A. C. valves

"Miniwatt" receiving valves

Series E

The "E" series of "Miniwatt" valves comprises a range of valves nearly all of which are of small dimensions; the heaters consume only a very small amount of power. They guarantee the best reception in A.C. receivers, A.C./D.C. sets and car radio.

Low current consumption

One of the outstanding features of the Miniwatt valve is the extremely small current consumption; in all of these valves, with the exception of the "four-channel" octode, the consumption is only 1.26 W, which, in an indirectly-heated valve of such power, is exceptionally low.

Improved cathode

The warming-up period is very much shorter than usual, being about 10 seconds. The thermal radiation is only slight, and the efficiency very high. Modern methods of construction have resulted in a much improved cathode insulation.

Small dimensions

The extremely low current consumption is an outcome of the reduced length of the cathode. Moreover, the short cathode does not tend to buckle and the other electrodes can be mounted more closely around it than was formerly the case. The physical dimensions of the valve are accordingly much smaller than usual.

Very slight background noise

The small dimensions have contributed towards robustness of structure and high stability. Background noise, attributable formerly to mechanical causes, has thus been eliminated. The interference level in Miniwatt E-type valves is very low in contrast with other types.

Reliability

When the valves in this series are used trouble-free and reliable performance of the receiver is assured.

Short-wave reception

Miniwatt valves are particularly suitable for short-wave reception. The triode-hexode and 4-channel octode are outstanding for their much reduced frequency-drift and induction effect. The R.F. pentodes have high input and output damping values and only very slight retroaction from anode to grid.

Compact chassis design

The low wattage of these valves necessitates only a small bulb and the spacing of the valves on the chassis, or between them and other components normally susceptible to heat, can therefore be quite small; the reduced dimensions of the valves may thus be employed to the best advantage.

The complete series

EAB 1	— Triple diode with common cathode serving the three diodes	1.26 W cathode
EB 4	— Double-diode with separate cathodes	1.26 W cathode
EBC 3	— Double-diode triode having a gain factor of 30	1.26 W cathode
EBF 2	— Double-diode and I.F. amplifier pentode; variable-mu and sliding screen voltage	1.26 W cathode
EBL 1	— Double-diode output pentode. The pentode is of very high mutual conductance	8.5 W cathode
ECH 3	— Triode-hexode for use as frequency-changer in all-wave receivers; variable-mu, low current consumption and small dimensions	1.26 W cathode
EEP 1 (EE 1)	— Secondary-emission valve for driving balanced output stages without driver transformer	3.8 W cathode
EF 5	— R.F. pentode; variable-mu and excellent characteristics from the point of view of freedom from cross-modulation	1.26 W cathode
EF 6	— R.F. and A.F. amplifier pentode; fixed mutual conductance	1.26 W cathode
EF 8	— Noise-free R.F. variable-mu amplifier valve	1.26 W cathode
EF 9	— Variable-mu R.F. pentode with sliding screen voltage	1.26 W cathode
EFM 1	— Variable-mu A.F. amplifier pentode with sliding screen voltage; combined with electronic indicator	1.26 W cathode
EH 2	— Heptode for use as modulator valve in short-wave receivers or as R.F. and I.F. amplifier	1.26 W cathode
EK 2	— Low-consumption octode for mixing stages in receivers in which no control is applied to the frequency-changer in the short-wave range; also for car radio	1.26 W cathode
EK 3	— Four-channel octode for use in receiver mixing stages when high-grade performance is also required in the short-wave range	3.8 W cathode
EL 2	— Normal slope output pentode with low current consumption, especially for car radio	1.26 W cathode
EL 3	— 9 W output pentode; high mutual conductance	5.7 W cathode
EL 5	— 18 W output pentode; high mutual conductance	8.5 W cathode
EL 6	— Very steep slope 18 W pentode, to deliver maximum output at the same signal input as the EL 3	7.5 W cathode

ELL 1	— Double output pentode for balanced output stages in car radio	2.8 W cathode
EM 1	— High-vacuum electronic indicator with built-in amplifier triode	1.26 W cathode
C/EM 2	— High-vacuum electronic indicator combined with amplifier triode which can also be used for other purposes	1.26 W cathode
EM 4	— High-vacuum electronic indicator with two triode amplifiers, providing two different sensitivity values for accurate tuning on strong and weak signals	1.26 W cathode
EZ 2	— Small indirectly-heated full-wave rectifying valve for car radio	2.5 W cathode
EZ 4	— Indirectly-heated full-wave rectifying valve for high-power receivers	5.7 W cathode

This series further includes the following directly-heated rectifying valves with 4 V heater voltage and fitted with side contacts (P-type base):

AZ 1 — Directly-heated full-wave rectifying valve for receivers of medium power
AZ 4 — Directly-heated full-wave rectifying valve for receivers with high current consumption

The 1.26 W-cathode valves take a current of 200 mA at a heater voltage of 6.3 V and they can also be used in A.C./D.C. receivers. These valves are equally serviceable in conjunction with the triode-hexode ECH 3, or with the 4-channel octode for A.C./D.C. operation, or again, with the CK 3 and different A.C./D.C. output and rectifying valves.

For A.C./D.C. receivers the following valves are available:

EAB 1	— Triple diode	6.3 V heater
EB 4	— Double diode with separate cathodes	6.3 V heater
EBC 3	— Double-diode triode	6.3 V heater
EBF 2	— Double-diode and I.F. pentode	6.3 V heater
ECH 3	— Triode-hexode	6.3 V heater
EF 6	— R.F. or A.F. pentode	6.3 V heater
EF 8	— Noise-free R.F. amplifier (200 V mains only)	6.3 V heater
EF 9	— Variable-mu R.F. or I.F. pentode	6.3 V heater
EFM 1	— L.F. amplifier pentode and electronic indicator (200 V mains only)	6.3 V heater
EH 2	— Mixer heptode and R.F. or I.F. amplifier	6.3 V heater
EK 2	— Mixer octode	6.3 V heater
EM 1	— Electronic indicator	6.3 V heater
C/EM 2	— Electronic indicator	6.3 V heater

EM 4	— Electronic indicator	6.3 V heater
CBL 1	— Double-diode output pentode	44 V heater
CK 3	— Four-channel octode	19 V heater
CL 4	— 9 W output pentode (200 V mains only)	33 V heater
CL 6	— 9 W output pentode (100 and 200 V)	35 V heater
CY 1	— Half-wave rectifying valve 80 mA	20 V heater
CY 2	— Half-wave rectifying valve and voltage-doubler	30 V heater

The following valves are recommended for car radio (6.3 V): EBC 3, EF 9, EK 2, EL 2, ELL 1, EM 4 and EZ 2.

New types of construction, resulting in fresh characteristics

For the latest developments in receiver design the E-type valves have numerous improvements and new characteristics to offer.

In some of the valves the electron-bunching principle has been adopted to meet the problem of the demand for a low-noise R.F. valve and variable-mu frequency-changer for short-wave reception. The octode EK 3 for A.C. and the CK 3 for A.C./D.C. sets work on the 4-channel electron stream principle and the sharp separation of the streams or channels for oscillation and modulation purposes has eliminated mutual. interference of these functions with all its drawbacks.

Another solution to the problem of frequency changing is provided by the ECH 3, a triode-hexode with combined oscillator triode. This valve has excellent characteristics for radio receivers which are required to give really good reception on all wave-bands; it permits of control of the mutual conductance, even on the short-wave range, without the disadvantage of any frequency drift.

A further innovation is the self-adjusting or sliding screen voltage in the R.F. and A.F. pentodes. Until recently pentodes worked on a fixed screen voltage, in other words, on a fixed characteristic; any increase in the grid bias, for the purpose of reducing the gain, resulted in a shifting of the working point along the Ia/Vg_1 curve, but with the sliding screen voltage every value of grid bias introduces a different characteristic, thus providing interesting new properties.

Amongst others, the R.F. pentode EF 9 and the I.F. pentode combined with two diodes, the EBF 2, are designed on this principle.

A very special type of valve is to be found in the secondary-emission valve EEP 1, which functions on the electron-bunching principle; the introduction of secondary emission provides in the anode and secondary-emission circuits two alternating voltages of exactly opposite phase, and this valve will drive a balanced-output circuit without the use of the usual driver transformer.

Among electronic indicators the EM 4 with its dual sensitivity is worthy of special mention. By means of this indicator it is possible to tune the receiver with just the same degree of accuracy on weak as on strong signals.

The EFM 1 is another interesting development, being a combination of A.F. amplifier pentode and electronic indicator. The pentode section of this valve is of the variable-mu type and also incorporates the sliding screen voltage; the voltage variations produced in the screen grid resistor by changes in the grid bias are employed to operate the built-in electronic indicator.

In conjunction with the double diode and I.F. pentode EBF 2, described in these pages, the EFM 1 provides us with an excellent 4-valve superhet. receiver embodying all the latest features including the electronic indicator, negative feed-back, etc.

The double diode EB 4 with its separated cathodes presents countless opportunities in the design of special circuits. The triple diode EAB 1 was specially designed for use in 3-diode circuits and its introduction has resulted in a considerable reduction of distortion in the diode stage of high-quality receivers.

The EBL 1, a double-diode pentode with high mutual conductance permits of the design of very simple superhet. receivers employing only three valves.

With a view to high-fidelity reproduction of music much attention has been paid to the question of output valves, and various steep-slope types are now available. The output valve EL 6, an 18 W pentode of unusually high mutual conductance, requires roughly the same signal input for full modulation as the 9 W pentode EL 3.

For car radio an output valve has been developed that consists of two complete output-valve units in a common envelope; in a balanced circuit the ELL 1, as it is designated, will deliver a maximum output of 4.5 W with a very small current consumption.

A new valve for A.C./D.C. receivers is the EL 6, a steep-slope output pentode for interchangeable mains operation, and a similar valve is to be designed for a screen voltage of 100 V, to provide adequate output power on 110/127 V mains. This latter valve will replace the earlier model, the CL 2.

EAB 1 Triple diode

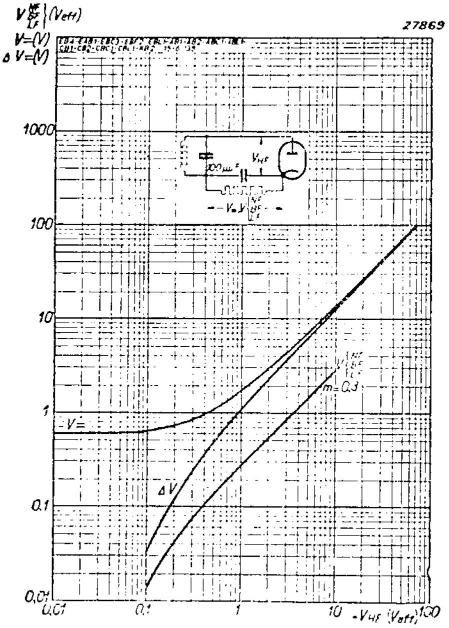

Fig. 3
Direct voltage V and direct voltage curve (ΔV) between the terminals of the grid leak connected to one of the diodes of the EAB1, as a function of the unmodulated R.F. voltage.
L.F. voltage V_{LF} between the terminals of the grid leak as a function of the R.F. voltage modulated to a depth of 30 % (m = 30 %). These characteristics apply to grid leaks of from 0.1 to 1 megohm.

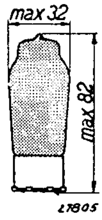

Fig. 1
Dimensions in mm.

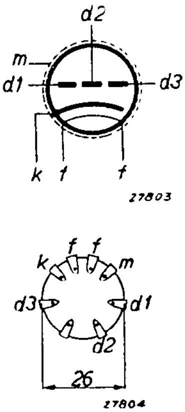

Fig. 2
Arrangement of electrodes and base connections.

The triple diode EAB 1 consists of three diodes arranged about a common, horizontally mounted, cathode, having been especially developed for 3-diode circuits. The object of this type of circuit is to eliminate distortion and other unpleasant effects arising from the use of delayed automatic gain control and it involves an arrangement employing three diodes, one of which serves as detector and one for the A.G.C., whilst the third is used for the delaying effect. With a view to suppressing hum, the detector diode, which is shown as d_1 in the diagram of base connections, Fig. 2, is mounted farthest from the heater. The diode nearest to the filament and marked d_2 in the diagram has a very low capacitance with respect to the detector diode, this being less than 0.08 μμF. Since the A.G.C. diode, for many reasons, is usually connected to the primary circuit of the preceding band-filter, the amount of capacitance between this diode and the detector diode is extremely important. As the reader is doubtless aware, this capacitance acts as a coupling between the two band-filter circuits and tends to have an adverse effect on the selectivity. It is for this reason that diode d_1 is employed for the A.G.C. Diode d_2, located between d_1 and d_3, is then available for other purposes, in particular to provide the delaying effect for the A.G.C. as employed in this type of circuit.

Heater ratings

Heating: indirect, A.C. or D.C., series or parallel supply.

Heater voltage	V_f = 6.3 V
Heater current	I_f = 0.200 A

Capacitances

Diodes d_1 — d_2	$C_{d_1d_2} < 0.65$ μμF
Diodes d_1 — d_3	$C_{d_1d_3} < 0.08$ μμF
Diodes d_2 — d_3	$C_{d_2d_3} < 0.4$ μμF
Diode d_1 — cathode	$C_{d_1k} = 1.5$ μμF
Diode d_2 — cathode	$C_{d_2k} = 1.35$ μμF
Diode d_3 — cathode	$C_{d_3k} = 2.2$ μμF

Maximum ratings

Voltage on d_1 (peak value) . . . . V_{d1} = max. 200 V
Voltage on d_2 (peak value) . . . . V_{d2} = max. 200 V
Voltage on d_3 (peak value) . . . . V_{d3} = max. 200 V
Direct current to d_1 . . . . I_{d1} = max. 0.8 mA
Direct current to d_2 . . . . I_{d2} = max. 0.8 mA
Direct current to d_3 . . . . I_{d3} = max. 0.8 mA
External resistance between filament and cathode R_{fk} = max. 20,000 ohms
Potential difference between filament and cathode (D.C. voltage or effective value of alternating voltage) . . . . V_{fk} = max. 100 V

Voltage on diode at diode current start . . . . $\left.\begin{array}{l}(I_{d1} = +\,0.3\,\mu\text{A})\ V_{d1}\\(I_{d2} = +\,0.3\,\mu\text{A})\ V_{d2}\\(I_{d3} = +\,0.3\,\mu\text{A})\ V_{d3}\end{array}\right\}$ = max. −1.3 V

EB 4 Double diode with separate cathodes

The double diode EB 4 embodies two separate and adjacent cathodes with an anode around each, the two complete units being screened from each other. The screen is connected to a separate contact and can thus be very simply maintained at zero potential; it effectively prevents any stray electrons from passing from one unit to the other. This separation of the cathodes offers numerous advantages and greatly extends the range of application of this type of valve. A considerable reduction in the capacitance normally occurring between the anodes prevents any unwanted capacitance between the relative circuits. The two diode units are exactly similar and it is immaterial which of the two is employed for detection purposes.

