is certainly possible to obtain higher efficieny and therefore a greater output from it, but on the other hand there is serious, audible distortion, arising from the alternating flow and cessation of the grid current. For high-fidelity reproduction, such as may be expected from a good amplifier, Class B circuits involving grid current are not recommended.

This does not imply that the valves are not suitable for that purpose, however, and particulars will be furnished on request.

4641 Triode



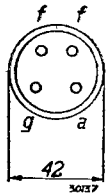


Fig. 2
Arrangement of electrodes and base connections.

The triode, type 4641, is a directly-heated 25 W valve intended mainly for use in balanced output stages, being equally satisfactory in Class AB or Class B circuits. In the latter instance the effective output is 68 W.
In view of the anode voltage this valve is fitted with the 4-pin base, whilst special precautions have been taken in the design to prevent flash-over within the valve.

FILAMENT RATINGS

Heating: direct by A.C.; parallel supply.
Filament voltage . . . . . $V_f = 4$ V
Filament current . . . . . $I_f = 2.1$ A

CAPACITANCES

Anode-grid . . . . . $C_{ag} = 7\ \mu\mu$F

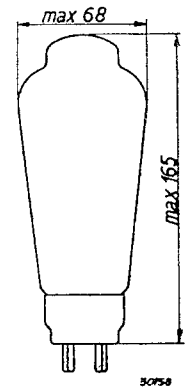


Fig. 1
Dimensions in mm.

OPERATING DATA

		Class B output with fixed grid bias (2 valves)	Class AB output with auto. grid bias (2 valves)	Class B output with fixed grid bias (2 valves)
Anode voltage	V_a (V)	1,000	1,000	1,500
Common cathode resistor for auto. grid bias . . .	R_k (ohms)	—	1,700	—
Fixed grid bias	V_g (V)	—93	—	—144
Anode current ($V_i = 0$ V)	I_{ao} (mA)	2 × 10	2 × 25	2 × 10
Anode current at maximum modulation	$I_{a\,max}$ (mA)	2 × 45	2 × 28	2 × 41
Load resistor (between anodes) . . .	R_{aa} (ohms)	20,000	35,000	40,000
Output power	W_o (W)	41	29	68
Alternating grid voltage (per grid) at maximum modulation	V_i (V_{eff})	65	58	105
Distortion at max. modulation	d_{tot} (%)	2.35	4.5	1. 9

STATIC DATA

Anode voltage	V_a	= 1,000 V	1,500 V
Grid bias	V_g	= —85 V	—140 V
Anode current	I_a	= 25 mA	15 mA
Mutual conductance	S	= 3 mA/V	2 mA/V
Internal resistance	R_i	= 3,400 ohms	4,600 ohms

MAXIMUM RATINGS

V_{ao}	= max. 3,000 V
V_a	= max. 1,500 V
W_a	= max. 25 W
V_g (I_g = + 0.3 μA)	= max. —2 V
I_k	= max. 60 mA
R_{gk} (auto bias)	= max. 0.3 M ohm
R_{gk} (fixed bias)	= max. 0.1 M ohm

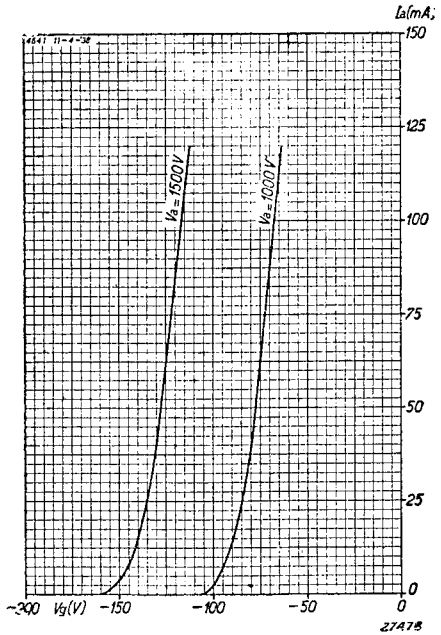


Fig. 3
Anode current as a function of the grid bias with Va = 1,000 and 1,500 V.

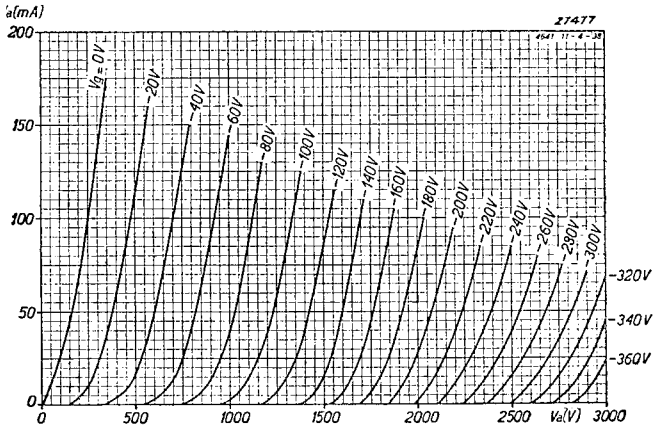


Fig. 4
Anode current as a function of the anode voltage for different values of grid bias.

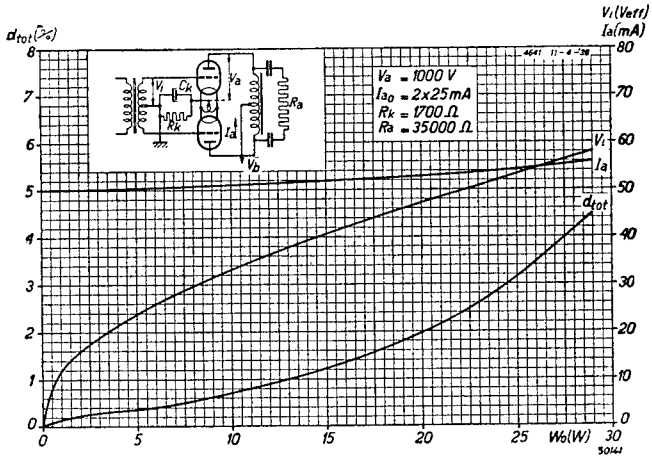


Fig. 5
Total distortion, alternating grid voltage and total anode current as functions of the output power of two 4641 valves in a Class AB output circuit with automatic bias. Va = 1,000 V.

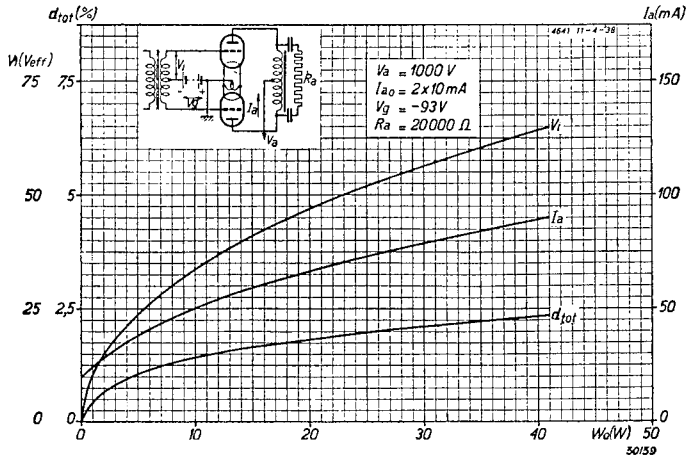


Fig. 6
Total distortion, alternating grid voltage per grid and total anode current as functions of the output power of two 4641 valves in a Class B output circuit with fixed bias. Va = 1,000 V.

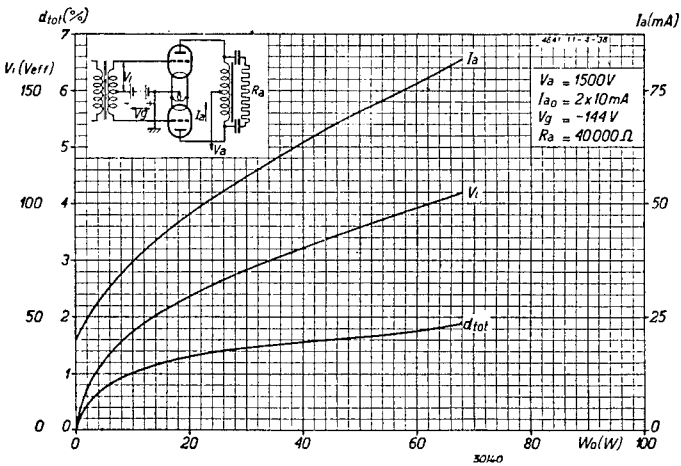


Fig. 7
Total distortion, alternating grid voltage per grid and total anode current as functions of the output power of two 4641 valves in a Class B output circuit, with fixed bias. Va = 1,500 V.

4654 Pentode

The 4654 is an indirectly-heated steep-slope 18 W output valve for a maximum anode voltage of 600 and maximum screen-grid voltage of 425. In view of the high anode voltage involved and the relatively small dimensions of the valve, the anode connection is located at the top of the envelope; high voltages in the pinch are thus avoided. The suppressor grid is connected to a separate contact on the base, making the valve also suitable for amateur transmission work; with the screen and suppressor grids joined, the valve can be employed as an electron-coupled master oscillator, in which case the top cap ensures a conveniently short connection between the anode and oscillator circuits.

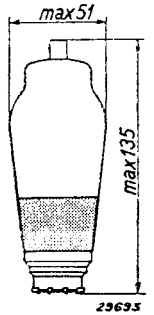
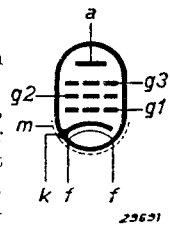


Fig. 1
Dimensions in mm.

The 4654 lends itself well to the following purposes in amateur transmitters:

1) modulator in Class A, AB or B circuits,
2) electron-coupled master oscillator,
3) R.F. amplifier or frequency-multiplier in intermediate stages (Class C),
4) class C output amplifier in telegraphy transmitters,
5) output valve for telephony (Class C), with modulation on both anode and screen grid.

It can be used as transmitter valve at all wavelengths from 50 m, for which purpose a single valve, in a Class C amplifier, will deliver a carrier-wave output power of 36 W, at 67 % efficiency, excluding circuit losses (anode voltage 600 V, screen voltage 200 V, and grid bias —60 V).



The valve is eminently suitable for simultaneous modulation of both anode and screen, in which case it should once more operate on an anode voltage of 600 V, a screen voltage of 200 V and a grid bias of —60 V, the output then being 24 W (less circuit losses). Complete details will gladly be furnished on request.

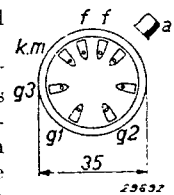


Fig. 2
Arrangement of electrodes and base connections.

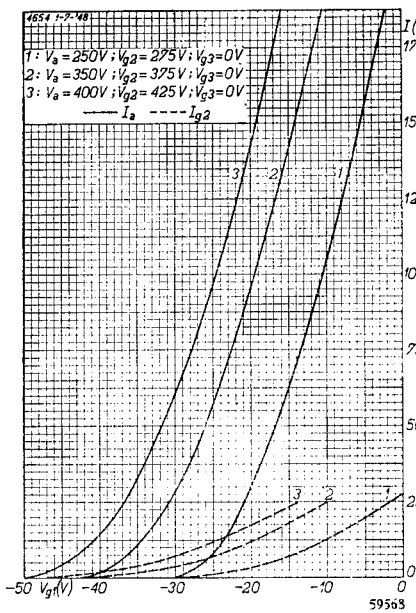


Fig. 3
Anode and screen current of the 4654 as functions of the grid bias, for various values of anode and screen potential.

As an amplifier valve the 4654 has various possibilities, both in amplifiers and modulator stages.