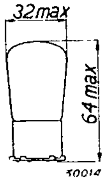

Fig. 1
Dimensions in mm

Heater ratings

Heating: indirect, by A.C. or D.C.; series or parallel supply.
Heater voltage . . . . $V_f = 6.3$ V
Heater current . . . . $I_f = 0.200$ A

Capacitances

$C_{d_1d_2} < 0.2$ μμF
$C_{d_1k} = 1.2$ μμF
$C_{d_2k} = 1.2$ μμF

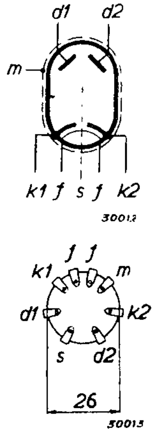

Fig. 2
Arrangement of electrodes and base connections.

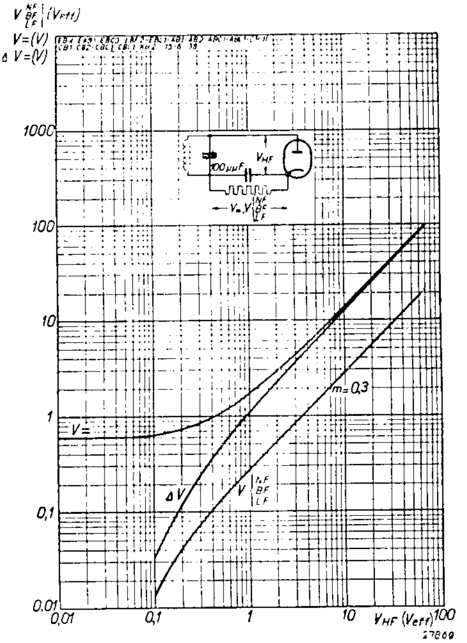

Fig. 3
Direct voltage V and direct voltage curve (ΔV) between the terminals of the grid leak connected to one of the diodes of the EB 4, as a function of the unmodulated R.F. voltage.
A.F. voltage V_{LF} between the terminals of the grid leak as a function of the R.F. voltage modulated to a depth of 30% (m = 30%) These characteristics apply to grid leaks of from 0.1. to 1 megohm.

MAXIMUM RATINGS

Voltage on diode d_1 (peak value)	V_{d1}	= max. 200 V.
Voltage on diode d_2 (peak value)	V_{d2}	= max. 200 V.
Direct current to diode d_1	I_{d1}	= max. 0.8 mA.
Direct current to diode d_2	I_{d2}	= max. 0.8 mA.
External resistance between cathode k_1 and filament	R_{fk1}	= max. 0.02 M ohm.
Potential difference between cathode k_1 and filament (direct current, or effective value of alternating voltage)	V_{fk1}	= max. 75 V.
Potential difference between cathode k_2 and filament (D.C. voltage or effective value of A.C. voltage)	V_{fk2}	= max. 75 V.
Potential difference between the two cathodes (D.C. voltage, or peak value of alternating voltage, or D.C. voltage + peak value of alternating voltage)	V_{k1k2}	= max. 150 V.
Voltage on diode at diode current start ($I_{d1} = +0.3\,\mu A$)	V_{d1}	= max. —1.3 V.
($I_{d2} = +0.3\,\mu A$)	V_{d2}	= max. —1.3 V.

EBC 3 Double-diode triode

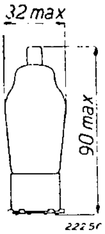

Fig. 1
Dimensions in mm.

The double-diode triode EBC 3 comprises a triode in combination with a double-diode unit, in a common envelope. These two systems are served by a single cathode.

The diode section may be employed for detection and delayed automatic gain control and the triode for A.F. amplification or for other purposes. The A.F. amplification, which may effected by means of resistance coupling, is about 20 times and this is ample for most purposes. Both the diodes have their own separate external connections and the grid connection of the triode is at the top of the valve.

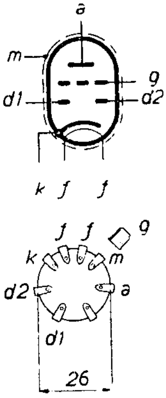

Fig. 2
Arrangement of electrodes and base connections.

HEATER RATINGS

Heating: indirect, by A.C. or D.C.; series or parallel supply.
Heater voltage . . . . $V_f = 6.3$ V
Heater current . . . . $I_f = 0.200$ A

CAPACITANCES

$C_{kd_1} = 1.9$ μμF
$C_{kd_2} = 2.5$ μμF
$C_{d_1d_2} < 0.5$ μμF
$C_{gd_1} < 0.005$ μμF
$C_{gd_2} < 0.005$ μμF
$C_{gf} < 0.002$ μμF

$C_{ag} = 1.3$ μμF
$C_{ak} = 3$ μμF
$C_{gk} = 2.9$ μμF
$C_{(d_1+d_2)g} < 0.006$ μμF
$C_{(d_1+d_2)a} < 1$ μμF

OPERATING DATA

Triode section:

Anode voltage	V_a =	100 V	200 V	275 V
Grid bias.	V_g =	—2.1 V	—4.3 V	—6.25 V
Anode current	I_a =	2 mA	4 mA	5 mA
Amplification factor	μ =	30	30	30
Mutual conductance	S =	1.6 mA/V	2.0 mA/V	2.0 mA/V
Internal resistance	R_i =	19.000 ohms	15,000 ohms	15,000 ohms

MAXIMUM RATINGS

Triode section:
V_{ao} = max. 550 V
V_a = max. 300 V
W_a = max. 1.5 W
I_k = max. 10 mA
V_g ($I_g = +0.3$ μA) = max. —1.3 V
R_{gk} (automatic) = max. 3 M ohms
R_{gk} (fixed) = max. 1 M ohm
V_{fk} = max. 75 V [1]
R_{fk} = max. 20,000 ohms

Diode section:
V_{d_1} (peak value) = max. 200 V
I_{d_1} (D.C. value) = max. 0.8 mA
V_{d_2} (peak value) = max. 200 V
I_{d_2} (D.C. value) = max. 0.8 mA

[1]) Direct voltage or effective value of alternating voltage.

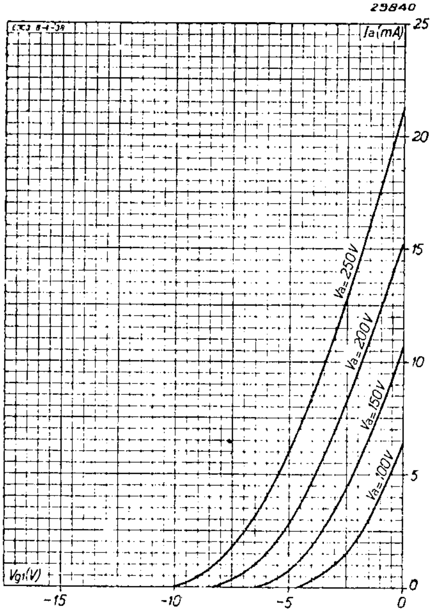

Fig. 3
Anode current as a function of the grid bias at different anode voltages.

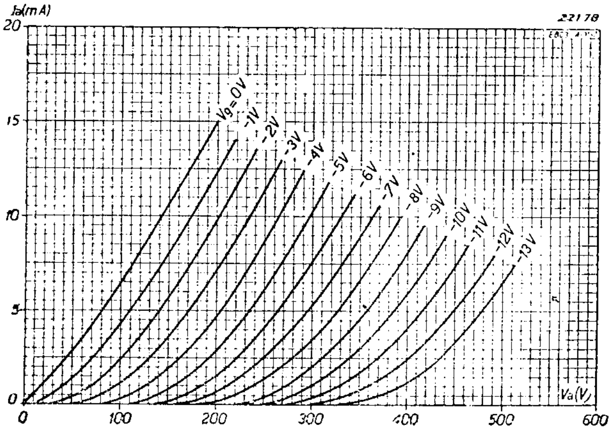

Fig. 4
Anode current as a function of the anode voltage at different values of grid bias.

The triode can also be employed as oscillator in conjunction with the variable-mu frequency-changer heptode EH 2.

To avoid feedback from the triode to the diodes, these two units are screened from each other, the screen being connected to the cathode. The metallizing is provided with a separate contact in the valve base.

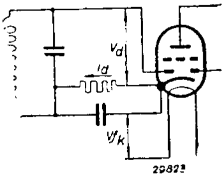

Fig. 5
Definition of *Vd* and *Id*

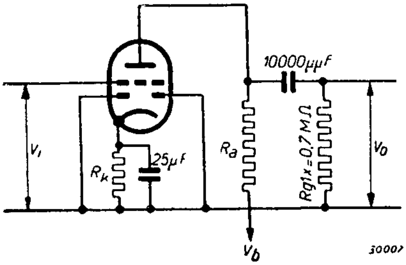

Fig. 6
Circuit upon which the measurements given in the table are based.

The diode shown as d_2 in the diagram of base connections (Fig. 2) should preferably be employed for detection. The other diode (d_1) can then serve for other purposes such as delayed automatic gain control. The curves relating to the rise in direct voltage (ΔV) across the grid leak, as a function of the unmodulated R.F. signal voltage, as well as that with respect to the increase in the A.F. voltage (V_{LF}) at one of the diodes with a grid leak of 0.5 M ohm, are the same as for the EB 4 (see Fig. 3, p. 22).

EBC 3 employed as A.F. amplifier, resistance-coupled to different output valves

Supply voltage Vb V	Anode coupling resistor Ra megohms	Anode current Ia mA	Cathode resistor Rk ohms	Voltage gain $\frac{Vo}{Vi}$	When used with the EL 2 as output valve $Va = Vg_2 = 250$ V		When used with the EL 3 or EL 6 as output valve $Va = Vg_2 = 250$		When used with the EL 5 as output valve $Va = 250$ V. $Vg_2 = 275$ V		When used with the AD 1 as output valve $Va = 250$ V		Remarks
					Alternating output voltage Vo $Veff$	Total distortion in the pre-amplifier $dtot$ %	Alternating output voltage Vo $Veff$	Total distortion in pre-amplifier $dtot$ %	Alternating output voltage Vo $Veff$	Total distortion in pre-amplifier $dtot$ %	Alternating output voltage Vo $Veff$	Total distortion in pre-amplifier $dtot$ %	
300	0.2	0.9	4,000	26	11.2	< 1	3.7	< 1	8.5	< 1	31	1.8	For receivers with heaters fed in parallel
250	0.2	0.75	4,000	26	11.2	< 1	3.7	< 1	8.5	< 1	31	2.2	
300	0.1	1.5	2,500	25	11.2	< 1	3.7	< 1	8.5	< 1	31	2.0	
250	0.1	1.3	2,500	25	11.2	< 1	3.7	< 1	8.5	< 1	31	2.6	
300	0.05	2.3	2,000	22	11.2	< 1	3.7	< 1	8.5	< 1	31	2.0	
250	0.05	1.8	2,000	22	11.2	< 1	3.7	< 1	8.5	< 1	31	2.6	
					When used with the CL 1 as output valve		When used with the CL 2 as output valve		When used with the CL 4 as output valve		When used with the EL 2 as output valve		
200 1)	0.2	0.35	12,500	22	9.6	1.7	10	1.8	5.0	1.0	8.5	1.6	For receivers with heaters fed in series
150 1)	0.2	0.25	12,500	21	—	—	10	2.7	4.0	1.0	6.5	1.7	
100 1)	0.2	0.20	12,500	19	—	—	10	4.6	2.4	1.0	—	-	
200 1)	0.1	0.55	8,000	21	9.6	2.1	10	2.3	5.0	1.2	8.5	1.8	
150 1)	0.1	0.45	8,000	20	—	—	10	3.0	4.0	1.2	6.5	1.8	
100 1)	0.1	0.30	8,000	18	—	—	10	4.9	2.4	1.2	—	—	
200 1)	0.05	0.8	6,000	19	9.6	3.0	10	3.2	5.0	1.5	8.5	2.6	
150 1)	0.05	0.6	6,000	18	—	—	10	4.3	4.0	1.6	6.5	3.0	
100 1)	0.05	0.4	6,000	17	—	—	10	7.0	2.4	1.6	—	—	

1) also anode voltage of the output valve.

EBF 2 Double-diode variable-mu pentode

This valve combines a pentode with two diodes, built round a common cathode. The pentode section has variable characteristics, sliding screen voltage having been adopted with a view to the use of the valve as an I.F amplifier; the anode current is accordingly low and the mutual conductance relatively high, but, since the cathode, which also serves the two diodes, is able to dissipate only 1.26 W, the slope is somewhat less than that of the EF 9. Without control (at — 2 V bias), the mutual conductance of the EBF 2 is 1.8 mA/V, which provides ample I.F. amplification.

The diode section is separated from the pentode by a very effective system of screening, to prevent any unwanted interaction between the two units. This combination of double diodes with an I.F. amplifier is very useful in all cases where an A.F. valve without diode is used, for example the EF 6, with or without feed-back.

The EBF 2 is particularly suitable for use in conjunction with the A.F. amplifier and electronic indicator EFM 1.

The latter arrangement permits of the design of a very simple receiver in which two valves do the work of I.F. amplifier and detector, at the same time producing the control voltage for automatic gain control, with A.F. amplification and electronic tuning indication.

Since both diodes are supplied by the same cathode as the pentode and, because the diode for the A.G.C. is delayed by the cathode potential of this valve, the delay voltage is limited, without the use of any special circuits, to the value of grid bias required by the pentode in the uncontrolled condition. By using special circuits it is possible to obtain a higher delay voltage for the A.G.C., but this merely tends to render the latter less effective.

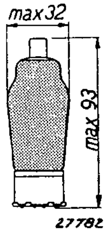

Fig. 1
Dimensions in mm.

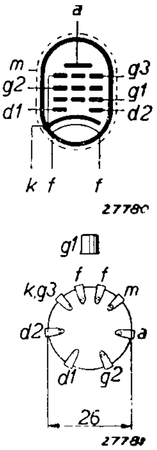

Fig. 2
Arrangement of electrodes and base connections.