With a fixed bias, a supply voltage of $V_b = 425$ V, an anode voltage of $V_a = 400$ V and a common screen series resistor of $R_{g2} = 500$ ohms, an output of 48 W can be obtained without exceeding the maximum anode dissipation of 18 W.

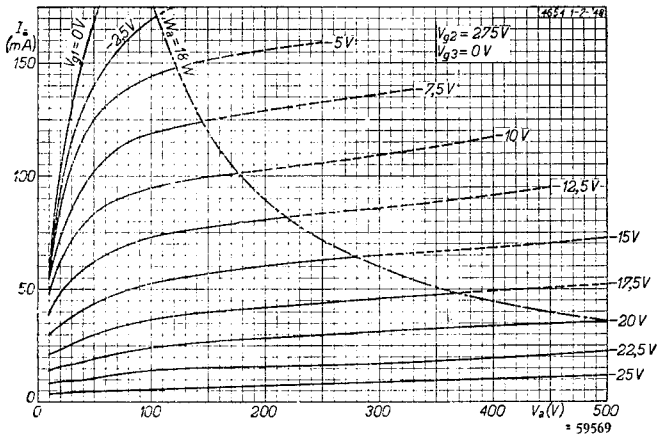


Fig. 4
Anode current as a function of the anode voltage for various values of grid bias. Vg_2 = 275 V.

HEATER RATINGS

Heating: indirect by A.C., parallel supply.

Heater voltage
V_f = 6.3 V

Heater current
I_f = 1.35 A

CAPACITANCES

Anode-grid
$C_{ag1} < 0.8\ \mu\mu F$

OPERATING DATA

The 4654 used as single output valve in class A

Anode voltage	V_a	=	250 V
Suppressor-grid voltage	V_{g3}	=	0 V
Screen-grid voltage	V_{g2}	=	275 V
Cathode resistor	R_k	=	175 ohms
Anode current	I_a	=	72 mA
Screen-grid current	I_{g2}	=	8 mA
Mutual conductance	S	=	8.5 mA/V
Amplification factor; screen with respect to control grid	$\mu_{fg}{}^{g1}$	=	11 —
Internal resistance	R_i	=	22,000 ohms
Load resistor	R_a	=	3,500 ohms
Alternating input voltage (I_{g1} = + 0.3 μA)	V_i	=	11.5 V_{eff}
Power output (I_{g1} = + 0.3 μA)	W_o	=	9.2 W
Total distortion (I_{g1} = + 0.3 μA)	d_{tot}	=	11.4 %
Alternating input voltage (W_o = 50 mW)	V_i	=	0.5 V_{eff}

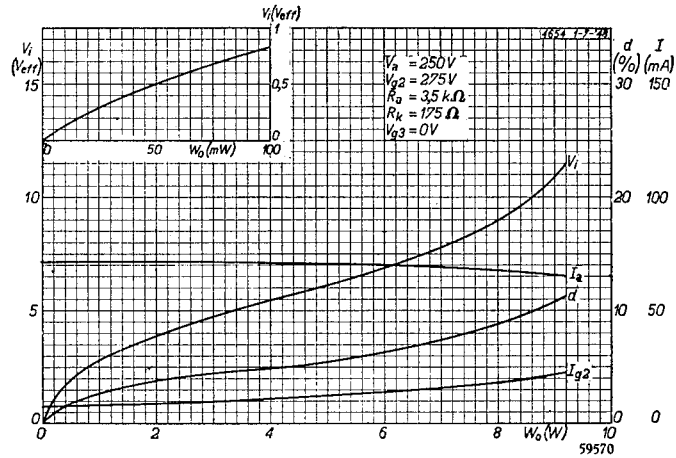


Fig. 5
Total distortion, anode and screen-grid current and alternating input voltage as functions of the output power; the 4654 used as single output valve class A with Va = 250 V and Vg_2 = 275 V.

The 4654 used in class B output stage with fixed grid bias (two valves)

Load resistor between anodes	R_{aa} =	5,000				5,000		ohms
Common screen-grid series resistor	R_{g2} =	500				500		ohms
Grid bias	V_{g1} =	—38				—32		V
Suppressor-grid voltage	V_{g3} =	0				0		V
Alternating input voltage	V_i =	0	26.5	26.5	0	22.4	22.4	V_{eff}
Supply voltage	V_b =	425	425	400	375	375	350	V
Anode voltage	V_a =	420	400	375	370	350	325	V
Anode current	I_a =	2 × 20	2 × 93	2×81.5	2 × 20	2 × 79	2 × 70	mA
Screed-grid current	I_{g2} =	2 × 2,2	2 × 21	2×18	2 × 2.2	2 × 17	2 × 15	mA
Power output	W_o =	0	48	39	0	35	29	W
Total distortion	d_{tot} =	—	2.5	4.2	—	2.5	4.0	%

The 4654 used in class AB output stage with auto. grid bias (two valves)

Supply voltage	V_b =	425		375		V
Load resistor between anodes	R_{aa} =	6,500		5,000		ohms
Common screen-grid series resistor	R_{g2} =	2,000		500		ohms
Common cathode resistor	R_k =	265		195		ohms
Suppressor-grid voltage	V_{g3} =	0		0		V
Alternating input voltage	V_i =	0	27	0	22.5	V_{eff}
Anode voltage	$V_a + V_{Rk}$ =	405	400	355	350	V
Anode current	I_a =	2×46.5	2×60	2× 53	2×66.5	mA
Screen-grid current	I_{g2} =	2× 5.4	2×13	2×6.5	2×15.5	mA
Power output	W_o =	0	27.5	0	26	W
Total distortion	d_{tot} =	—	5	—	3.5	%

The 4654 used in triode connection as single output valve class A (screen-grid connected to anode)

Supply voltage	V_b =	375 V	Anode current	I_a =	50 mA
Suppressor-grid voltage	V_{g3} =	0 V	Alternating input voltage	V_i =	17.5 V_{eff}
Cathode resistor	R_k =	470 ohms	Power output	W_o =	4.5 W
Load resistor	R_a =	3,000 ohms	Total distortion	d_{tot} =	9 %

The 4654 used in triode connection in class AB output stage with auto. grid bias (two valves)

Supply voltage	V_b =	400		V
Load resistor between anodes	R_{aa} =	5,500		ohms
Suppressor-grid voltage	V_{g3} =	0		V
Common cathode resistor	R_k =	280		ohms
Alternating input voltage	V_i =	0	21	V_{eff}
Anode current	I_a =	2 × 50	2 × 56	ohms
Power output	W_o =	0	13	W
Total distortion	d_{tot} =	—	1	%

MAXIMUM RATINGS

V_{ao}	= max. 1,200 V	I_k	= max. 120 mA
V_a	= max. 600 V	V_{g1} (I_{g1} = + 0.3 μA)	= max. —1.3 V
W_a	= max. 18 W	R_{g1} *(auto. bias)*	= max. 0.7 M ohm
V_{g20}	= max. 1,000 V	R_{g1} *(fixed bias)*	= max. 0.5 M ohm
V_{g2}	= max. 425 V	V_{fk}	= max. 50 V
W_{g2} (V_i = 0)	= max. 3 W	R_{fk}	= max. 20,000 ohms
W_{g2} (W_o = max.)	= max. 10 W		

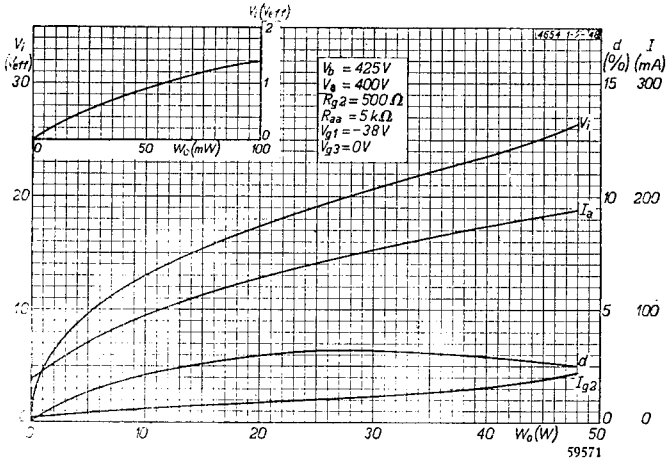


Fig. 6
Total distortion, anode and screen-grid current and alternating input voltage as functions of the output power; 2 valves 4654 used in class B output stage with fixed grid bias, Vb = 425 V.

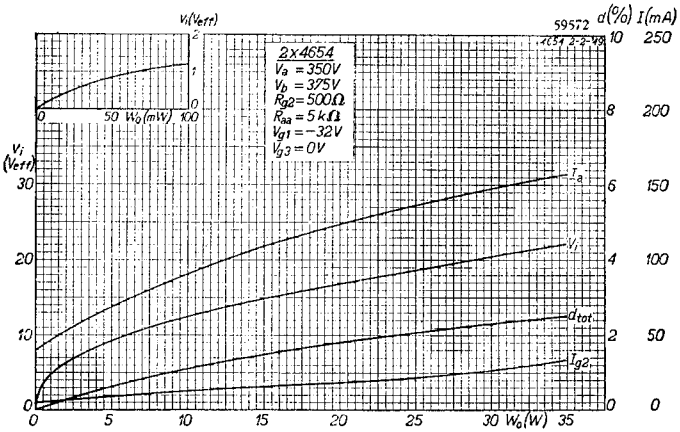


Fig. 7
Total distortion, anode and screen-grid current and alternating input voltage as functions of the output power; 2 valves 4654 used in class B output stage with fixed grid bias, Vb = 375 V.

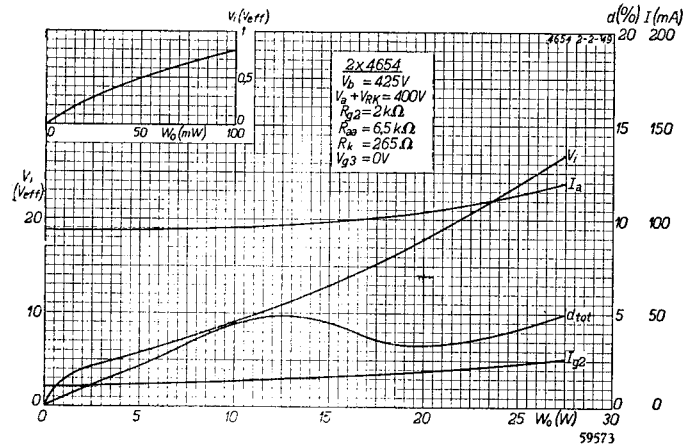


Fig. 8
Total distortion, anode and screen-grid current and alternating input voltage as functions of the output power; 2 valves 4654 used in class AB output stage with auto. grid bias, Vb = 425 V.

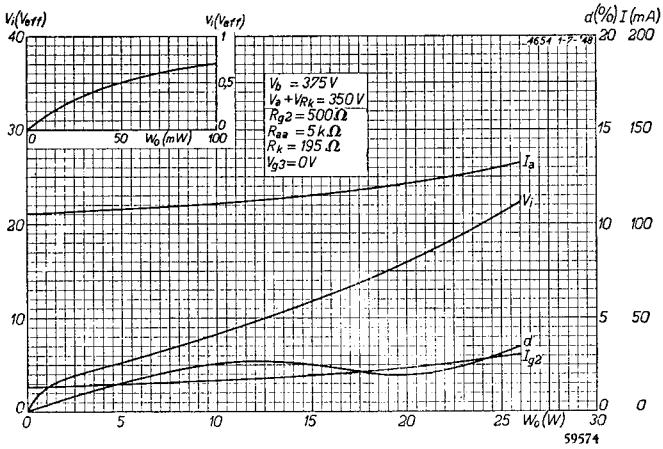


Fig. 9
Total distortion, anode and screen-grid current and alternating input voltage as functions of the output power; 2 valves 4654 used in class AB output stage with auto. grid bias, $Vb = 375$ V

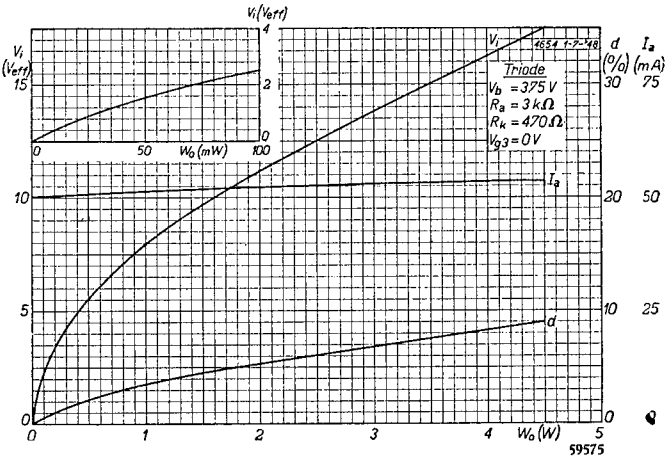


Fig. 10
Total distortion, anode current and alternating input voltage as functions of the output power; the 4654 used as single output valve in triode connection (screen-grid connected to anode) class A with $Vb = 375$ V.

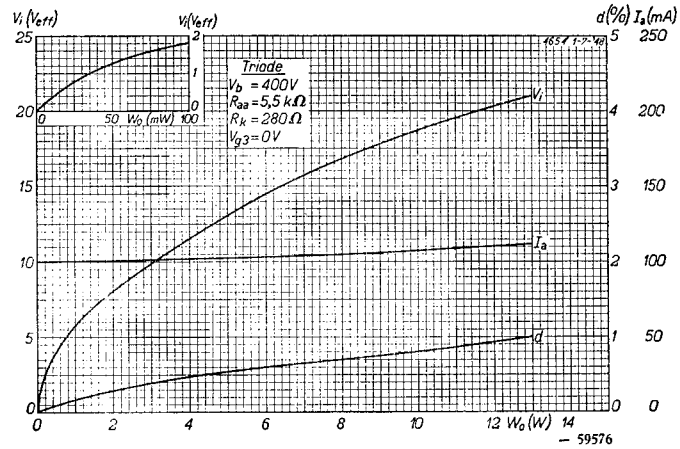
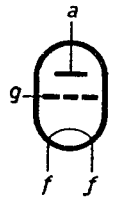


Fig. 11
Total distortion, anode current and alternating input voltage as functions of the output power; 2 valves 4654 in triode connection (screen-grid connected to anode) used in class AB output stage with $Vb = 400$ V

4683 Triode



The 4683 is a directly-heated power triode having an anode dissipation of 15 W.

FILAMENT RATINGS

Heating: direct, A.C., parallel supply.

Filament voltage	V_f	= 4 V
Filament current	I_f	= 0.95 A

CAPACITANCES

Anode-grid	C_{ag}	< 20 $\mu\mu$F

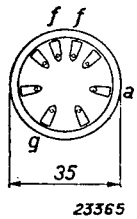


Fig. 2
Arrangement of electrodes and base connections.

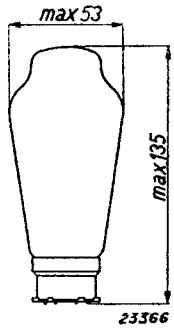


Fig. 1
Dimensions in mm.

OPERATING DATA

		Class AB output with auto. grid bias. (2 valves)	Class B output with fixed grid bias. (2 valves)
Anode voltage	V_a =	350 V	350 V
Common cathode resistor for automatic bias	R_k =	850 ohms	—
Fixed grid bias	V_g =	—	—75 V
Anode current (without signal)	I_{ao} =	2 × 43 mA	2 × 35 mA
Anode current at max. modulation	$I_{a\,max}$ =	2 × 46 mA	2 × 70 mA
Load resistor (between anodes)	R_{aa} =	8,000 ohms	5,000 ohms
Output power	W_o =	15.6 W	20 W
Alternating grid voltage (per grid) at max. modulation	V_i =	51 V_{eff}	49 V_{eff}
Distortion at max. modulation	d_{tot} =	2.3 %	2.1 %

MAXIMUM RATINGS per valve

V_{ao}	= max. 600 V	I_k	= max. 90 mA
V_a	= max. 350 V	R_{gk} (*auto. bias*)	= max. 0.7 M ohm
W_a	= max. 15 W	R_{gk} (*fixed bias*)	= max. 0.3 M ohm
V_g (I_g = + 0.3 μA)	= max. —2 V		

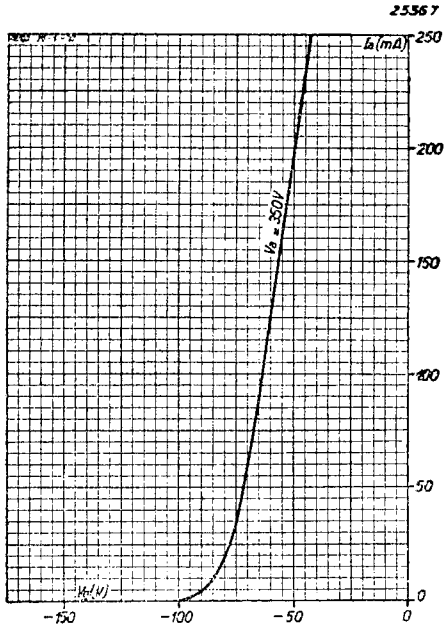


Fig. 3
Anode current as a function of the grid bias, with $Va = 350$ V.

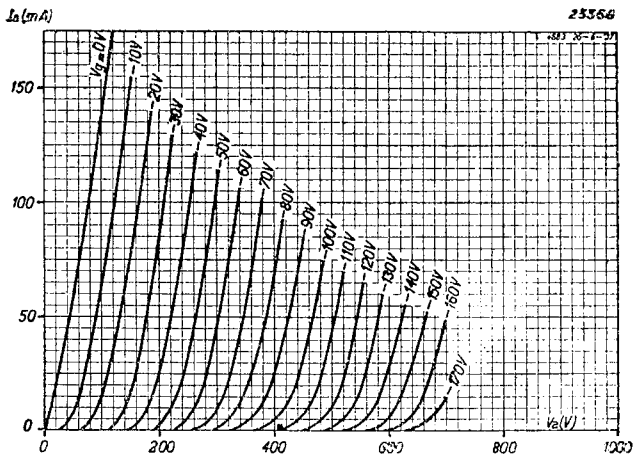


Fig. 4
Anode current as a function of the anode voltage for different values of grid bias.

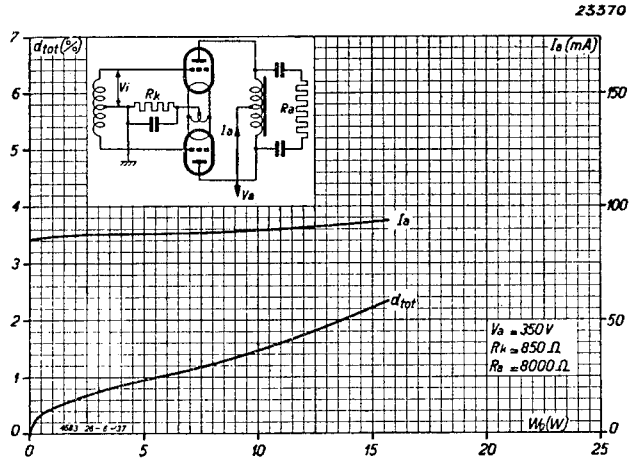


Fig. 5
Total distortion and total anode current as functions of the output power; 2 valves 4683 in a balanced circuit with automatic grid bias.

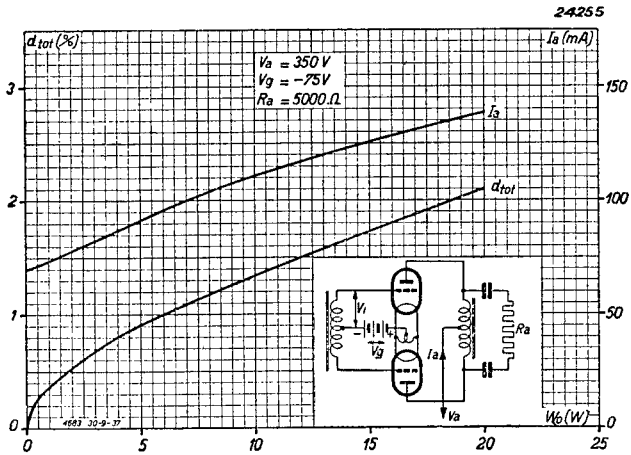


Fig. 6
Total distortion and total anode current as functions of the output power; 2 valves 4683 in a balanced circuit with fixed bias.

4689 Pentode

This is an indirectly-heated steep-slope 18 W output valve using a maximum anode potential of 375 V. Two of these valves in a balanced circuit will deliver a combined output of nearly 29 W and, due to the high mutual conductance, an output stage of this type will operate on a very moderate grid input; any ordinary A.F. amplifier valve is therefore sufficient to excite fully the output stage. In view of the high mutual conductance, it is advisable to employ automatic grid bias; the published data relate to a constant screen potential of 275 V. Should a potential divider be used for the feed in order to reduce the screen voltage to 250 V, the screen voltage will fall on an increasing input signal, if the current passing through the potential divider is not sufficiently high; in consequence, the grid swing is reduced and, with it, the output. It is therefore recommended in all cases where such losses of power are undesirable, that the screen voltage be kept constant by means of stabilizer tubes, e.g. type 4687; this also has the advantage that the main voltage will not decrease as much as it is likely to do without stabilization.

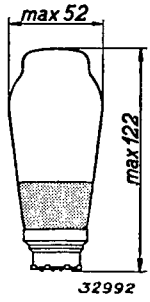
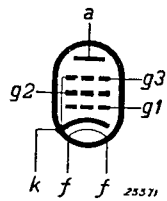


Fig. 1
Dimensions in mm.



HEATER RATINGS

Heating: indirect by A.C. or D.C.; parallel supply.

Heater voltage	V_f	= 6.3 V
Heater current	I_f	= 1.35 V

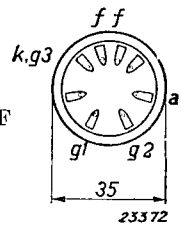


Fig. 2
Arrangement of electrodes and base connections.

CAPACITANCES

Anode-grid

$C_{ag_1} < 0.8\ \mu\mu F$

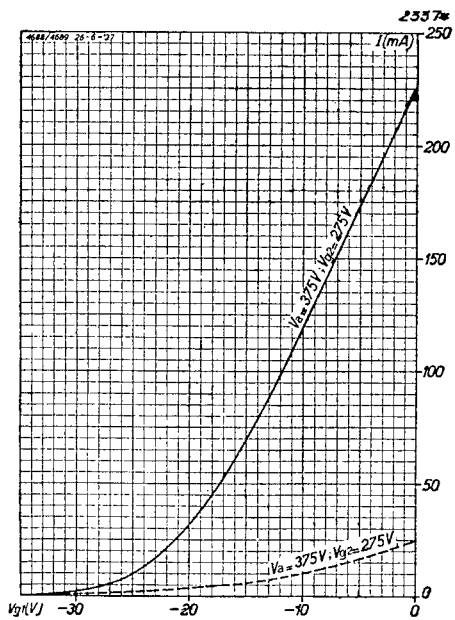


Fig. 3
Anode and screen-grid current of the 4689 as functions of the grid bias. Va = 375 V, Vg_2 = 275 V.