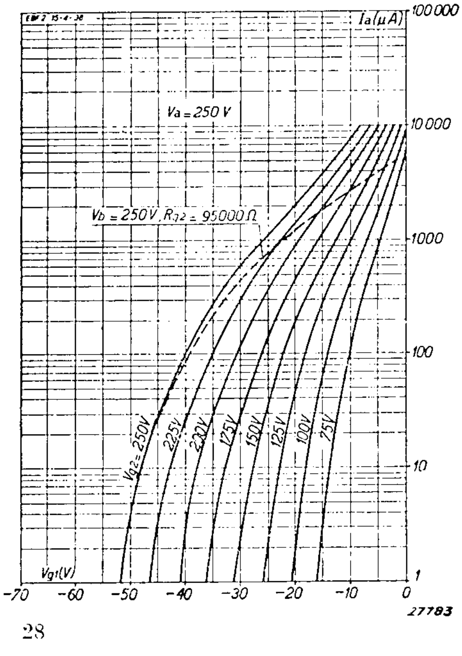

Fig. 3
Ia/Vg_1 characteristic of the EBF 2, with Vg_2 as parameter. The broken line shows the anode current of the controlled valve with a screen series resistor of 95000 ohms and a supply voltage of 250 V.

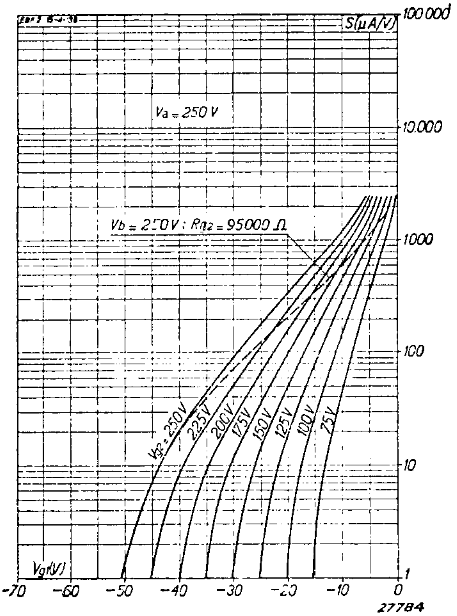

Fig. 4
S/Vg_1 characteristic of the EBF 2, with Vg_2 as parameter. The broken line gives the slope of the controlled valve with a screen series resistor of 95,000 ohms and a supply voltage of 250 V.

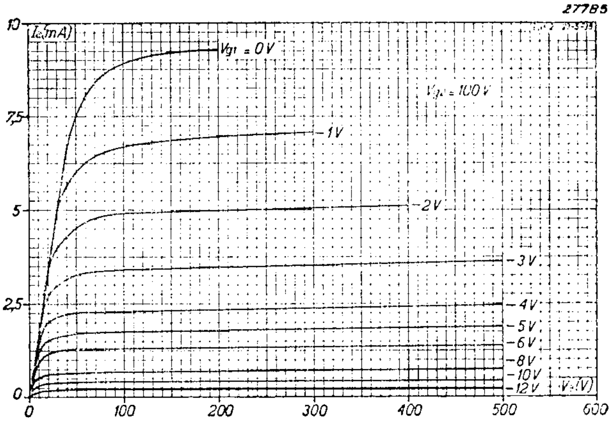

Fig. 5
Anode current as a function of the anode voltage at different values of grid bias and with a fixed screen potential of 100 V.

HEATER RATINGS

Heating: indirect, on A.C. or D.C.; series or parallel supply.

Heater voltage	$V_f = 6.3$ V
Heater current	$I_f = 0.200$ A

CAPACITANCES

$C_{ag_1} < 0.002$ μμF	$C_{(d_1+d_2)g_1} < 0.001$ μμF	$C_{d_2a} < 0.25$ μμF
$C_{g_1} = 4.4$ μμF	$C_{d_1k} = 3$ μμF	$C_{(d_1+d_2)a} < 0.4$ μμF
$C_a = 8.6$ μμF	$C_{d_2k} = 3$ μμF	$C_{g_1f} < 0.01$ μμF
$C_{d_1g_1} < 0.0005$ μμF	$C_{d_1d_2} < 0.3$ μμF	
$C_{d_2g_1} < 0.0005$ μμF	$C_{d_1a} < 0.3$ μμF	

OPERATING DATA: pentode section employed as I.F. amplifier

250 V

Anode voltage	V_a	= 250 V	
Screen-grid series resistor (at 250 V)	R_{g_2}	= 95,000 ohms	
Cathode (bias) resistor	R_k	= 300 ohms	
Grid bias	V_{g_1}	= —2 V ¹)	—38 V ²)
Screen voltage	V_{g_2}	= 100 V	250 V
Anode current	I_a	= 5 mA	—
Screen current	I_{g_2}	= 1.6 mA	—
Mutual conductance	S	= 1800 μA/V	18 μA/V
Internal resistance	R_i	= 1.3 M ohms	> 10 M ohms

200 V

Anode voltage	V_a	= 200 V	
Screen-grid series resistor (at 200 V)	R_{g_2}	= 60,000 ohms	
Cathode resistor	R_k	= 300 ohms	
Grid bias	V_{g_1}	= —2 V ¹)	—32.5 V ²)
Screen voltage	V_{g_2}	= 100 V	200 V
Anode current	I_a	= 5 mA	—
Screen current	I_{g_2}	= 1.6 mA	—
Mutual conductance	S	= 1800 μA/V	18 μA/V
Internal resistance	R_i	= 1 M ohm	> 10 M ohms

100 V

Anode voltage	V_a	= 100 V	
Screen-grid voltage	V_{g_2}	= 100 V	
Cathode resistor	R_k	= 300 ohms	
Grid bias	V_{g_1}	= —2 V ¹)	—16.5 V ²)
Anode current	I_a	= 5 mA	—
Screen current	I_{g_2}	= 1.6 mA	—
Mutual conductance	S	= 1800 μA/V	18 μA/V
Internal resistance	R_i	= 0.4 M ohm	> 10 M ohms

¹) valve not controlled.

²) Mutual conductance controlled to 1 : 100 and to limit of control.

MAXIMUM RATINGS

a) Pentode section

Anode voltage in cold condition	V_{ao}	= max. 550 V
Anode voltage	V_a	= max. 300 V
Anode dissipation	W_a	= max. 1.5 W
Screen-grid voltage in cold condition	V_{g2o}	= max. 550 V
Screen voltage at $I_a = 5$ mA	V_{g2}	= max. 125 V
Screen voltage at $I_a < 2$ mA	V_{g2}	= max. 300 V
Screen-grid dissipation	W_{g2}	= max. 0.3 W
Cathode current	I_k	= 10 mA
Grid voltage at grid current start ($I_{g1} = + 0.3\ \mu$A)	V_{g1}	= max. —1.3 V
Resistance between grid and cathode	R_{g1k}	= max. 3 M ohms
Resistance between filament and cathode	R_{fk}	= max. 20,000 ohms
Voltage between filament and cathode (direct voltage or effective value of alternating voltage)	V_{fk}	= max. 100 V

b) Diode section

Voltage on diode d_1 (peak value)	V_{d1}	= max. 200 V
Voltage on diode d_2 (peak value)	V_{d2}	= max. 200 V
Direct current to diode d_1	I_{d1}	= max. 0.8 mA
Direct current to diode d_2	I_{d2}	= max. 0.8 mA
Voltage on diode at diode current start ($I_{d1} = + 0.3\,\mu$A)	V_{d1}	= max. —1.3 V
Voltage on diode at diode current start ($I_{d2} = + 0.3\,\mu$A)	V_{d2}	= max. —1.3 V

APPLICATIONS

The EBF 2 is used mainly in I.F. stages with the two diodes serving as detector and for automatic gain control. The data and characteristics apply both to A.C. receivers operating on mains of about 250 V and A.C./D.C. sets on mains of approximately 200 or 100 volts. At mains voltages other than 250 or 200 V, the required screen potential can be calculated from the screen current of 1.6 mA and the potential difference between the supply voltage and the screen voltage of 100 V.

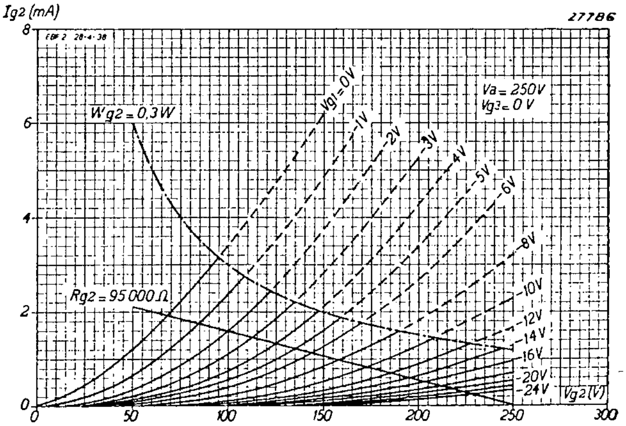

Fig. 6
Screen current as a function of the screen voltage at different values of grid bias. The curves apply roughly to all anode voltages between 100 and 250 V. The diagram also includes the limit line for the maximum continuous load on the screen and the resistance line with respect to a series resistor R_{g2} = 95,000 ohms, at 250 V supply voltage

The characteristics in Figs 3, 4, 7 and 8 relating to I_a and S will then be no longer fully applicable; at 100 V supply voltage the sliding-screen-potential principle is not valid and the screen must be maintained at 100 V. The modulation distortion curve is then certainly less satisfactory, but the valve is none the less quite effective as a normal A.F. amplifier, following a diode detector.

If a potential divider is used instead of a series resistor, careful adjustment of the resistance values will produce a more or less steep mutual conductance curve; the modulation distortion curve is then somewhat modified.

The bias resistor should be decoupled with an electrolytic capacitor of about 25 μF; if this is not done, the rectification, due to the curvature of the I_a/V_{g1} characteristic, produces an A.F. voltage which, when the volume control is turned down, would be applied to the grid of the A.F. amplifier valve. This involves a residual signal and makes it impossible to render the receiver mute.

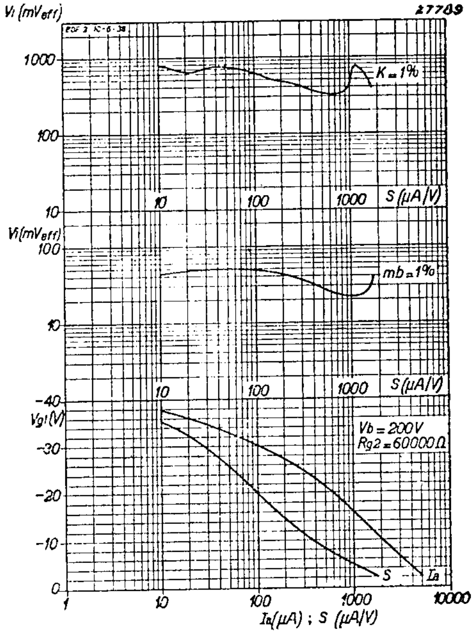

Fig. 8

Upper diagram. Effective alternating grid voltage as a function of the mutual conductance with 1 % cross modulation, with a screen series resistor of 60,000 ohms and a supply voltage of 200 V.

Centre diagram. Effective alternating grid voltage as a function of the mutual conductance with 1 % modulation hum.

Lower diagram. Mutual conductance S and anode current Ia as a function of the grid bias.

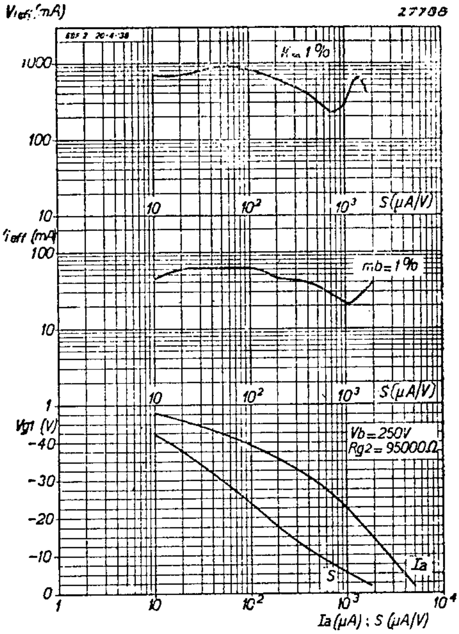

Fig. 7

Upper diagram. Effective alternating grid voltage as a function of the mutual conductance, with 1% cross modulation, a screen-grid series resistor of 95,000 ohms and a supply voltage of 250 V.

Centre diagram. Effective alternating grid voltage as a function of the mutual conductance, with 1 % modulation hum.

Lower diagram. Mutual conductance S and anode current Ia as a function of the grid bias.

Diode d_2 is preferably used for detection and diode d_1 as rectifier for the A.G.C. In the circuit diagram of Fig. 10 the A.G.C. diode receives its delay voltage from the cathode potential of the EBF 2. To ensure optimum amplification in the uncontrolled condition this voltage should always be kept as low as possible (according to the data it is about 2 V), whereby the A.F. amplification should be such that the strength of the signal on the A.G.C. diode is below the threshold of the delay, with a fully driven output valve.

At the same time, a lower A.F. gain may

be desired, or it may be impossible to obtain the high amplification referred to above, so that special steps have to be taken to provide a higher delay voltage for the A.G.C. if the latter is not to be operative on signals which are insufficient to drive the output valve fully. For the characteristics of the diode section, reference should be made to the relative curves for the EAB 1 and EB 4, which apply also to these valves.

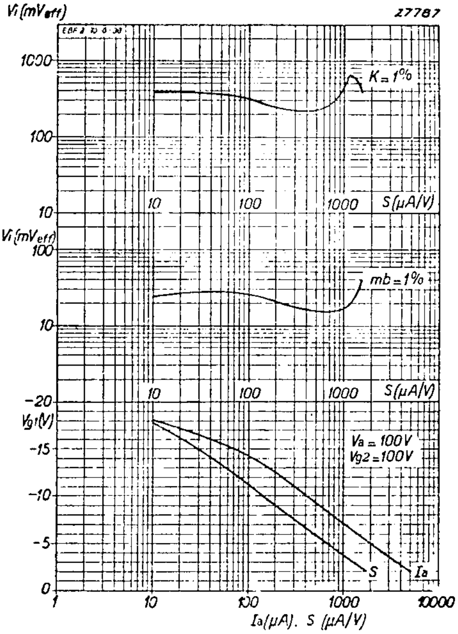

Fig. 9

Upper diagram. Effective alternating grid voltage as a function of the mutual conductance with 1 % cross modulation, at $Va = 100$ V; $Vg_2 = 100$ V (fixed screen potential).