OPERATING DATA

		Class AB output with auto. grid bias (2 valves)
Anode voltage	V_a =	375 V
Screen-grid voltage	V_{g2} =	275 V
Common cathode resistor	R_k =	165 ohms
Anode current (without signal)	I_{ao} =	2 × 48 mA
Anode current at max. modulation	$I_{a\,max}$ =	2 × 62 mA
Screen-grid current (without signal)	I_{g2o} =	2 × 5 mA
Screen-grid current at max. modulation	I_{g2max} =	2 × 9 mA
Load resistor (between anodes)	R_{aa} =	6,500 ohms
Output power	W_o =	28.5 W
Alternating grid voltage (per grid)	V_i =	16 V_{eff}
Distortion at maximum output	d_{tot} =	2.25 %

MAXIMUM RATINGS per valve

V_{ao} = max. 600 V
V_a = max. 375 V
W_a = max. 18 W
V_{g2o} = max. 600 V
V_{g2} = max. 275 V
W_{g2} ($V_i = 0$)
= max. 2 W
W_{g2} (W_o = max.)
= max. 3.5 W
I_k = max. 90 mA
V_{g1} (I_{g1} = + 0.3 μA)
= max. —1.3 V
R_{g1k} = max. 0.7 M ohm
R_{fk} = max. 5,000 ohms
V_{fk} = max. 50 V

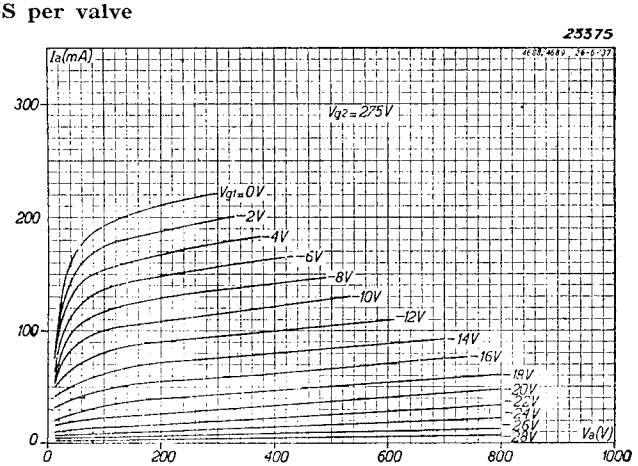


Fig. 4
Anode current of the 4689 as a function of the anode voltage for different values of grid bias. Vg_2 = 275 V.

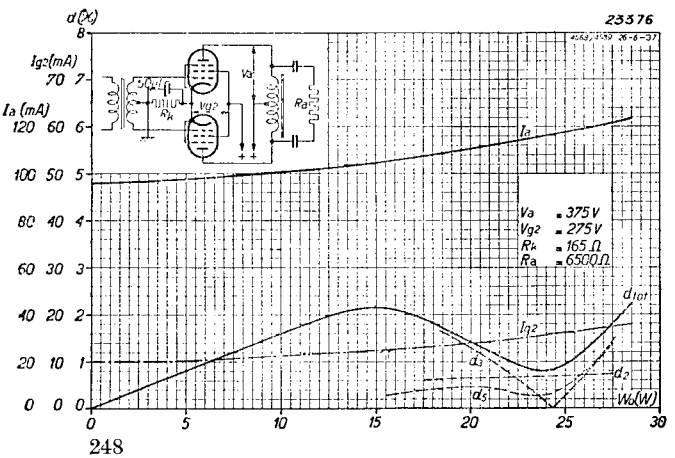


Fig. 5
Total distortion, total anode and screen-grid current as functions of the output power; two valves 4689 in a Class B output circuit with automatic grid bias.

4694 Pentode

The 4694 is an indirectly-heated steep-slope 9 W pentode. In balanced stages the available output is 12 to 13 W, which makes the valve very attractive for use in 10 W amplifiers. The maximum anode voltage is 400 V, that is to say 400 V on the anode and 425 V on the screen; the latter potential is thus slightly higher than that of the anode, so that allowance may be made for the voltage drop occurring across the output transformer. It is not necessary to feed the screen from a potential divider and the losses inherent in this type of feed are thus avoided, whilst the output is not reduced by decreases in the screen voltage at max. modulation. The relatively high working voltages of this valve make it possible to employ pre-amplification stages of very high sensitivity. Moreover, due to the high mutual conductance the alternating grid voltage is extremely low; grid bias, therefore, must be of the automatic type.

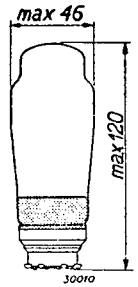
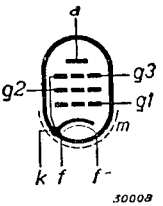


Fig. 1
Dimensions in mm.

HEATER RATINGS

Heating: indirect, A.C.; parallel supply.

Heater voltage	V_f	= 6.3 V
Heater current	I_f	= 0.9 A



CAPACITANCES

Anode-grid	C_{ag1}	< 0.8 $\mu\mu$F

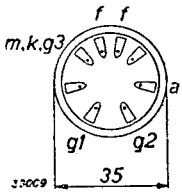
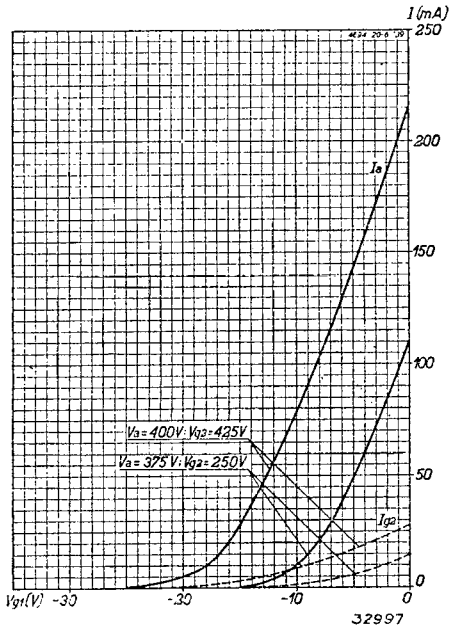


Fig. 2
Arrangement of electrodes and base connections.



STATIC DATA

Anode voltage	V_a	= 400 V
Screen-grid voltage	V_{g2}	= 425 V
Grid bias	V_{g1}	= —15.6 V
Anode current	I_a	= 22 mA
Screen-grid current	I_{g2}	= 2.8 mA
Mutual conductance	S	= 7 mA/V
Internal resistance	R_i	= 75,000 ohms

Fig. 3
Anode and screen-grid current of the 4694 as functions of the grid bias, with respect to different anode and screen voltages.

OPERATING DATA

		Class AB output with auto. bias (2 valves)
Anode voltage	V_a =	400 V
Screen-grid voltage	V_{g2} =	425 V
Common cathode resistor	R_k =	315 ohms
Anode current (without signal)	I_{ao} =	2 × 22 mA
Anode current at max. modulation	$I_{a\,max}$ =	2 × 25 mA
Screen current (without signal)	I_{g2o} =	2 × 2.8 mA
Screen current at max. modulation	$I_{g2\,max}$ =	2 × 6.2 mA
Load resistor (between anodes)	R_{aa} =	20,000 ohms
Power output	W_o =	13 W
Alternating grid voltage	V_i =	9 V_{eff}
Distortion at maximum modulation	d_{tot} =	5 %

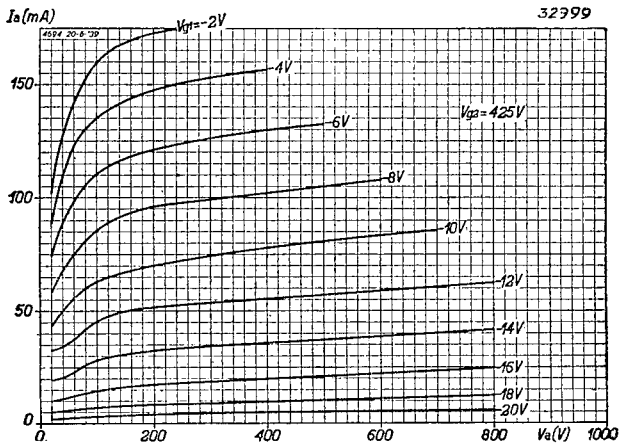


Fig. 4
Anode current as a function of the anode voltage for various values of grid bias. Vg_2 = 425 V.

MAXIMUM RATINGS per valve

V_{ao}	= max. 650 V
V_a	= max. 400 V
W_a	= max. 9 W
V_{g2o}	= max. 650 V
V_{g2}	= max. 425 V
W_{g2} (V_i = 0)	= max. 1.3 W
W_{g2} (W_o = max.)	= max. 2.7 W
I_k	= max. 55 mA
V_{g1} (I_{g1} = + 0.3 μA)	= max. —1.3 V
R_{g1k}	= max. 1 M ohm
R_{fk}	= max. 5,000 ohms
V_{fk}	= max. 50 V

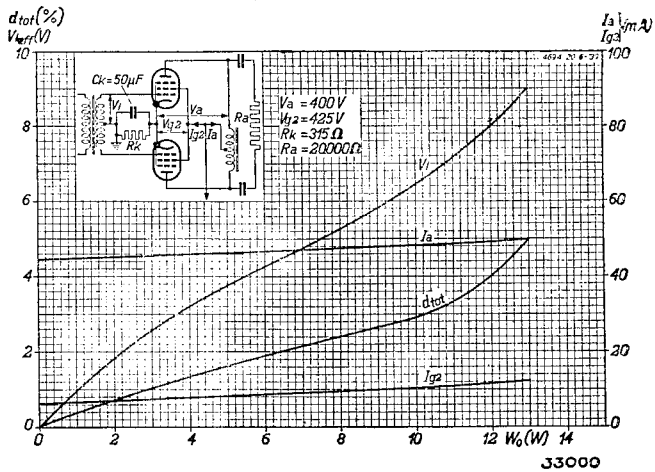


Fig. 5
Total distortion, total anode and screen-grid current and alternating grid voltage, per grid, as functions of the output power. 2 valves 4694 in a Class AB output stage with auto. bias.

4699 Pentode

This pentode is an indirectly-heated 18 W output valve of extremely high mutual conductance, for A.C. heater-supply. It was designed especially for small amplifiers with Class AB output stages. In view of the high mutual conductance the valve is extremely useful for supersensitive amplifiers. For two 4699 used in class AB output stage with automatic grid bias an alternating input voltage of 17 V_{eff} is sufficient to obtain a power output of 29 W. Older types of amplifying valves such as the 4689 are supplied with an anode voltage of 375 V, with 275 V screen; owing to the necessity for feeding the screen from a potential divider for this type of valve, there is a considerable drop in output at maximum modulation as the current passing through the potential divider is not high enough. When the grid signal increases, the screen current also rises, so that when a high resistance potential divider is used the screen voltage and grid swing are reduced. In practice the decrease in output due to this potential divider is 10 to 20 %.

The maximum anode and screen voltages of the 4699 are such that the latter may be fed direct, without the use of any potential divider, and the advantages of equal anode and screen potentials may be listed as follows:

a) Less costly circuit, since two fairly high-wattage resistors and a smoothing capacitor are then unnecessary.

b) Lower current consumption, in view of the absence of the potential divider.

c) No reduction in output at maximum modulation, such as exists when the screen is fed from a potential divider.

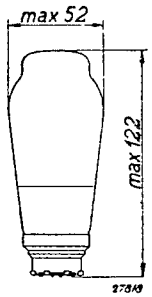
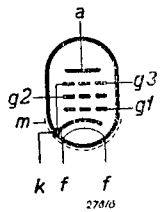


Fig. 1
Dimensions in mm.