Centre diagram. Effective alternating grid voltage as a function of the mutual conductance with 1 % modulation hum.

Lower diagram. Mutual conductance S and anode current Ia as a function of the grid bias.

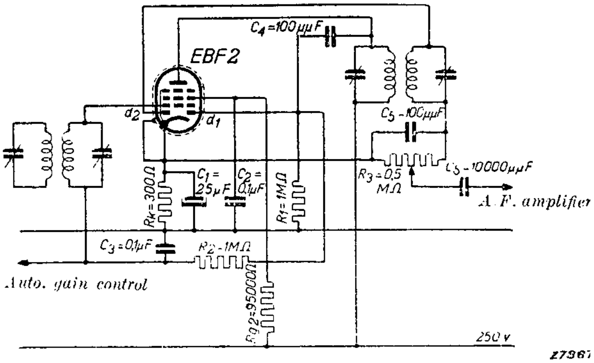

Fig. 10

Circuit diagram showing the EBF 2 employed as I.F. amplifier. Diode d_2 is used for detection and diode d_1 as rectifier for the A.G.C.

EBL 1 Double-diode output pentode

The EBL 1 is a combination of double-diode and steep-slope, 9 W output pentode, in one envelope and sharing a common cathode. The characteristics of the pentode unit place this valve among the high-mutual-conductance pentodes and it may be used in the construction of very low-priced receivers, for instance of the superheterodyne type, having a limited number of valves and which, without a stage of A.F. amplification, will nevertheless give a reasonably high output.

The two diodes are mounted below the pentode section opposite to the cathode, in such a way that the two anodes, which are not completely semi-cylindrical, are located at the same height on the mount; the diodes are therefore electrically identical. A screen separates the diode section from the pentode unit and, to prevent the grid of the latter from being affected in any way by the diodes, the grid connection is brought out at the top of the envelope.

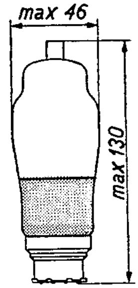

Fig. 1
Dimensions in mm

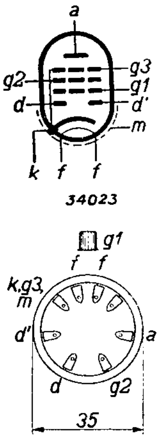

Fig. 2
Arrangement of electrodes and base connections.

HEATER RATINGS

Heating: indirect, A.C. or D.C., parallel supply.
Heater voltage . . . . $V_f = 6.3$ V
Heater current . . . . $I_f = 1.18$ A

CAPACITANCES

$C_{ag1} < 0.8$ μμF
$C_{d1a} < 0.2$ μμF
$C_{d2a} < 0.2$ μμF
$C_{d1g1} < 0.08$ μμF
$C_{d2g1} < 0.08$ μμF
$C_{d1k} = 3.5$ μμF
$C_{d2k} = 3.5$ μμF
$C_{d1d2} < 0.25$ μμF

OPERATING DATA

Anode voltage . . . . V_a = 250 V
Screen-grid voltage . . . . V_{g2} = 250 V
Cathode resistor . . . . R_k = 150 ohms
Grid bias . . . . V_{g1} = —6 V
Anode current . . . . I_a = 36 mA
Screen current . . . . I_{g2} = 4 mA
Mutual conductance at the working point . . . . . S = 9 mA/V
Internal resistance . . . . R_i = 50,000 ohms
Load resistor . . . . R_a = 7,000 ohms
Output with 10 % distortion . . . . W_o = 4.5 W
Alternating grid voltage for $W_o = 4.5$ W . . . . . V_i = 4.2 V_{eff}
Sensitivity ($W_o = 50$ mW) . . . . V_i = 0.35 V_{eff}

MAXIMUM RATINGS

Pentode section:

V_{ao} = max. 550 V
V_a = max. 250 V
W_a = max. 9 W
I_k = max. 55 mA
V_{g2o} = max. 550 V
V_{g2} = max. 260 V

W_{g2} ($V_i = 0$) = max. 1.2 W
W_{g2} (W_o = max.) = max. 2.5 W
V_{g1} ($I_{g1} = + 0.3\ \mu$A) = max. —1.3 V
R_{g1k} = max. 1 M ohm
R_{fk} = max. 5,000 ohms
V_{fk} = max. 50 V [1])

Diode section:

Voltage on diode (peak value) $V_d = V_d'$ = max. 200 V
Diode current $I_d = I_d'$ = max. 0.8 mA
(direct current through the grid leak)
Voltage on diode at diode current start ($I_d = + 0{,}3\ \mu$A) V_d = max. —1.3 V
Voltage on diode at diode current start ($I_d' = + 0.3\ \mu$A) V_d' = max. —1.3 V

---

[1]) Direct voltage or effective value of alternating voltage.

The curves relating to the increase in the direct voltage (Δ V) across the grid leak, as a function of the unmodulated R.F. voltage, as well as for the A.F. voltage (V_{LF}) across the grid leak as plotted against the 30 % modulated R.F. voltage on one of the diodes (0.5 M ohm grid leak) are the same as for the EB 4.

Grid bias must be obtained by means of a cathode resistor only; semi-automatic bias may be employed provided that the cathode current is more than 50 % of the total current passing through the biasing resistor. Leads to the valve connections should be as short as possible and it is essential to include a resistor of about 1000 ohms in the control-grid lead.

A stage of audio-frequency amplification between one of the diodes as detector and the output valve may possibly give rise to hum and oscillation, for which reason the gain between that diode and the pentode should not exceed a factor of 15; this may be obtained by using the EBC 3 as pre-amplifier with slight negative feed-back.

The characteristics of the EL 3 relating to output power, having regard to the voltage drop across the output transformer, apply also to the EBL 1.

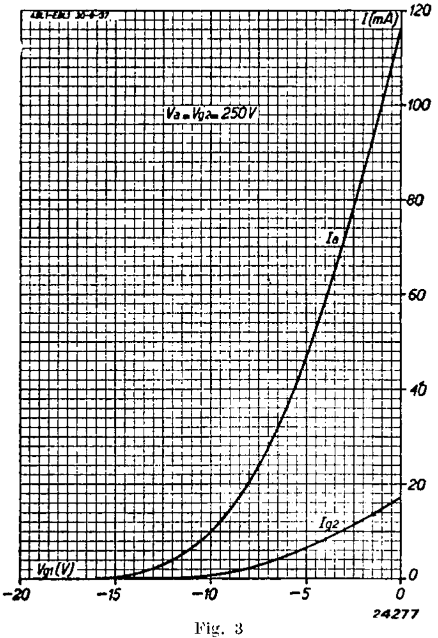

Fig. 3
Anode current and screen-grid current as a function of the grid bias at $V_a = V_{g2} = 250$ V.

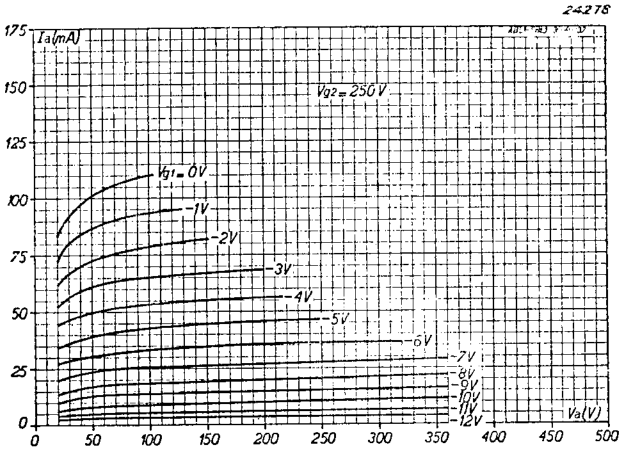

Fig. 4
Anode current as a function of the anode voltage at V_{g_2} = 250 V and at different values of grid bias.

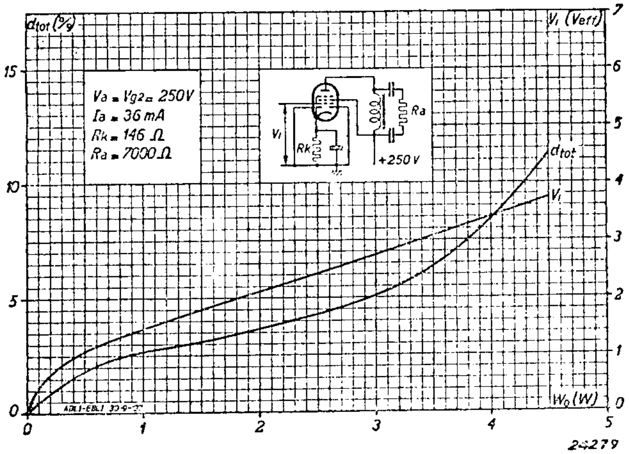

Fig. 5
Alternating grid voltage (V*i*) and total distortion *dtot* as a function of the output power of the EBL1 used as a Class A output valve

ECH 3 Triode hexode

The ECH 3 is a variable-mu frequency-changer, constructed on the principle of the triode-hexode and thus consisting of a hexode — the frequency-changer proper — and a triode to function as oscillator. Both units are mounted round a common cathode, of which the heater power is 1.26 W. The heater current at 6.3 V is 200 mA, which makes the valve suitable for A.C. receivers with their heaters in parallel, as well as for A.C./D.C. sets with the heaters in series, in a 200 mA circuit. The first grid of the hexode is wound with varying pitch; this grid carries the R.F. signal and the control voltage for the automatic gain control. Grids 2 and 4 are screen grids, whilst grid 3 is connected directly to the control grid of the triode section and therefore carries the alternating oscillator voltage.

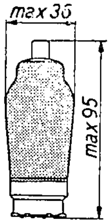

Fig. 1
Dimensions in mm.

Although the heater current of this valve is only small, very high conversion amplification is possible; on 250 V anode and 100 V screen, it is 650 μA/V, without control, the internal resistance being 1.3 M ohms.

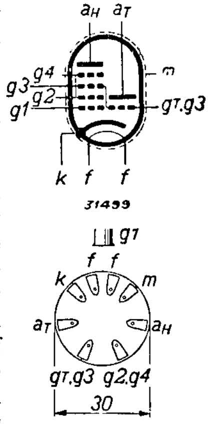

Fig. 2
Arrangement of electrodes and base connections.

The ECH 3 is eminently suitable for short-wave reception with controlled mutual conductance, without too much frequency drift; the drift is very slight when occasioned by mains voltage fluctuations. If the tuned oscillator circuit is connected to the anode, with the feedback coil in the grid circuit, the frequency drift arising from mains fluctuations of 10 % will be less than 1 kc/s at 15 m: at this wavelength, with a tuning capacitance of 50 $\mu\mu$F in the oscillator circuit and full control applied to the grid, the drift is less than 2 kc/s. The relatively low input and output capacitances of this valve are also favourable features from the aspect of short-wave work.

Due to the hexode principle employed in this valve, there is no electronic coupling between the oscillator grid (grid 3) and the R.F. grid (grid 1). Grid 3, however, has a certain capacitance with respect to grid 1, so that on very short waves (13 m) an alternating voltage of about 0.5 V exists at the grid, although this has very little effect on the conversion conductance. Because of the high mutual conductance of the hexode unit and the rapid decrease in the slope in respect of the first grid when the negative voltage on grid 3 (see Fig. 21) is increased, it is possible to obtain very high conversion conductance in the uncontrolled condition; moreover, the alternating oscillator voltage need be only very small. The effective alternating oscillator voltage for

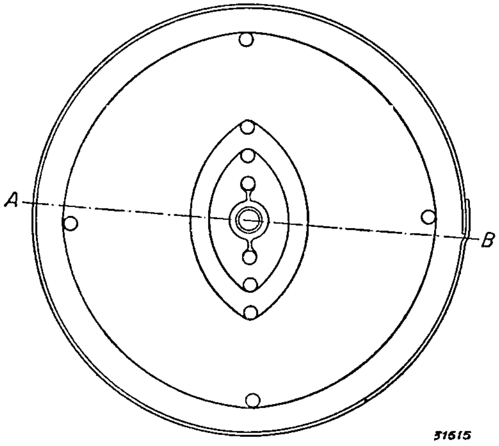

Fig. 3
Cross-section of the system of electrodes in the hexode unit.

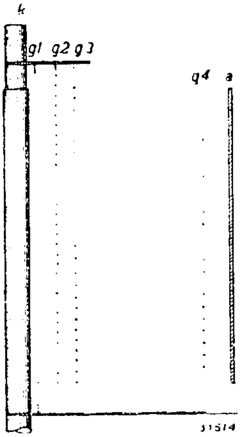

Fig. 4
Vertical cross-section through the system of electrodes of the hexode (see A–B, Fig.3).

good results is only 8 V, which can be developed in the triode section of the valve without any difficulty by means of standard coils.

However, at lower oscillator voltages the conversion conductance is still quite high, being about 580 μA/V at 5 V (see Fig. 9), so that satisfactory conversion amplification is also possible on short waves. At very much higher oscillator voltages than 8 V the conversion conductance deviates only slightly from the optimum value; the conductance, and also the amplification, therefore, vary only to a small degree as a result of wide fluctuations in the oscillator voltage within the wave-range. The value of 8 V (200 μA passing through the grid leak of 50.000 ohms) gives a satisfactory compromise between background noise, whistles and the desired conversion conductance. With a view to the control and prevention of cross-modulation, the ECH 3 is designed for potential-divider feeding of the screen grid. Although from the aspect of economy a screen series resistor would take less current, this involves one great disadvantage in that the potential of the screen in that case increases to such an extent with rises in the control voltage that it approaches that of the anode. At higher screen-grid voltages, however, secondary electrons emitted by the anode are attracted by the screen grid, with the result that the internal resistance

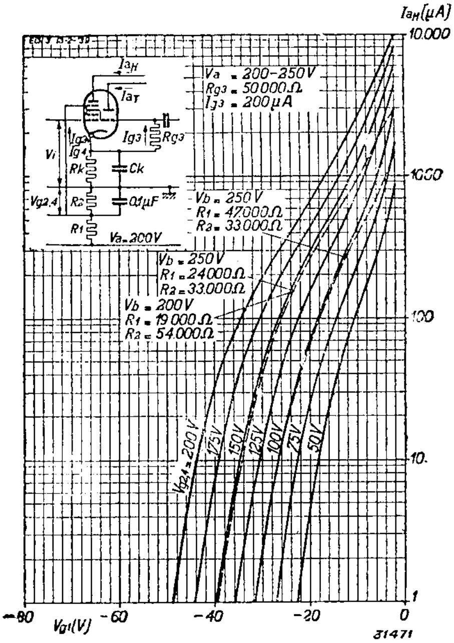

Fig. 5
Anode current of the hexode unit as a function of the grid bias, at different screen potentials with an anode voltage of 200 to 250 V.

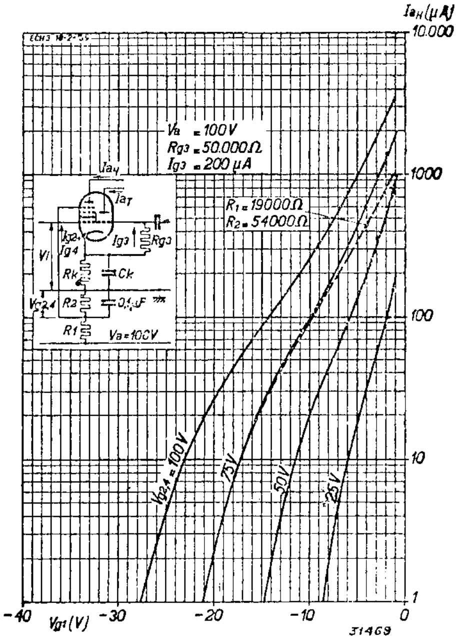

Fig. 6
Anode current of the hexode unit as a function of the grid bias, at different screen potentials, with an anode voltage of 100 V.

is greatly reduced. Consequently, when the control is in operation the selectivity of the band-pass filter in the anode circuit also suffers. A correct choice of resistances for the potential-divider network will place a limit on the increase in screen voltage and thus avoid any alteration in the internal resistance of the valve; the control on the amplification can also be made to operate more slowly or rapidly by a judicious arrangement of the values of the resistances in this network.

Adjustment of the conversion conductance may be fairly rapid, and the characteristics with regard to cross-modulation are very good throughout the whole range of control (see Figs 15 to 20).

HEATER RATINGS

Heating: indirect, A.C. or D.C., series or parallel supply.

Heater voltage	V_f	= 6.3 V
Heater current	I_f	= 0.200 A

CAPACITANCES

a) Hexode section	b) triode section	c) between hexode and triode
C_{g1} = 4.9 $\mu\mu$F	C_g = 8.8 $\mu\mu$F	C_{gTg1H} < 0.3 $\mu\mu$F
C_a = 9.0 $\mu\mu$F	C_a = 4.4 $\mu\mu$F	
C_{ag1} < 0.003 $\mu\mu$F	C_{ag} = 1.4 $\mu\mu$F	
C_{g1f} < 0.001 $\mu\mu$F		

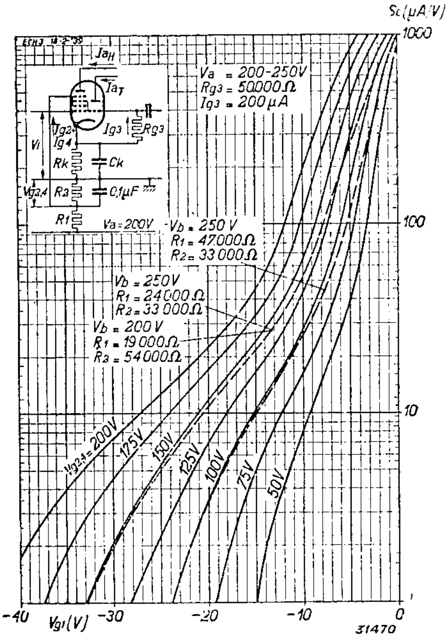

Fig. 7
Conversion conductance *Sc* as a function of the grid bias Vg_1 at different screen-grid voltages and for an anode voltage of 200–250 V.

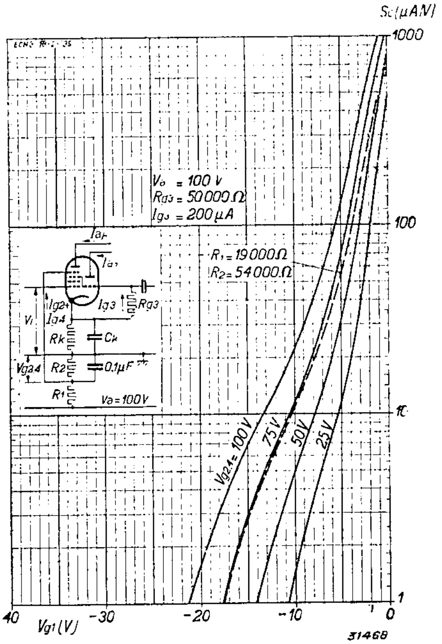

Fig. 8
Conversion conductance *Sc* as a function of the grid bias Vg_1 at different screen voltages and for an anode voltage of 100 V.

OPERATING DATA (hexode section employed as frequency-changer)

a) FIXED SCREEN VOLTAGE

Anode voltage V_a	200 V			250 V		
Screen-grid voltage $V_{g2,4}$	100 V			100 V		
Cathode resistor R_k	215 ohms			215 ohms		
Oscillator-grid leak R_{g3}	50,000 ohms			50,000 ohms		
Oscillator-grid current I_{g3}	200 μA			200 μA		
Grid bias (grid 1) V_{g1}	-2 V 1)	-17 V 2)	-23 V 1)	-2 V 2)	-17 V 2)	-23 V 3)
Anode current I_a	= 3 mA	—	—	3 mA	—	—
Screen-grid current $I_{g2} + I_{g4}$	= 3 mA	—	—	3 mA	—	—
Conversion conductance S_c	= 650 μA/V	6.5	1.5	650 μA/V	6.5	1.5
Internal resistance R_i	= 0.9	> 5	> 5	1.3	> 5	> 6 M ohms

1) Without control 2) Conversion conductance reduced to one-hundredth of uncontrolled value
3) Extreme limit of control

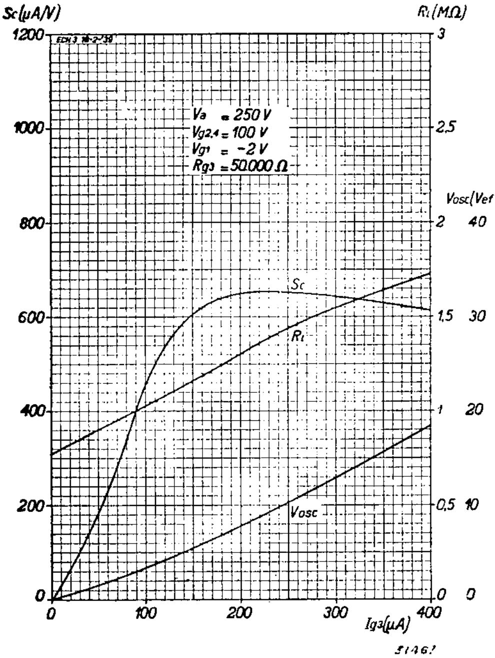

Fig. 9
Conversion conductance Sc, internal resistance Ri and alternating oscillator voltage $Vosc$ as a function of the oscillator grid current Ig_3, at $Va = 250$ V, $Rg_3 = 50{,}000$ ohms and with fixed screen voltage of 100 V.

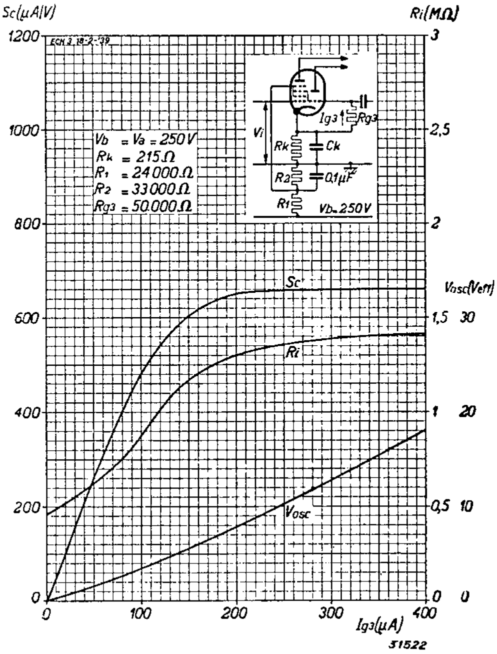

Fig. 10
Conversion conductance Sc, internal resistance Ri and alternating oscillator voltage $Vosc$ as a function of the oscillator-grid current Ig_3, at $Va = 250$ V, $Rg_3 = 50{,}000$ ohms and with screen fed from a potential divider of 24,000 + 33,000 ohms (normal operation).

b) SCREEN FED FROM A POTENTIAL DIVIDER (normal operation) (current passing through the potential divider itself: 3 mA).

Supply or anode voltage	$V_b = V_a$	250 V		
Resistance of potential divider (see Fig. 28)	R_1	24,000 ohms		
Resistance of potential divider (see Fig. 28)	R_2	33,000 ohms		
Cathode resistor	R_k	215 ohms		
Oscillator grid leak	R_{g3}	50,000 ohms		
Grid bias (grid 1)	V_{g1}	—2 V [1]	—23.5 V [2]	—31 V [3]
Screen-grid voltage	$V_{g2,4}$	100 V	—	145 V
Anode current	I_a	3 mA	—	—
Screen-grid current	$I_{g2} + I_{g4}$	3 mA	—	—
Conversion conductance	S_c	650 μA/V	6.5 μA/V	1.5 μA/V
Internal resistance	R_i	1.3 M ohms	> 3 M ohms	> 4 M ohms

[1] Without control [2] Conversion conductance reduced to one-hundredth of uncontrolled v a.
[3] Extreme limit of control

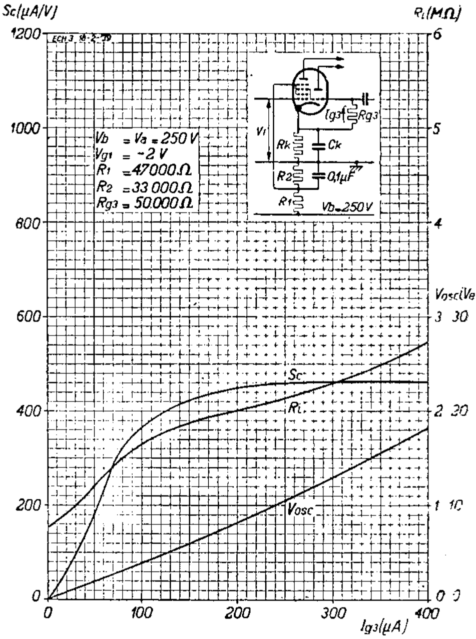

Fig. 11
Conversion conductance S_c, internal resistance R_i and alternating oscillator voltage V_{osc} as a function of the oscillator-grid current I_{g3} at V_a = 250 V, R_{g3} = 50,000 ohms and with screen fed from a potential divider of 47,000 + 33,000 ohms (noise-free operation).

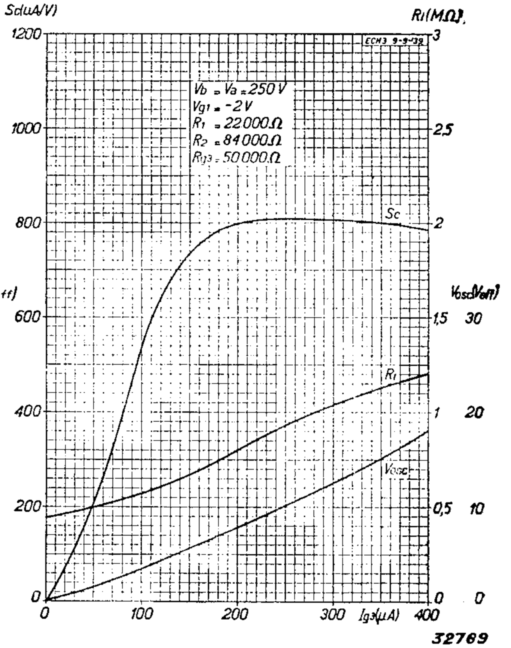

Fig. 12
Conversion conductance S_c, internal resistance R_i and alternating oscillator voltage V_{osc} as a function of the oscillator-grid current I_{g3}, at V_a = 250 V, R_{g3} = 50,000 ohms and with screen fed from a potential divider of 22,000 + 84,000 ohms (optimum setting from the point of view of freedom from cross-modulation).

c) ARRANGEMENT FOR LEAST POSSIBLE BACKGROUND NOISE; SCREEN GRID FED FROM A POTENTIAL DIVIDER (current passing through the potential divider itself: 2.1 mA).

Supply or anode voltage	$V_b = V_a$	=	250 V		
Resistance of the potential divider (see Fig. 28)	R_1	=	47,000 ohms		
Resistance of the potential divider (see Fig. 28)	R_2	=	33,000 ohms		
Cathode resistor	R_k	=	310 ohms		
Oscillator-grid leak	R_{g3}	=	50,000 ohms		
Oscillator-grid current	I_{g3}	=	200μA		
Grid bias (grid 1).	V_{g1}	=	—2 V ¹)	—19 V ²)	—23 V ³)
Screen-grid voltage	$V_{g2,4}$	=	70 V	—	100 V
Anode current	I_a	=	1.5 mA	—	—
Screen current	$I_{g2} + I_{g4}$	=	1.6 mA	—	—
Conversion conductance	S_c	=	450 μA/V	4.5 μA/V	1.5 μA/V
Internal resistance	R_i	=	2 M ohms	> 5 M ohms	> 6 M ohms

¹) Without control ²) Conversion conductance reduced to one-hundredth of uncontrolled value. Extreme limit of control

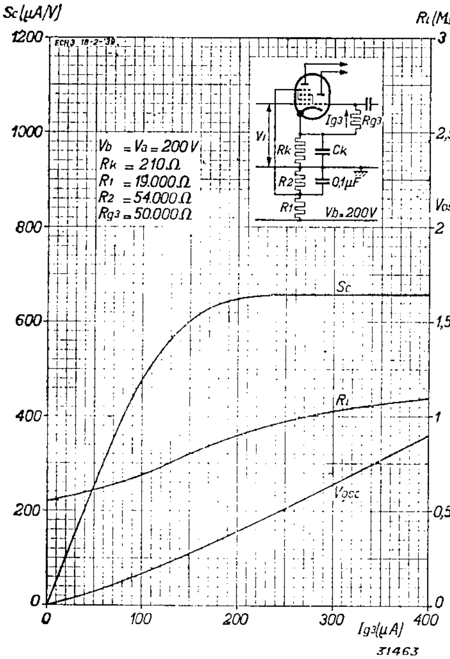

Fig. 13
Conversion conductance *Sc*, internal resistance *Ri* and alternating oscillator voltage *Vosc* as a function of the oscillator grid current I_{g3}, at $Va = 200$ V, $Rg_2 = 50{,}000$ ohms and with screen fed from a potential divider of 19,000 + 54,000 ohms (for receivers with switch for A.C. or D.C.).