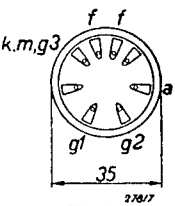


Fig. 2
Arrangement of electrodes and base connections.

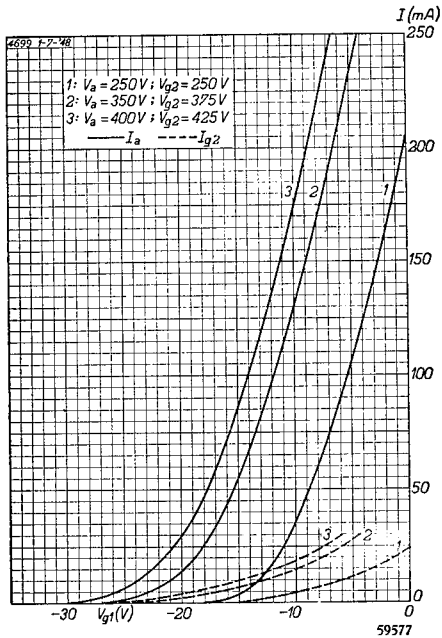


Fig. 3
Anode and screen current of the 4699 as functions of the grid bias for various values of anode and screen potential.

The 4699 gives good results on both high and low voltages (V_b = 450 V and V_b = 375 V respectively); in the latter instance it is possible to economise in the supply section of the amplifier, whilst in the other case the stages of pre-amplification may be made more sensitive.

For a valve with such high mutual conductance the 4699 has an unusually low heater consumption (about 6.3 W), this being due mainly to the special form of the cathode.

HEATER RATINGS

Heating: indirect by A.C.; parallel supply.
Heater voltage . . . . . V_f = 6.3 V
Heater current . . . . . I_f = 1.0 A

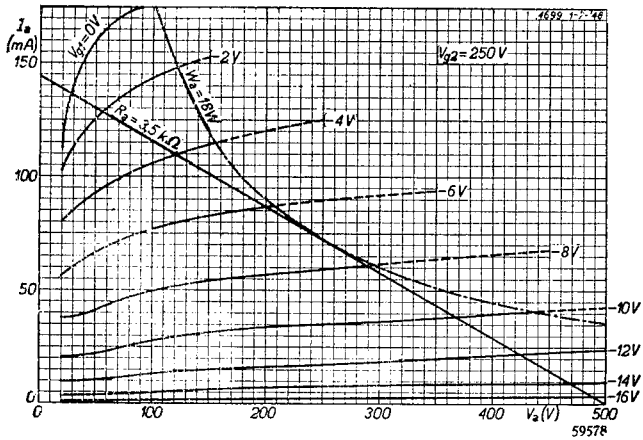


Fig. 4
Anode current as a function of the anode voltage for various values of grid bias with V_{g_2} = 250 V.

CAPACITANCES

Anode-grid . . . . . $C_{ag1} < 0.7\ \mu\mu F$

OPERATING DATA

The 4699 used as single output valve in class A

Anode voltage	V_a	= 250	V
Screen-grid voltage	V_{g2}	= 250	V
Cathode resistor	Rk	= 90	ohms
Anode current	I_a	= 72	mA
Screen-grid current	I_{g2}	= 8	mA
Mutual conductance	S	= 14.5	mA/V
Amplification factor; screen with respect to control grid	μ_{g2g1}	= 20	—
Internal resistance	R_i	= 20,000	ohms
Load resistor	R_a	= 3,500	ohms
Alternating input voltage (I_{g1} = + 0.3 μA)	Vi	= 5.3	V_{eff}
Power output (I_{g1} = + 0.3 μA)	W_o	= 8	W
Total distortion (I_{g1} = + 0.3 μA)	d_{tot}	= 10	%
Alternating input voltage (W_o = 50 mW)	V_i	= 0,3	V_{eff}

The 4699 used in class AB output stage with auto. grid bias (two valves)

Supply voltage	V_b	=	425	375		V
Load resistor between anodes	R_{aa}	=	8,000	6,000		ohms
Common screen-grid series resistor	R_{g2}	=	2,200	700		ohms
Cathode resistor	R_k	=	170	125		ohms
Alternating input voltage	V_i	=	0	17	0	14 V_{eff}
Anode voltage	$V_a + V_{Rk}$	=	405	400	355	350 V
Anode current	I_a	=	2×46	2×58	2×52	2×64 mA
Screen-grid current	I_{g2}	=	2×5	2×14.5	2×6.5	2×16.5 mA
Power output	W_o	=	0	29	0	27.5 W
Total distortion	d_{tot}	=	—	5	—	4 %

The 4699 used in triode connection as single output valve class A (screen-grid connected to anode)

Supply voltage	V_b	=	375 V	Alternating input voltage	V_i	=	11 V_{eff}
Cathode resistor	R_k	=	300 ohms	Power output	W_o	=	4.5 W
Load resistor	R_a	=	4,000 ohms	Total distortion	d_{tot}	=	9 %
Anode current	I_a	=	50 mA				

The 4699 used in triode connection in class AB output stage with auto. grid bias (two valves)

Supply voltage	V_b	=	400	V
Load resistor between anodes	R_{aa}	=	5,500	ohms
Common cathode resistor	R_k	=	175	ohms
Alternating input voltage	V_i	=	0	13.5 V_{eff}
Anode current	I_a	=	2×48	2×54 mA
Power output	W_o	=	0	13 W
Total distortion	d_{tot}	=	—	1.5 %

MAXIMUM RATINGS

Anode voltage in cold condition	V_{ao}	= max.	800	V
Anode voltage	V_a	= max.	425	V
Anode dissipation	W_a	= max.	18	W
Screen-grid voltage in cold condition	V_{g2o}	= max.	650	V
Screen-grid voltage	V_{g2}	= max.	425	V
Screen dissipation without signal	W_{g2}	= max.	2	W
Screen dissipation at max. modulation	W_{g2}	= max.	5	W
Cathode current	I_k	= max.	90	mA
Grid voltage at grid current start ($I_{g1} = +0.3\,\mu A$)	V_{g1}	= max.	−1.3	V
External resistance between grid and cathode (auto. bias)	R_{g1}	= max.	0.7	M ohm
External resistance between grid and cathode (fixed bias)	R_{g1}	= max.	0.5	M ohm
External resistance between heater and cathode	R_{fk}	= max.	20,000	ohms
Voltage between heater and cathode	V_{fk}	= max.	50	V

The 4699 is operated with automatic grid bias; semi-automatic bias may be employed, provided that the cathode current in the output stage constitutes more than 50 % of the total current flowing in the resistor producing the bias. The value of R_{g1} must then be reduced in accordance with the following:

$$\frac{\text{Cathode current of output valve}}{\text{Total current passing through resistor producing the voltage drop}} \times R_{g1}.$$

Due to the high mutual conductance, a stopper resistor of about 1,000 ohms is included in the grid lead to prevent oscillation.

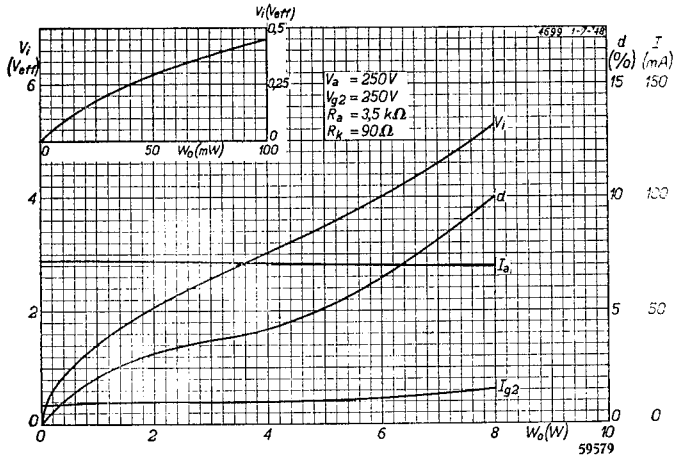


Fig. 5
Total distortion, anode and screen-grid current and alternating input voltage as functions of the output power; the 4699 used as single output valve class A with $Va = 250$ V and $Vg_2 = 250$ V.

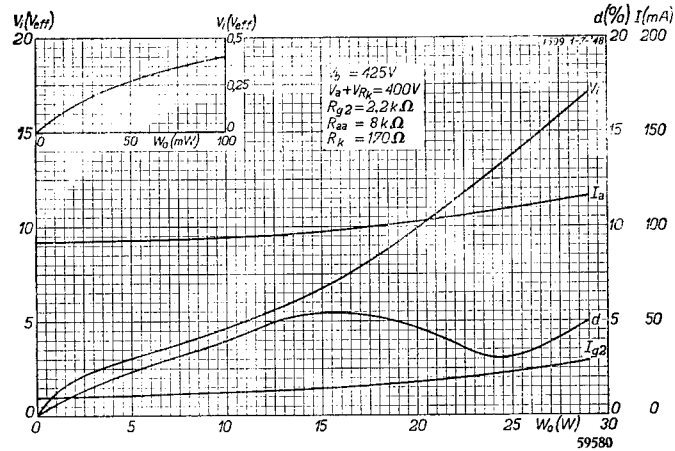


Fig. 6
Total distortion, anode and screen-grid current and alternating input voltage as functions of the output power; 2 valves 4699 used in class AB output stage with auto. grid bias, $Vb = 425$ V.

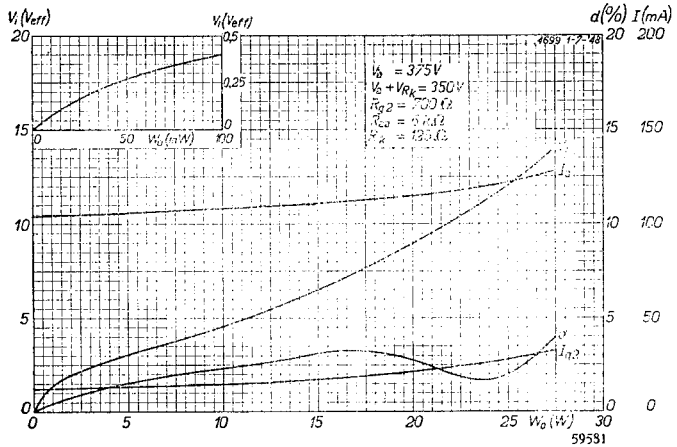


Fig. 7
Total distortion, anode and screen-grid current and alternating input voltage as functions of the output power; 2 valves 4699 used in class AB output stage with auto. grid bias, Vb = 375 V

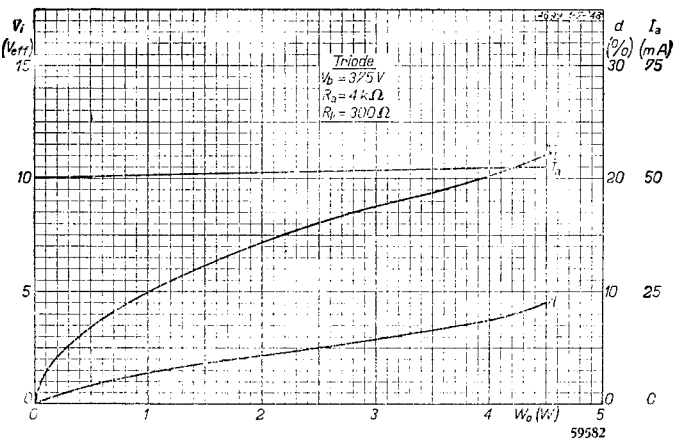


Fig. 8
Total distortion, anode current and alternating input voltage as functions of the output power; the 4699 used as single output valve in triode connection (screen-grid connected to anode) class A with Vb = 375 V.