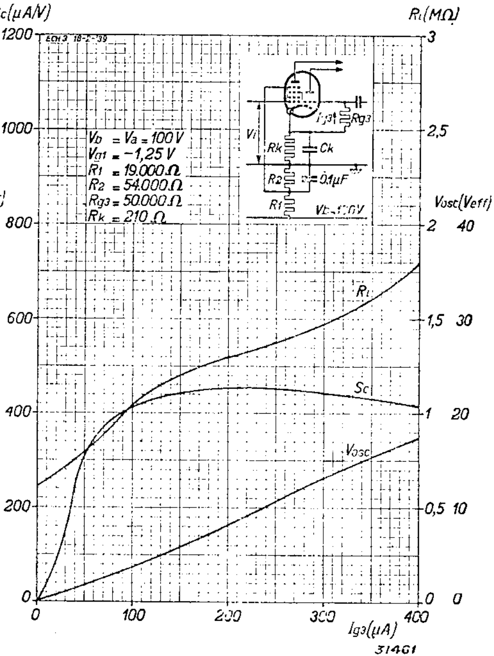

Fig. 14
Conversion conductance *Sc*, internal resistance *Ri* and alternating oscillator voltage *Vosc* as a function of the oscillator-grid current I_{g3}, at $Va = 100$ V, $Rg_3 = 50{,}000$ ohms and with screen fed from a potential divider of 19,000 + 54,000 ohms (for receivers with switch for A. C. or D.C.).

d) OPTIMUM SETTING FROM THE POINT OF VIEW OF CROSS-MODULATION; SCREEN GRID FED FROM A POTENTIAL DIVIDER (current passing through the potential divider itself 1.5 mA).

Supply or anode voltage	$V_b = V_a$	=	250 V		
Resistance of the potential divider (see Fig. 28) . . .	R_1	=	22,000 ohms		
Resistance of the potential divider (see Fig. 28) . . .	R_2	=	84,000 ohms		
Cathode resistor	R_k	=	165 ohms		
Oscillator-grid leak	R_{g3}	=	50,000 ohms		
Oscillator-grid current	I_{g3}	=	200 μA		
Grid bias (grid 1)	V_{g1}	=	—2 V ¹)	—28.5 V ²)	—40 V ³)
Screen-grid voltage	$V_{g2,4}$	=	125 V	—	200 V
Anode current	I_a	=	4.5 mA	—	—
Screen-grid current	$I_{g2} + I_{g4}$	=	4.3 mA	—	—
Conversion conductance . . .	S_c	=	800 μA/V	8 μA/V	1.5 μA/V
Internal resistance	R_i	=	0.8 M ohm	< 0.8 M ohm	< 1.1 M ohms

¹) Without control ²) Conversion conductance reduced to one-hundredth of uncontrolled value.
³) Extreme limit of control

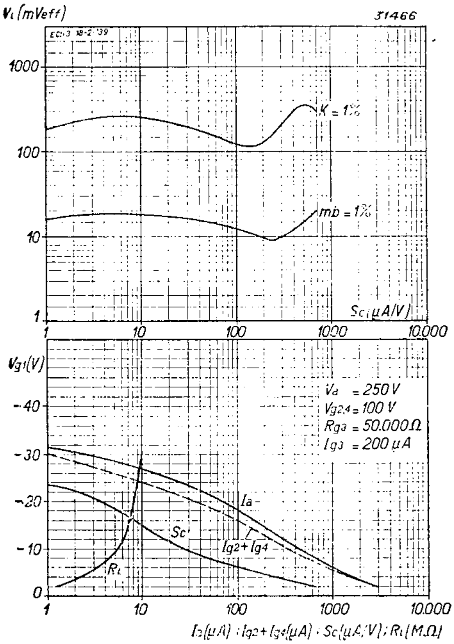

Fig. 15
At V_a = 250 V and with fixed screen-grid voltage of 100 V:
Upper diagram. Permissible R.F. voltage at 1 % cross-modulation (K = 1 %) and permissible alternating voltage of the interfering signal on the grid, with 1 % modulation hum (mb = 1 %), as a function of the conversion conductance. *Lower diagram.* Anode current Ia, screen-grid current $Ig_2 + Ig_4$, conversion conductance Sc and internal resistance Ri as a function of the bias on grid 1.

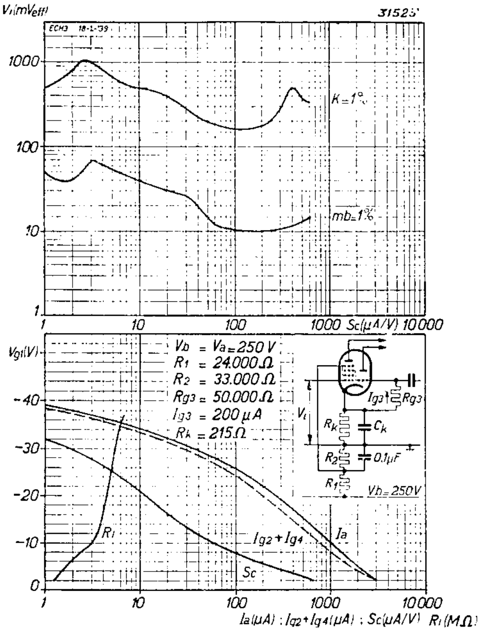

Fig. 16
At V_a = 250 V and with screen fed from a potential divider of 24,000 + 33,000 ohms (normal setting):
Upper diagram. Permissible R.F. voltage at 1 % cross-modulation (K = 1 %) and permissible alternating voltage of the interfering signal on the grid at 1 % modulation hum (mb = 1 %), as a function of the conversion conductance. *Lower diagram.* Anode current Ia, screen-grid current $Ig_2 + Ig_4$, conversion conductance Sc and internal resistance Ri as a function of the bias on grid 1.

e) FOR A.C./D.C. RECEIVERS; SCREEN GRID FED FROM A POTENTIAL DIVIDER (current passing through the potential divider itself: at $V_b = 200$ V, 1.85 mA, at $V_b = 100$ V, 1 mA).

Supply or anode voltage $V_b = V_a =$	100 V			200 V		
Resistance of potential divider (see Fig. 28) $R_1 =$	19,000 ohms			19,000 ohms		
Resistance of potential divider (see Fig. 28) $R_2 =$	54,000 ohms			54,000 ohms		
Cathode resistor $R_k =$	210 ohms			210 ohms		
Oscillator-grid leak $R_{g3} =$	50,000 ohms			50,000 ohms		
Oscillator-grid current $I_{g3} =$	200 μA			200 μA		
Bias on grid 1 $V_{g1} =$	—1.25 V1)	—13.5 V2)	—16.5 V3)	—2 V1)	—23.5 V2)	—31 V3)
Screen voltage $V_{g2,4} =$	55 V	—	75 V	100 V	—	145 V
Anode current $I_a =$	1 mA	—	—	3 mA	—	—
Screen current $I_{g2} + I_{g4} =$	1.4 mA	—	—	3 mA	—	—
Conversion conductance $S_c =$	450 μA/V	4.5 μA/V	1.5 μA/V	650 μA/V	6.5 μA/V	1.5 μA/V
Internal resistance $R_i =$	1.3 M ohms	$>$ 4 M ohms	$>$ 5 M ohms	0.9 M ohms	$>$ 2 M ohms	$>$ 2.5 M ohms

1) Without control 2) Conversion conductance reduced to one-hundredth of uncontrolled value.
3) Extreme limit of control

OPERATING DATA: Triode section employed as oscillator

Supply voltage	$V_b =$	100 V	150 V	250 V
Anode load resistor	$R_a =$	—	—	45,000 ohms
Anode current under oscillation ($R_g = 50{,}000$ ohms, $I_g = 200$ μA). .	$I_a =$	3.3 mA	8 mA	3.3 mA
Anode current at commencement of oscillation ($V_{osc} = 0$)	$I_a =$	10 mA	18 mA	6.3 mA
Mutual conductance at commencement of oscillation ($V_{osc} = 0$)	$S_o =$	2.8 mA/V	3.8 mA/V	2.8 mA/V
Amplification factor ($V_g = 0$ V; $V_{osc} =$ 0 V).	$\mu =$	24	24	24

MAXIMUM RATINGS for the hexode section

Anode voltage in cold condition . . . . V_{ao} = max. 550 V
Anode voltage . . . . V_a = max. 300 V
Anode dissipation . . . . W_a = max. 1.2 W
Screen voltage in cold condition . . . . V_{g2o} = max. 550 V
Screen voltage ($I_a = 4.5$ mA) . . . . V_{g2} = max. 125 V
Screen voltage ($I_a < 0.5$ mA) . . . . V_{g2} = max. 200 V
Screen dissipation . . . . W_{g2} = max. 0.6 W
Grid voltage at grid current start ($I_{g1} = + 0.3\,\mu$A) V_{g1} = max. —1.3 V
Grid voltage at grid current start ($I_{g3} = + 0.3\,\mu$A) V_{g3} = max. —1.3 V
Cathode current . . . . I_k = max. 15 mA
External resistance in circuit, grid 1 . . . . R_{g1k} = max. 3 M ohms
External resistance in circuit, grid 3 . . . . R_{g3k} = max. 100,000 ohms
External resistance between heater and cathode . . R_{fk} = max. 20,000 ohms
Voltage between heater and cathode (direct voltage or effective value of alternating voltage) . . . V_{fk} = max. 100 V

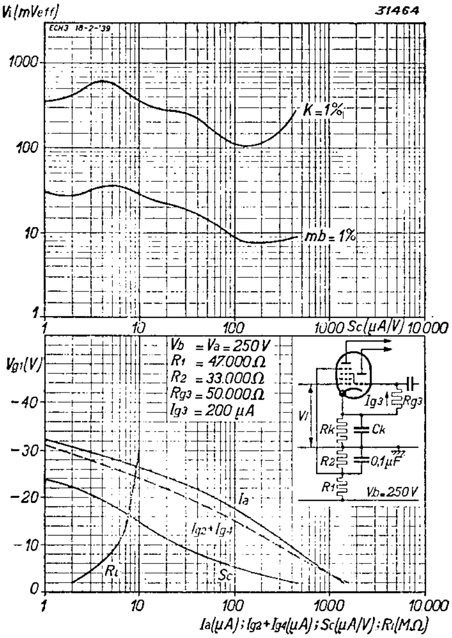

Fig. 17

At $Va = 250$ V, with screen fed from a potential divider of 47,000 + 33,000 ohms (noise-free setting).

Upper diagram. Permissible R.F. voltage with 1 % cross-modulation ($K = 1$ %) and permissible alternating voltage of the interfering signal on the grid with 1 % modulation hum ($mb = 1$ %), as a function of the conversion conductance.

Lower diagram. Anode current Ia, screen current $Ig_2 + Ig_4$, conversion conductance Sc and internal resistance Ri as a function of the bias on grid 1.

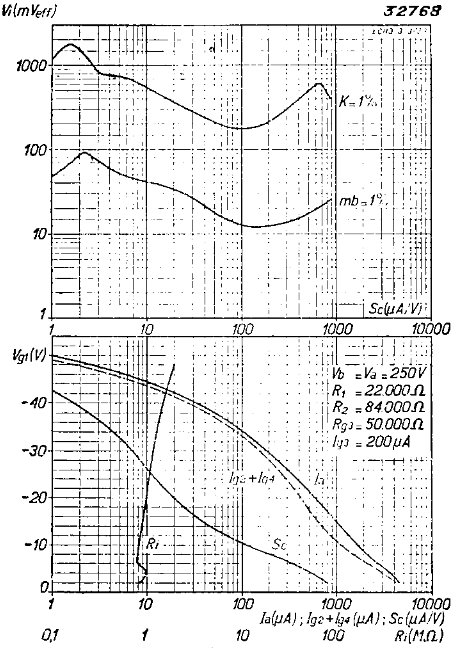

Fig. 18

At $Va = 250$ V with screen fed from a potential divider of 22,000 + 84,000 ohms (for freedom from appreciable cross-modulation).

Upper diagram. Permissible R.F. voltage with 1 % cross-modulation ($K = 1$ %) and permissible alternating voltage of the interfering signal on the grid with 1 % modulation hum ($mb = 1$ %), as a function of the conversion conductance.

Lower diagram. Anode current Ia, screen current $Ig_2 + Ig_4$, conversion conductance Sc and internal resistance Ri as a function of the bias on grid 1.

MAXIMUM RATINGS for the triode section

Anode voltage in cold condition	V_{ao}	= max. 550 V
Anode voltage	V_a	= max. 150 V
Anode dissipation	W_a	= max. 1.5 W
Grid voltage at grid current start (I_g = + 0.3 μA)	V_g	= max. —1.3 V
External resistance in the grid circuit	R_{gk}	= max. 100,000 ohms

The triode oscillates very freely, owing to its high mutual conductance, and, since it is also brought into oscillation easily, the reaction can with advantage be fairly loose. A grid leak of 50,000 ohms is recommended and a grid capacitor of 50 $\mu\mu$F is satisfactory; these values can be maintained on all wave-ranges.

In order to limit possible frequency drift and "pulling" of the oscillator tuning by the R.F. circuit, it is advisable to incorporate the tuned oscillator circuit in the anode circuit of the triode section. If the tuned circuit is connected to the grid circuit, the frequency drift is about twice as much as in the former case. The alternating voltage at the oscillator frequency occurring in the input circuit due to the capacitance C_{g1g3}

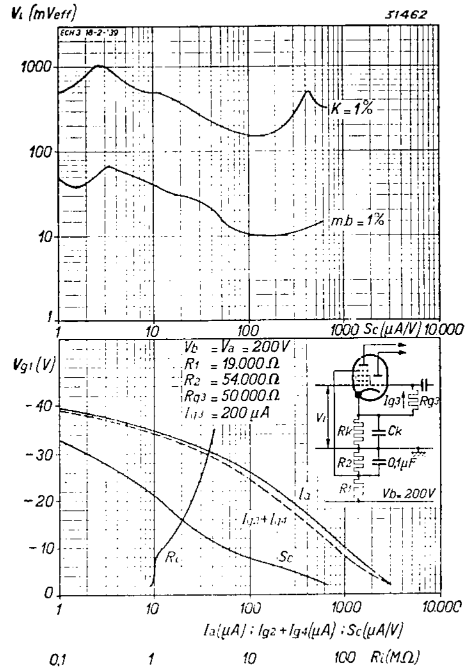

Fig. 19

At *Va* = 200 V, with screen fed from a potential divider of 19,000 + 54,000 ohms (for receivers with switch for A.C. or D.C.).

Upper diagram Permissible effective R.F. voltage at 1 % cross modulation (K = 1 %) and permissible alternating voltage of the interfering signal on the grid at 1 % modulation hum (*mb* = 1 %), as a function of the conversion conductance.

Lower diagram. Anode current *Ia*, screen voltage $Ig_2 + Ig_4$, conversion conductance *Sc*, and internal resistance *Ri* as a function of the bias on grid 1

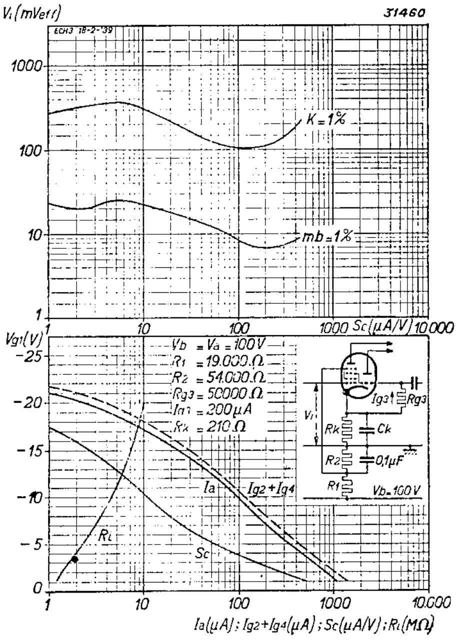

Fig. 20

At *Va* = 100 V, with screen fed from a potential divider of 19,000 + 54,000 ohms (for receivers with switch for A.C. of D.C.).

Upper diagram. Permissible R.F. voltage at 1 % cross modulation (K = 1 %) and permissible alternating voltage of the interfering signal on the grid at 1 % modulation hum (*mb* = 1 %), as a function of the conversion conductance.

Lower diagram. Anode current *Ia*, screen current $Ig_2 + Ig_4$, conversion conductance *Sc* and internal resistance *Ri*, as a function of the bias on grid 1.

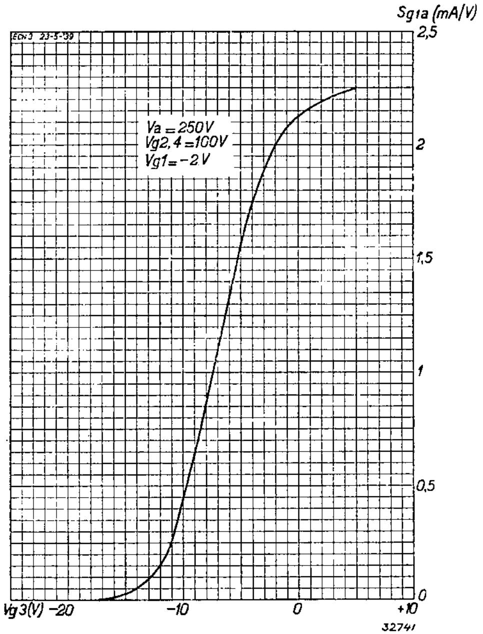

Fig. 21
Grid-current slope S_{g_1a} as a function of the grid bias.

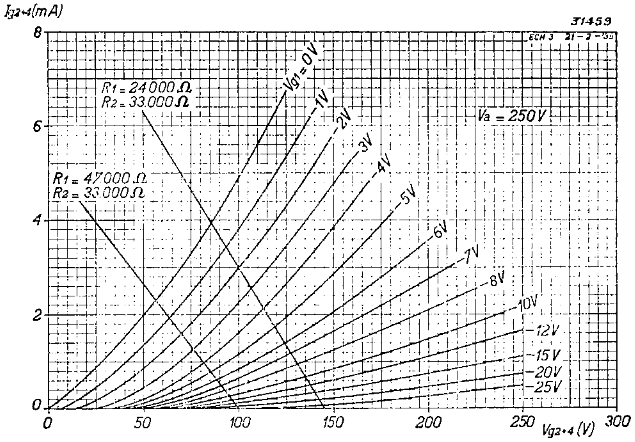

Fig. 22
Screen-grid current $I_{g_2} + I_{g_4}$ as a function of the screen voltage $V_{g_{2,4}}$ at various values of grid bias V_{g_1}

augments or decreases the conversion conductance according as the oscillator frequency is higher or lower than the input frequency, and it is therefore advisable, on the short wave ranges, to employ a higher oscillator frequency than the input frequency. Fig. 28 shows the theoretical circuit diagram of the ECH 3 employed as frequency-changer. The oscillator circuit may be parallel-fed in the usual manner, in which case the resistor in series with the anode should be about 30,000 ohms with a supply voltage V_b = 250 V; the coupling capacitor should be between 50 and 500 $\mu\mu$F.

In order to keep the alternating oscillator voltage constant in the medium and long wave ranges it is important to connect the reaction coil by means of a padding capacitor; the oscillator-grid current on the medium and long waves will then be 200-300-200 μA, whilst on short waves the oscillator voltage can be stabilized by a resistor of 75 ohms in series with the reaction coil. This resistor, in conjunction with the input capacitance of the triode, has a damping effect which closely follows any increase in the frequency.

In A.C./D.C. receivers the circuit arrangement described above can be employed on a 250 V supply, provided that the feed voltage of the valve is not too low (say not less than 200 V). On a supply voltage of 100 V the anode potential is too low, in view of the fact that the anode of the triode has to be fed through a 30,000 ohm resistor; if a lower value were used for this purpose the oscillator circuit would be damped too much and, moreover, the padding curve would be unsatisfactory (greater fluctuations in the oscillator frequency, due to detuning of the oscillator circuit by the feed resistor). Since, generally speaking, the requirements of A.C./D.C. receivers working on lower voltage mains are not so stringent as otherwise, in such cases the oscillator circuit can be included in the grid circuit. In receivers designed for switching over either to A.C. or to D.C. and which are suitable for both 220 and 110 V mains, it is simpler to leave the tuned oscillator circuit in the anode feed circuit and to use the normal feed resistor for the parallel feed, also on low voltage. Naturally, there will then be a considerably lower oscillator voltage on 110 V mains than on 220 V.

Different values of resistance in the potential divider for the screen feed of the hexode

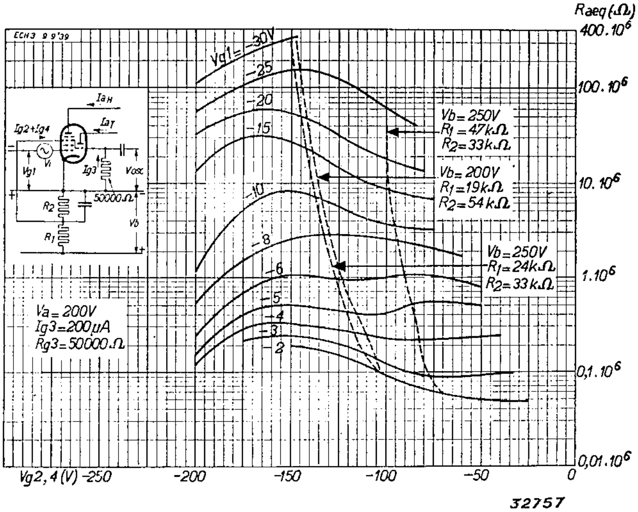

Fig. 23
Equivalent noise resistance *Req* as a function of the screen-grid voltage $Vg_{2,4}$ at different values of grid bias Vg_1.

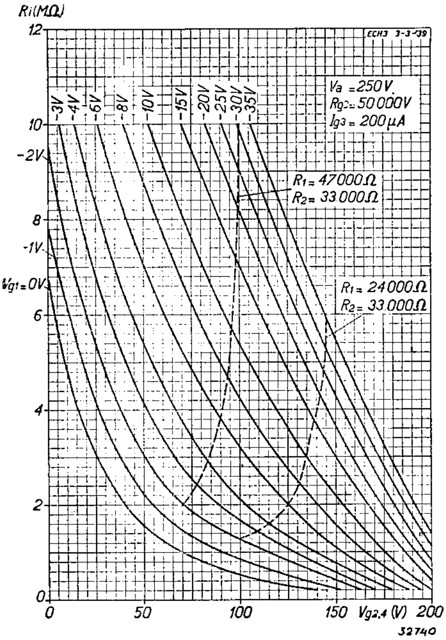

Fig. 24
Internal resistance Ri as a function of the screen-grid voltage $Vg_{2,4}$ at different values of grid bias Vg_1, with Va = 250 V.

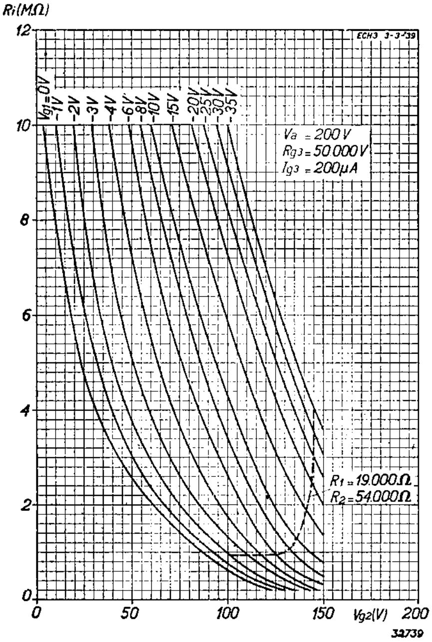

Fig. 25
Internal resistance Ri as a function of the screen-grid voltage $Vg_{2,4}$ at different values of grid bias Vg_1, with Va = 200 V.

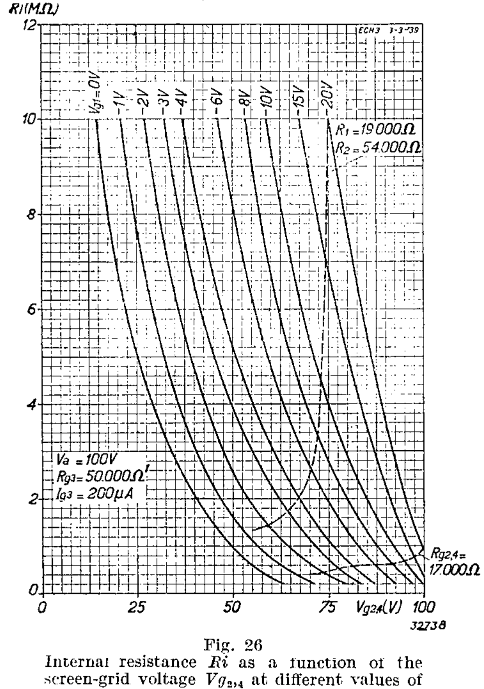

Fig. 26
Internal resistance Ri as a function of the screen-grid voltage $Vg_{2,4}$ at different values of grid bias Vg_1, with Va = 100 V.

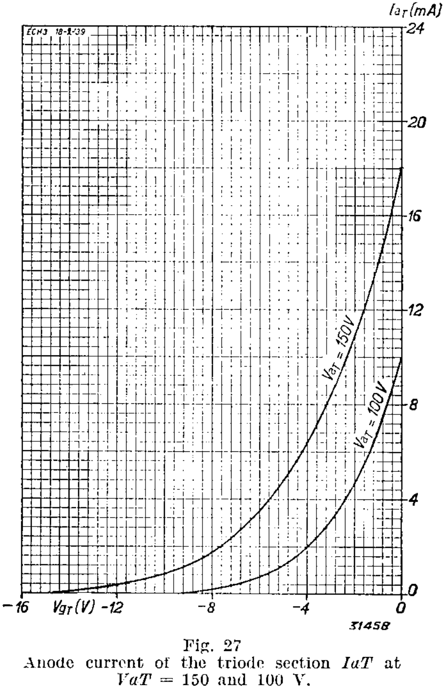

Fig. 27
Anode current of the triode section IaT at VaT = 150 and 100 V.

section have a very marked effect on the range of control, besides giving rise to different effects with respect to the signal-to-noise ratio, the control cut-off, cross-modulation and so on. The valve data therefore include various values for this potential divider, firstly for average operation, secondly to produce a good signal-to-noise ratio during the time that the valve is under the effect of the control and, lastly, a combination that will give an improved cross-modulation characteristic. For the use of the ECH 3 in A.C./D.C.receivers the different values are such as to render the valve suitable for the type of receiver that is fitted with a switch for the different mains voltages, the screen-grid potential divider and cathode resistor thus being adapted to both high and low voltage mains. On 110 V mains the grid bias in the uncontrolled condition is certainly only – 1.25, which means that grid current may occur, but since the demands made of sets working on 110 V are not so high this may be regarded as acceptable.

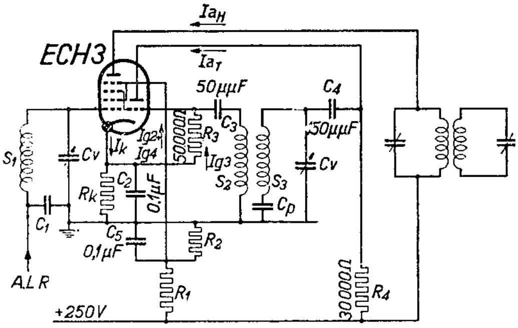

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Fig. 28
Theoretical circuit diagram showing the ECH 3 employed as a frequency-changer. A value of 100 pF for capacitor C_4 will usually give a more constant oscillator voltage throughout the whole wave-range.

Fig. 23 shows the characteristics with respect to the equivalent noise resistance plotted against screen voltage at different values of the grid bias. By means of Fig. 22, which gives the screen current as a function of the screen voltage, it is possible to derive the noise resistance curve for any given potential divider and this, again, in conjunction with the dynamic characteristic of the A.G.C. of a receiver will give the signal-to-noise ratio. Figs 24 to 26 reproduce the internal resistance curves as a function of the screen-grid voltage; these, together with Fig. 22, will supply the resistance as a function of the control voltage on grid 1.

The latter is often of great interest, since many potential dividers as employed for feeding the screen will cause the screen voltage to rise too rapidly when the control operates, thus reducing the resistance of the valve. In order to avoid parasitic oscillation a resistor of about 30 ohms may be included in the anode and control-grid leads.