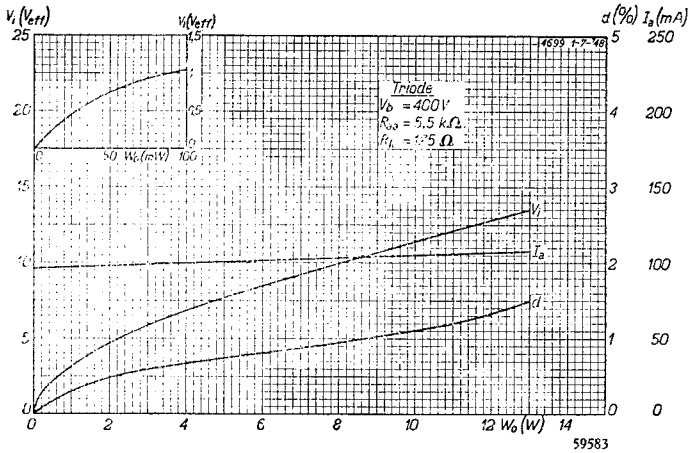


Fig. 9
Total distortion, anode current and alternating input voltage as functions of the output valve; 2 valves 4654 in triode connection (screen-grid connected to anode) used in class AB output stage with $Vb = 400$ V.

EL 51 Pentode

The EL 51 is a 45 W pentode for use in large amplifier equipment. Two of these valves in a balanced circuit with an anode and screen potential of 750 V will deliver an output of 140 W. A 68 W electric lamp must be connected in series with the screen grids to prevent the screen-grid being overloaded. The fact that the screen carries the same potential as the anode affords many possibilities in connection with the application of this valve, since the screen can be fed directly from the high-tension line, without necessitating the use of a potential divider carrying a high current.
The grid input for maximum modulation is quite small on account of the high mutual conductance; the heater consumption is, nevertheless, relatively low, being 12 W.

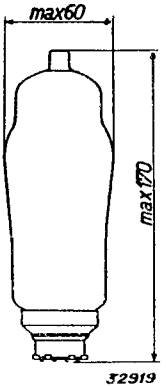


Fig. 1
Dimensions in mm.

HEATER RATINGS

Heating: indirect by A.C. or D.C.; parallel supply.

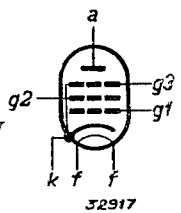
Heater voltage	V_f	= 6.3 V
Heater current	I_f	= 1.9 A

CAPACITANCES

Anode-grid	C_{ag1}	< 1.5 $\mu\mu$F

STATIC RATINGS

Anode voltage	V_a	=	500	750	V
Screen-grid voltage	V_{g2}	=	500	750	V
Grid bias	V_{g1}	=	—20	—37.5	V
Anode current	I_a	=	87	60	mA
Screen-grid current	I_{g2}	=	13	10	mA
Mutual conductance	S	=	11	8	mA/V
Amplification factor; screen with respect to control grid	μ_{g2g1}	=	16,500	16,500	—
Internal resistance	R_i	=	33,000	50,000	ohms



OPERATING DATA

The EL 51 used in class B output stage with fixed grid bias (two valves)

Anode voltage	V_a	=		750	V
Screen-grid voltage	V_{g2}	=		750	V [1]
Grid bias	V_{g1}	=		—40	V
Load resistor between anodes	R_{aa}	=		6,000	ohms
Alternating input voltage	V_i	=	0	28.5	V_{eff}
Anode current	I_a	=	2×40	2×145	mA
Screen-grid current	I_{g2}	=	2×7.5	2×30	mA
Power output	W_o	=	0	140	W
Total distortion	d_{tot}	=	—	5	%

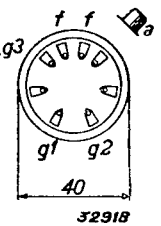


Fig. 2
Arrangement of electrodes and base connections.

[1]) A resistor of 1,000 ohms should be included in series with the common screen-grid lead, or, better still, a special electric lamp (550 V, 68 W).

The EL 51 used in class AB output stage with auto. grid bias (two valves)

Anode voltage	V_a =	500		V
Screen-grid voltage	V_{g2} =	500		V
Common cathode resistor	R_k =	100		ohms
Load resistor between anodes	R_{aa} =	4,800		ohms
Alternating input voltage	V_i =	0	19	V_{eff}
Anode current	I_a =	2×87	2×110	mA
Screen-grid current	I_{g2} =	2×13	2×23	mA
Power output	W_o =	0	67.5	W
Total distortion	d_{tot} =	—	5	%

MAXIMUM RATINGS

V_{ao}	= max.	1,500	V	I_k	= max.	200	mA
V_a	= max.	750	V	V_{g1} (I_{g1} = + 0.3 μA)			
W_a	= max.	45	W		= max.	—1.3	V
V_{g2o}	= max.	1,500	V	R_{g1} (fixed bias)	= max.	0.35	M ohm
V_{g2}	= max.	750	V	R_{g1} (auto. bias)	= max.	0.7	M ohm
W_{g2} (V_i = 0)	= max.	7	W	V_{fk}	= max.	50	V
W_{g2} (W_o = max.)	= max.	25	W	R_{fk}	= max.	20,000	ohms

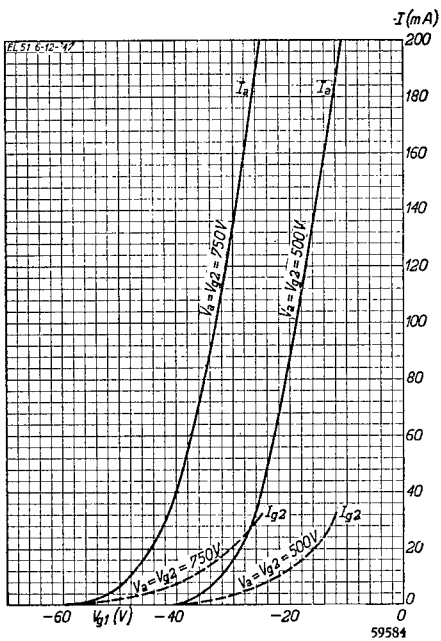


Fig. 3
Anode and screen current of the EL 51 as functions of the grid bias, for various values of anode and screen potential.

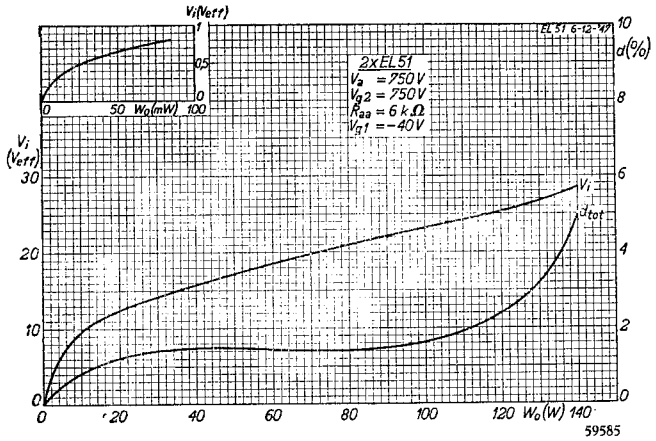


Fig. 4
Total distortion and alternating input voltage as functions of the output power; 2 valves EL 51 used in class B output stage with fixed grid bias, $Va = Vg_2 = 750$ V.

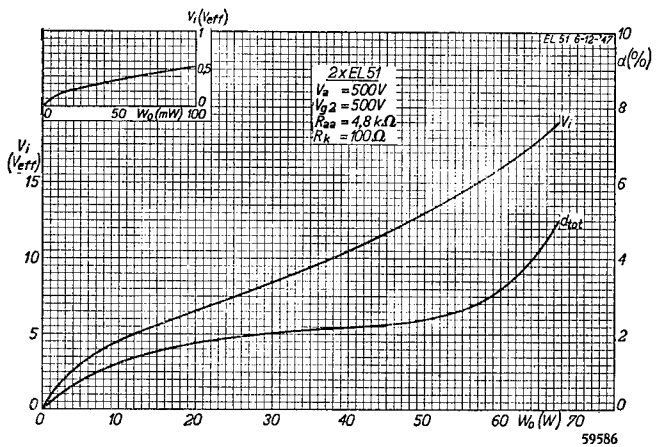
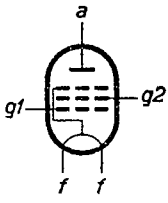


Fig. 5
Total distortion and alternating input voltage as functions of the output power; 2 valves EL 51 used in class AB output stage with auto. grid bias, $Va = Vg_2 = 500$ V.

F 443 N Pentode



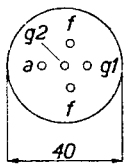


Fig. 2
Arrangement of electrodes and base connections.

This is a directly-heated 25 W output pentode, fitted with a 5-pin base and suitable for a maximum anode potential of 550 V; the maximum screen voltage is 300 V.
On an anode voltage of 300 V the same potential may be applied to the screen, thus avoiding the necessity for potential divider feeding, possibly with voltage stabilization. In balanced circuits, however, the maximum output power is then considerably lower than in the case of operation with an anode voltage of 550 V and a screen voltage of 250 V; a Class AB output stage employing two of these valves at the last-mentioned rating and with automatic bias will yield 41 W with 4.3 % distortion.

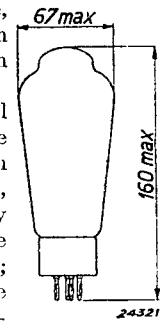


Fig. 1
Dimensions in mm.

FILAMENT RATINGS

Heating: direct, A.C., parallel supply.

Filament voltage	$V_f = 4$ V
Filament current	$I_f = 2$ A

CAPACITANCES

$C_{ag_1} < 3\ \mu\mu F$

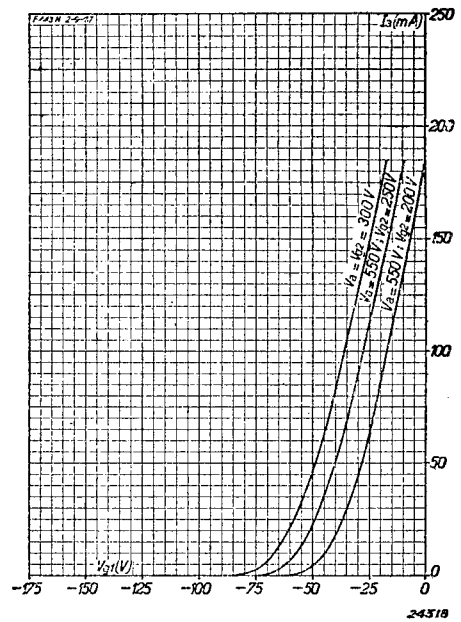


Fig. 3
Anode current as a function of the grid bias, with $Va = 550$ V, $Vg_2 = 250$ V; $Va = 550$ V, $Vg_2 = 200$ V and $Va = Vg_2 = 300$ V.

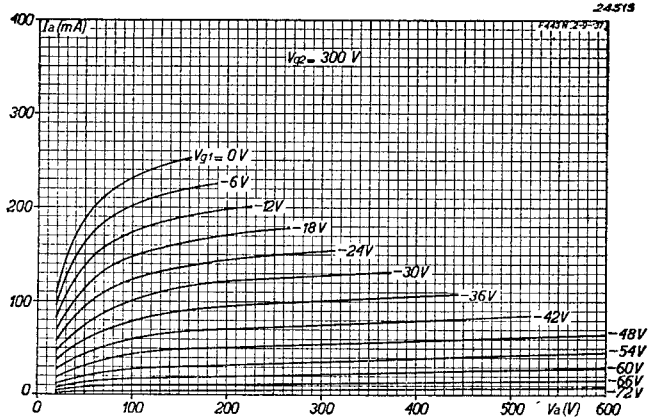


Fig. 4
Anode current as a function of the anode voltage for different values of grid bias. $Vg_2 = 300$ V.

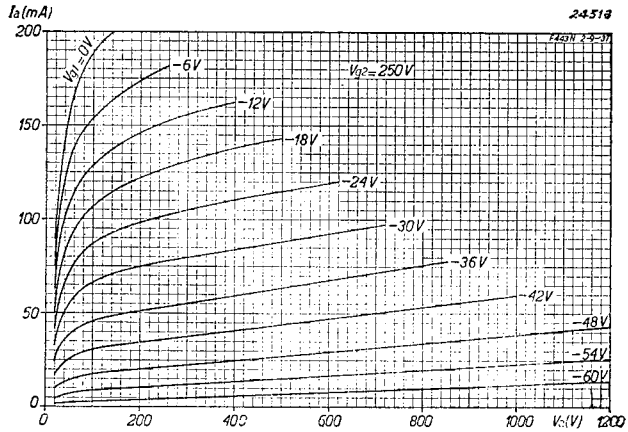


Fig. 5
Anode current as a function of the anode voltage for different values of grid bias. $Vg_2 = 250$ V.

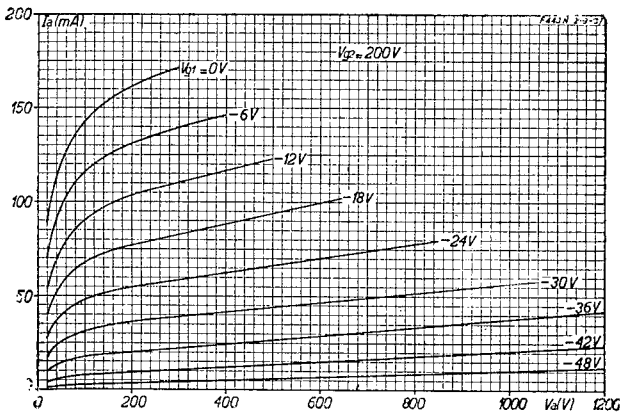


Fig. 6
Anode current as a function of the anode voltage for different values of grid bias. $Vg_2 = 200$ V.

OPERATING DATA

		Single amplifier (Class A)	Single amplifier (Class A)	Class AB output with auto. bias (two valves)	Class AB output with fixed bias (two valves)	Class AB output with auto. bias (two valves)
Anode voltage	V_a (V)	550	300	500	300	300
Screen voltage	V_{g2} (V)	200	300	250	300	300
Fixed grid bias	V_{g1} (V)	—30	—40	—	—63	—
Common cathode resistor for auto. bias	R_k(ohms)	647	455	445	—	330
Anode current (without signal)	I_{a0} (mA)	45	83	2 × 45	2 × 15	2 × 64
Anode current at max. modulation	$I_{a\ max}$ (mA)	—	—	2 × 53	2×72.5	2×72.5
Screen current (without signal)	I_{g20}(mA)	1.4	4.6	2 × 0.8	2 × 0.4	2 × 2.0
Screen current at max. modulation	$I_{g2\ max}$ (mA)	—	—	2 × 7.4	2×14.3	2×11.9
Mutual conductance	S (mA/V)	3.2	3.9	—	—	—
Internal resistance	R_i(ohms)	30,000	20,000	—	—	—
Load resistor (between anodes)	R_{aa}(ohms)	12,000	3,600	12,000	4,500	4,000
Power output	W_o (W)	12	10.3	41	26.5	24
Distortion at max. output	d_{tot} (%)	10	10	4.3	4.5	2.9
Alternating grid voltage at max. modulation	V_i (V_{eff})	15.5	20	37	46	39

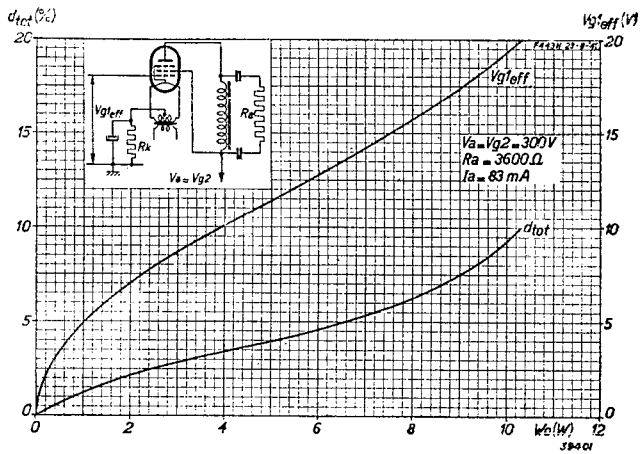


Fig. 7
Total distortion and alternating grid voltage as functions of the output power with $Va = Vg_2 = 300$ V. F 443 N used as a single output valve.

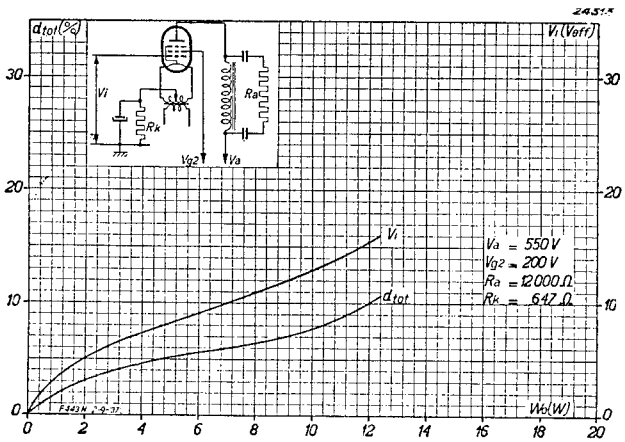


Fig. 8
Total distortion and alternating grid voltage as functions of the output power, with $Va = 550$ V and $Vg_2 = 200$ V. F 443 N used as a single output valve.

MAXIMUM RATINGS

V_{ao}	= max. 900 V	I_k	= max. 100 mA
V_a	= max. 550 V	V_{g1} ($I_{g1} = +0.3\ \mu A$)	= max. —2 V
W_a	= max. 25 W	R_{g1k} (*auto. bias*)	= max. 0.3 M ohm
V_{g2o}	= max. 500 V	R_{g1k} (*fixed bias*)	= max. 0.1 M ohm
V_{g2}	= max. 300 V		
W_{g_2} ($V_i = 0$)	= max. 1.5 W		
W_{g_2} (W_o = max)	= max. 4.3 W		

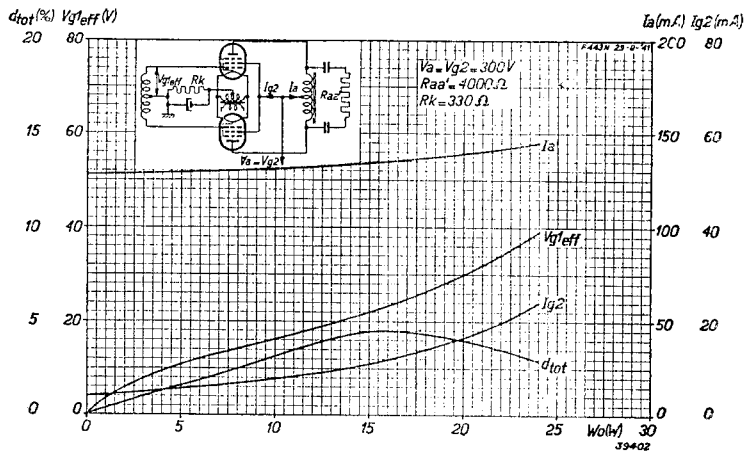


Fig. 9
Total distortion, total anode and screen-grid current and alternating grid voltage as functions of the output power. Two F 443 N valves in a balanced output stage with automatic bias. $Va = Vg_2 = 300$ V.

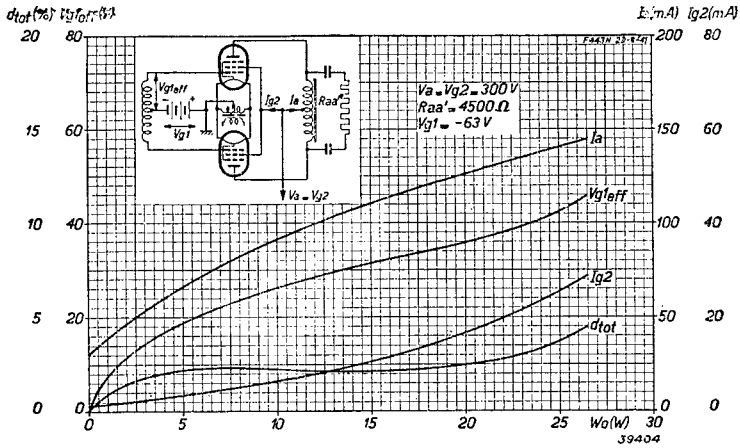


Fig. 10
Total distortion, total anode and screen-grid current and alternating grid voltage as functions of the output power. Two F 443 N valves in a balanced output stage with fixed bias. $Va = Vg_2 = 300$ V.

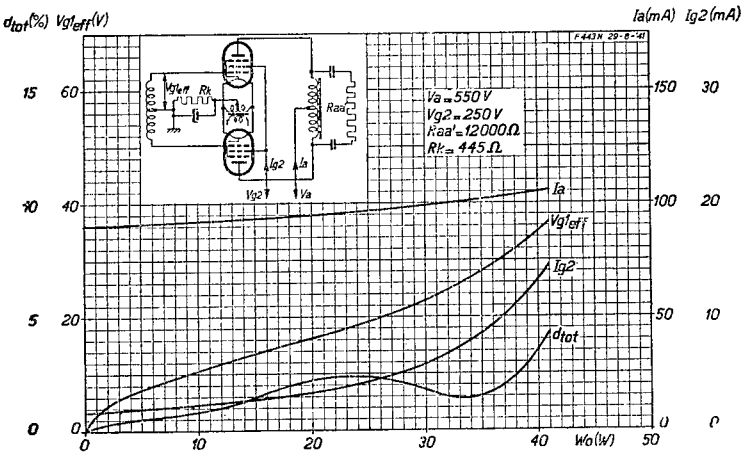


Fig. 11
Total distortion, total anode and screen-grid current, and alternating grid voltage as functions of the output power. Two F 443 N valves in a balanced output stage with automatic bias. $Va = 550$ V, $Vg_2 = 250$ V.

CF 50 Microphone pre amplifier pentode

The CF 50 was specially designed for the amplification of very low voltages. Hum, background noise and microphony have all been reduced to a minimum and the principal application of the valve is as a pre-amplifier in crystal or ribbon-microphone equipment.

This valve is capable of being operated to give a stage gain of about 300, producing an effective alternating output voltage of 3 V with less than 1 % distortion or, if required, a gain factor of between 395 and 45 with distortion less than 0.4 % and an output voltage of 0.1 V_{eff}. This versatility of the valve may be ascribed to the fact that the input signals in this case are extremely small.

Details of the operating possibilities of this valve are set out in Tables I and II.

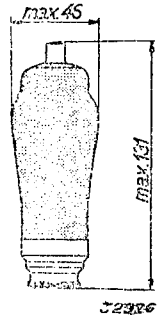


Fig. 1
Dimensions in mm.

In view of the fact that the valve is specially intended for the amplification of very small signals, extra care must be taken to prevent hum, since otherwise the level of the hum will quickly approach that of the input signal itself. For this latter reason the valve is equipped with a bifiliar filament, in consequence of which the external magnetic field is very weak; as this field is proportional to the strength of the current, the heater current has been kept as low as possible, namely 200 mA, so that, in effect, there is hardly any external field at all. To ensure sufficient emission from the cathode on this current it has been necessary to employ a heater voltage of 30 V. The ultimate result is that, using a grid impedance of 0.5 megohm, the voltage on the grid corresponding to the hum on both grid and anode is less than 1 μV. Taking into consideration the fact that the voltage delivered by the microphone is of the order of 1 mV, it may be claimed that the ripple level is very low indeed. In a cathode resistor without a decoupling capacitor the induced ripple voltage will be about 20 μV.

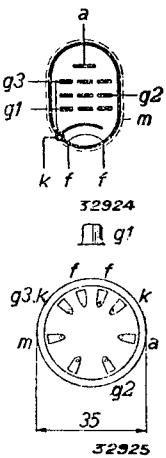


Fig. 2
Arrangement of electrodes and base connections.

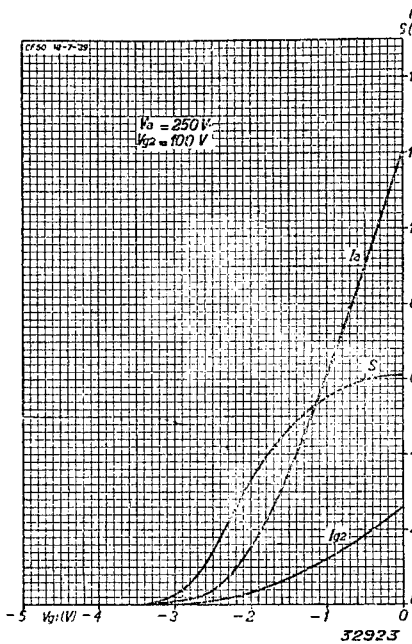


Fig. 3
Anode current Ia, screen-grid current Ig_2 and mutual conductance S as functions of the grid bias Vg_1 with Va = 250 V and Vg_2 = 100 V.

The equivalent noise resistance of the CF 50 is 2,500 ohms, which corresponds to an effective value of 0.7 μV for the noise voltage on the grid at a bandwidth of 10,000 c/s and this, compared with the voltages applied to the grid, is also extremely low. In fact, the equivalent noise resistance gives the impression of being unnecessarily low in com-

parison with the customary value of the grid leak, but it should be remembered that crystal microphones have a markedly capacitive character, due to which fact the noise resistance of the microphone, for the greater part of the frequency range, is considerably lower than the matching resistance based on the response over a relatively small range of low frequencies. The low value of the equivalent noise resistance of the CF 50 is a result of the high mutual conductance with a low anode current (S = 3.3 mA/V, I_a = 1.5 mA).

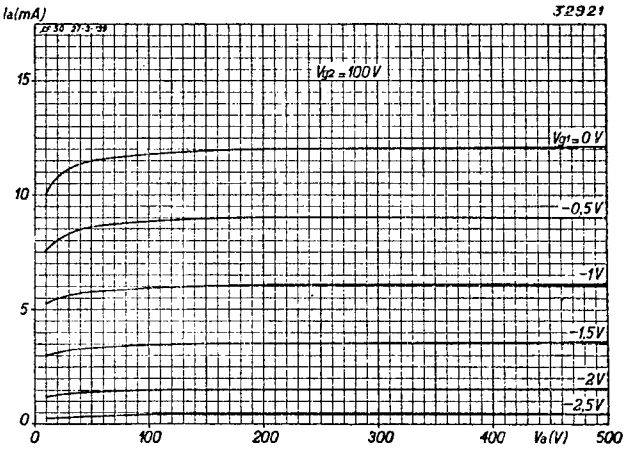


Fig. 4
Anode current as a function of the anode voltage for different values of grid bias, at a screen potential of 100 V.

Finally it may be noted that microphony is eliminated as far as possible by the use of special double mica supports for the system of electrodes; on the whole, then, the CF 50 is an excellent valve for the pre-amplification stage of the more sensitive type

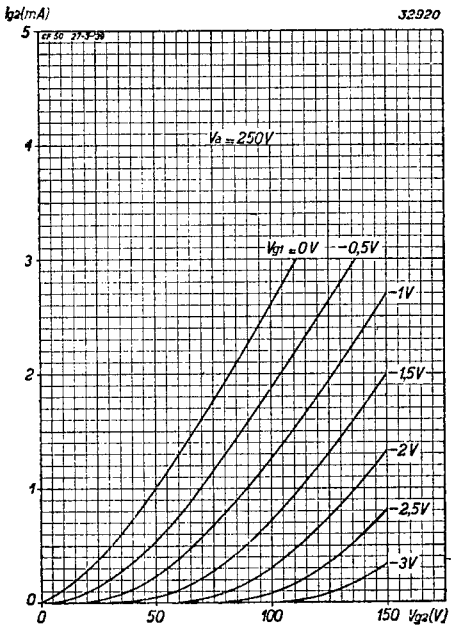


Fig. 5
Screen-grid current as a function of the screen voltage for different values of grid bias, with 250 V anode voltage.

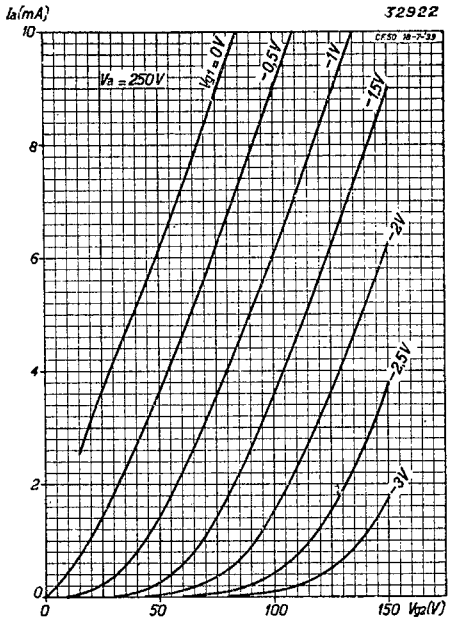


Fig. 6
Anode current as a function of the screen voltage for different values of grid bias, with 250 V anode voltage.

of amplifier, more especially on account of the low noise resistance in cases where the voltage to be amplified comes from a source of which the noise resistance is also comparatively low.

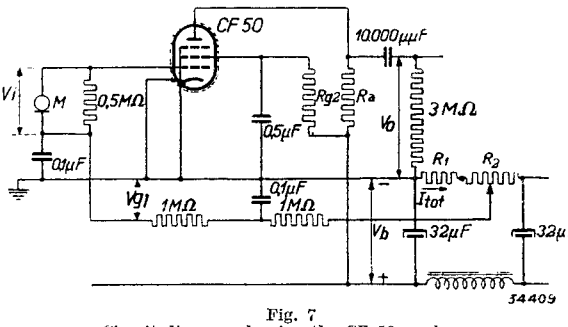


Fig. 7
Circuit diagram showing the CF 50 used as a microphone pre-amplifier.

HEATER RATINGS

Heating: indirect, A.C. or D.C., series or parallel supply.
Heater voltage V_f = 30 V.
Heater current I_f = 0.200 A.

CAPACITANCES

$C_{ag_1} < 0.03$ μμF
$C_{g_1} = 13$ μμF
$C_a = 14.5$ μμF

STATIC RATINGS

Anode voltage	V_a	= 100 V	250 V
Screen-grid voltage	V_{g_2}	= 100 V	100 V
Grid bias	V_{g_1}	= —2 V	—2 V
Anode current	I_a	= 1.5 mA	1.5 mA
Screen-grid current	I_{g_2}	= 0.3 mA	0.3 mA
Mutual conductance	S	= 3.3 mA/V	3.3 mA/V
Internal resistance	R_i	= 2 M ohms	2.5 M ohms
Amplification factor; screen with respect to control grid	$\mu_{g_2/1}$	= 45	45
Equivalent noise resistance in the frequency range 50 to 10,000 c/s	R_{eq}	= —	2,500 ohms

TABLE I

OPERATING DATA: CF 50 used as resistance-coupled A.F. amplifier without gain control (see Fig. 7)

Supply voltage *Vb* (V)	Anode resistor *Ra* (M ohm)	Screen-grid series resistor *Rg₂* (M ohm)	Cathode resistor *Rk* (ohms)	Anode current *Ia* (mA)	Screen current *Ig₂* (mA)	Voltage gain *Vo/Vi*	Output voltage *Vo* (*Veff*)	Total distortion *d* tot (%)
250	0.3	0.9	2,000	0.7	0.18	315	3	< 1
200	0.3	0.8	3,000	0.5	0.15	260	3	< 1
100	0.3	0.4	7,000	0.2	0.07	150	3	< 1
250	0.2	0.7	1,800	0.9	0.22	295	3	< 1
200	0.2	0.64	2,000	0.7	0.18	245	3	< 1
100	0.2	0.32	5,000	0.3	0.09	145	3	< 1
250	0.1	0.64	1,800	0.9	0.22	280	3	< 1
200	0.1	0.56	2,200	0.7	0.19	230	3	< 1
100	0.1	0.28	5,000	0.3	0.09	140	3	< 1

TABLE II

OPERATING DATA: CF 50 used as a resistance-coupled A.F. amplifier with control of the amplification (see Fig. 7)

Supply voltage Vb (V)	Anode resistor Ra (M ohm)	Screen-grid series resistor Rg_2 (M ohm)	Grid bias Vg_1 (V)	Anode current Ia (mA)	Screen-grid current Ig_2 (mA)	Voltage gain Vo/Vi	Output voltage Vo ($Veff$)	Total distortion $dtot$ (%)
450	0.3	1.0	—2	1.4	0.38	395	0.1	0.2
450	0.3	1.0	—6	0.72	0.18	260	0.1	0.2
450	0.3	1.0	—10	0.22	0.06	90	0.1	0.2
450	0.3	1.0	—11	0.11	0.04	45	0.1	0.4
450	0.3	1.0	—12	0.04	0.02	7	0.1	3
450	0.2	0.8	—2	1.78	0.44	350	0.1	< 0.2
450	0.2	0.8	—6	0.94	0.23	230	0.1	< 0.2
450	0.2	0.8	—10	0.18	0.05	45	0.1	< 0.2
450	0.2	0.8	—11	0.08	0.02	20	0.1	0.4
450	0.2	0.8	—12	0.03	0.01	3	0.1	3
450	0.1	0.5	—2	2.8	0.64	245	0.1	< 0.2
450	0.1	0.5	—6	1.5	0.33	180	0.1	< 0.2
450	0.1	0.5	—10	0.25	0.05	38	0.1	0.3
450	0.1	0.5	—11	0.09	0.02	15	0.1	1.1
450	0.1	0.5	—12	0.03	0.01	3	0.1	5

MAXIMUM RATINGS

Anode voltage in cold condition	V_{ao}	= max. 550 V
Anode voltage	V_a	= max. 250 V
Anode dissipation	W_a	= max. 1 W
Screen voltage in cold condition	V_{g2o}	= max. 550 V
Screen voltage at $I_a = 1.5$ mA	V_{g2}	= max. 125 V
Screen voltage at $I_a < 0.25$ mA	V_{g2}	= max. 450 V
Screen dissipation	W_{g2}	= max. 0.5 W
Cathode current	I_k	= max. 10 mA
Grid voltage at grid current start ($I_{g1} = + 0.3$ μA)	V_{g1}	= max. —1.3 V
External resistance between control grid and cathode	R_{g1k}	= max. 3 M ohms
External resistance between heater and cathode	R_{fk}	= 20,000 ohms
Voltage between heater and cathode	V_{fk}	= max. 100 V