EEP 1 (EE 1) Secondary-emission valve

The EEP 1 is an amplifier with secondary-emission cathode. Although originally designed for wide-band amplification in television receivers, it is now recommended for use exclusively as a driver valve for radio receivers and amplifiers with a balanced output stage. The use of this valve not only saves the expense of the transformer normally required to produce the two alternating voltages of opposite phase, but it also provides a very high degree of amplification. In amplifiers especially, this tends to reduce the total number of valves required and also allows the use of negative feed-back, without losing too much of the gain.

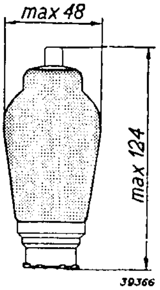

Fig. 1
Dimensions in mm.

Secondary emission and construction of the valve

When electrons strike a metal surface at a certain velocity a small number of them are thrown back, whilst the majority of them penetrate the superficial layer and there liberate electrons from the local atoms. Due to the impact of the primary electrons on the metallic surface, considerable velocity is imparted to the liberated electrons and if their direction of movement is favourable they are able to leave the surface. These electrons liberated from the surface of the metal by the primary electrons are known as secondary electrons. The capacity for emitting secondary electrons is expressed by the "secondary-emission factor" δ, which is the average number of secondary electrons liberated by the primaries. The number of secondary electrons and the path which they follow depend on the construction of the valve, on the potential at the various electrodes and on the physical properties of the bombarded surface. A nickel surface, for instance, gives a secondary emission factor of only 0.94 at a potential difference of 150 V, so the number of secondaries will not be greater than the number of primaries; in other words there will be no multiplication of electrons. The latter can take place only when the factor is greater than 1. Fig 3 shows the principle of the secondary-emission valve, and its action as applicable to the EEP 1 is briefly as follows. Electrons are drawn away from a primary, indirectly-heated cathode by a secondary-emission cathode at a positive potential (150 V). A screen and grid are mounted between the cathode proper and the secondary cathode and each electron reaching the latter liberates a large number of secondary electrons from it, these being attracted by the anode which is at a high potential (250 V).

It will be clear that every variation in the current flowing to the secondary-emission cathode, atten-

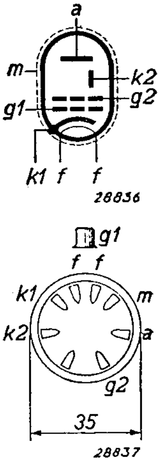

Fig. 2
Arrangement of electrodes and base connections.

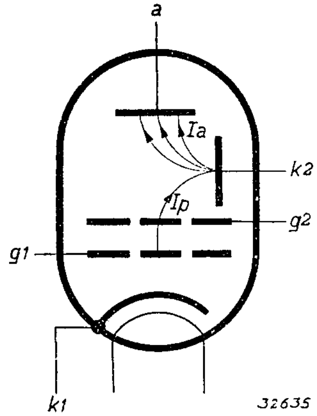

Fig. 3
Diagram of the system employed in the secondary-emission valve. Primary electrons, leaving the cathode k_1, are deflected towards the secondary-emission cathode k_2 and the secondary electrons liberated from the latter pass to the anode. The direction followed by the electrons is shown by means of arrows and it is just the opposite to that of the stream in an ordinary receiving valve.

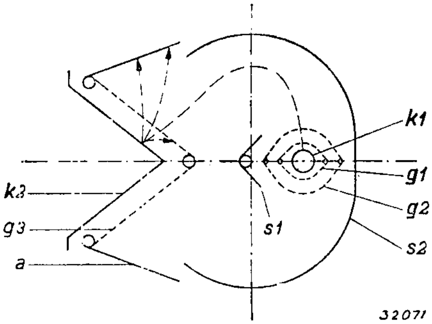

Fig. 4
Cross-section through secondary-emission valve, showing the path of the primary electrons and also that of the secondary electrons liberated from the cathode k_2.

k_1 = primary cathode
g_1 = control grid
g_2 = screen grid (150 V)
s_1 = screen for protection of secondary cathode (0 V) from deposits caused by evaporation of the cathode
s_2 = deflector screen (0 V)
k_3 = secondary-emission cathode (150 V)
$a + g_3$ = anode (250 V).

dant upon changes of voltage on the grid g_1, must produce a much greater variation in the current flowing from the secondary cathode to the anode, thus imparting steep-slope characteristics to the secondary emission, without necessitating an abnormally large cathode or an extremely small space between cathode and grid. If a comparison be made between two valves having similar cathodes, control grids and anodes, one of these valves employing the secondary-emission principle whilst the other does not, it will be found that the mutual conductance of the former is very much the greater.

For the same anode current, the mutual conductance of the secondary-emission valve is $\delta^{1/k}$ times greater than that of the ordinary valve, k being a factor related to both the design of the valve and the anode voltage. If the primary cathode current is not too low the value of the factor k will be constant at about 1.6, the mutual conductance in that case being $\delta^{0.6}$ times greater. Suppose that $\delta = 5$, then $\delta^{0.6}$ will be 2.6.

If the primary cathode (indirectly-heated, with oxide layer) and the secondary-emission area were provided inside the valve without any precautions to avoid this, the secondary emission area would in time become covered with a deposit of material produced by evaporation of the cathode (e.g., barium and barium oxide) and the stability of the secondary emission would thus be seriously affected; the use of an electron-optical device, coupled with a careful arrangement of the paths for the electron streams, however, prevents the deposition of any material on the secondary cathode. In the EEP 1 this difficulty, namely the tendency of the primary cathode to produce deposits, is overcome by employing an electron deflector. It is assumed that the molecules liberated from the primary cathode move virtually in a straight line and an appropriate arrangement of the electrodes in the valve makes the secondary-emission cathode accessible to electrons from the primary cathode, but not to material thrown off by this cathode. The action of the secondary-emission valve can best be explained in relation to Fig. 4 1)), which shows a section through the system of electrodes in the EEP 1. The primary cathode k_1 (indirectly-heated oxide cathode), the control grid g_1, concentric with

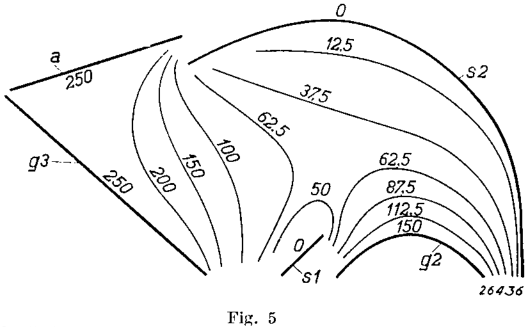

Fig. 5
Equipotential areas in the secondary-emission valve. For designation of the electrodes see Fig. 4.

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*) The diagram shows the construction of the original model of the EEP 1, but in later models the anode plate a is omitted to ensure satisfactory operation of the valve as a pre-amplifier and phase-nverter in balanced output stages, thus leaving only the anode-"grid" g_3 as virtual anode.

the latter, and the screen grid g_2 (at a potential of about 150 V with respect to k_1) together constitute the first three electrodes of a normal screen-grid valve; k_2 is the secondary-emission cathode, which is usually also given a potential of 150 V. Between the system of three electrodes already mentioned and the secondary cathode a screen plate s_1 is provided to prevent the deposition of material from the primary cathode upon the secondary; this screen is connected internally to the cathode. A second screen s_2 is fitted about the electrode system, this being also at cathode potential and suitably shaped for correct deflection of the electrons. Finally, the valve contains an anode-grid g_3, stretched parallel to the emission cathode and connected to the anode plates a. The shape of the screen s_2 is such that the field produced between the primary and secondary cathodes causes the electrons to follow curved paths around the screen s_1 towards the secondary cathode k_2 (see Fig. 4). Fig 5 shows the equipotential areas in one half of the valve. Between the screen grid g_2 and the secondary cathode the electrons travel through two concentrating fields, deflection taking place in the low-potential area formed by screen s_2, and Fig. 5 clearly illustrates the so-called focusing arrangement. An electron arriving at the secondary-emission cathode liberates a number of secondary electrons (sec. emission factor $\delta = 5$) which are collected by the anode-grid g_3, mounted at about 1.5 mm distance from it and operating at a voltage of some 100 V higher than that of the secondary cathode.

It is worthy of note that the electrons released from the secondary cathode set up a negative current to this cathode; whereas normally the external current flows towards the positive electrode, the current in this case passes away from the secondary cathode and follows a path through the source of voltage to the primary cathode. Simultaneously, however, the positive current flows to the secondary cathode, so that the emission current must be diminished by the value of this primary current.

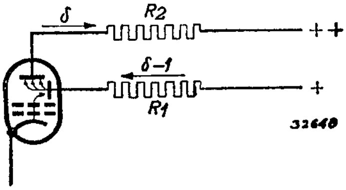

Fig. 6
Schematic arrangement showing the action of the secondary-emission valve employed as driver valve. The arrows indicate the direction followed by the electrons. The normal current flow is in the opposite direction to that of the arrows.

The secondary-emission valve as pre-amplifier in balanced output stages without transformer.

When balanced output stages are driven by means of the secondary-emission valve EEP 1, use is made of the fact that the secondary-emission current (in a positive sense) passes externally to the anode and is taken away at the secondary cathode. It must then be remembered that the current from the latter cathode is reduced to the extent of the primary electrons flowing in the opposite direction. The phases of the currents passing to the two electrodes are therefore 180° opposed and, if these currents be passed to or from the electrodes across resistors, voltages will be obtained which will also be 180° out of phase (see also Fig. 6).

These two alternating voltages of opposite phase may be applied through coupling capacitors with grid leaks to the grids of two output valves in a balanced circuit, and the values of the resistors in both anode and secondary-cathode circuit should naturally be such that the two opposed alternating voltages are exactly equal.

As already stated, the action of the valve depends upon the fact that for every electron reaching the secondary cathode δ electrons arrive at the anode; the number of electrons at the secondary cathode is therefore augmented by (δ—1) electrons passing through R_1 [1]) to the secondary cathode, whilst δ electrons leave the anode through R_2 in respect of these.

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[1]) In Fig. 16 R_1 is made up of R_2 and R_3 in parallel.

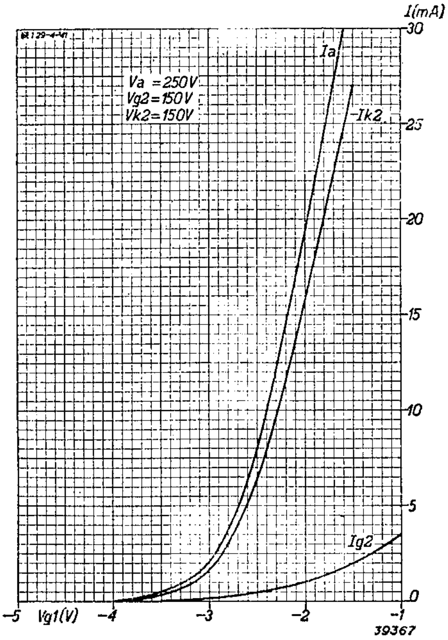


Fig. 7
Anode current, screen-grid current and secondary-cathode current as a function of the grid bias.

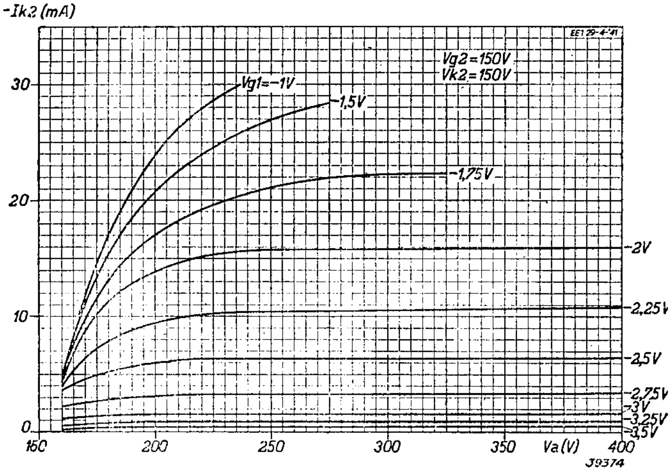


Fig. 8
Anode current plotted against anode voltage at different values of grid bias.

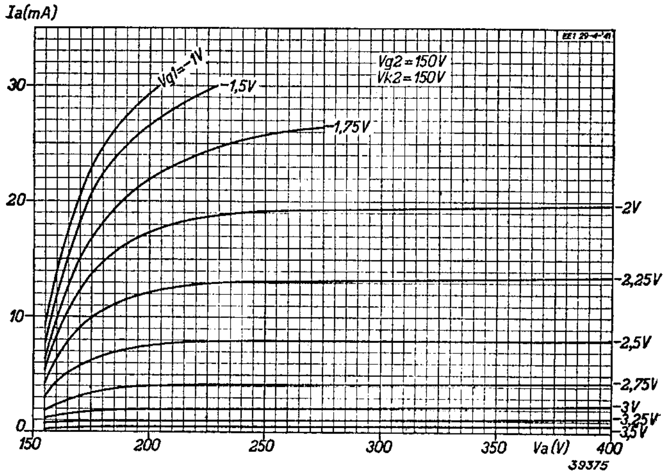


Fig. 9
Secondary-emission cathode current as a function of the anode voltage, for different values of grid bias.

If the effect of the secondary cathode on the anode current is ignored, equal voltages will depend on the following expression:

$$(\delta - 1)\ R_1 = \delta\ R_2, \text{ or } R_2 = \frac{\delta - 1}{\delta}\ R_1$$

In practice R_2 will have to be slightly less than this value, in view of the fact that the alternating voltage at the secondary cathode also contributes to the anode current. Fig. 16 shows the theoretical circuit diagram of the EEP 1 driving a balanced output circuit. Since the factor δ is governed by the negative potential of the grid of the EEP 1, a method of stabilizing the grid bias is employed; the cathode is given a potential of about 23 V positive with respect to the earth line or negative H.T. line, whilst the first grid and screen grid are fed from a potential divider. In this way the first grid receives a positive potential of about 20 V.

Negative feed-back may be included in the cathode circuit as shown in Fig. 17. A potential divider, R_9, R_8, is connected across the loudspeaker; resistor R_8 is simultaneously included in the cathode circuit of the EEP 1 and the speech voltage across R_8 therefore occurs between the cathode and the grid of this valve. The sum of the resistances of R_7 and R_8 should correspond to the value of the cathode resistor as specified for this valve (the value of R_7 in Fig. 16; see also the following data).

HEATER RATINGS

Heating: indirect, A.C. or D.C. parallel supply.

Heater voltage . . . . V_f = 6.3 V
Heater current . . . . I_f = 0.6 A

CAPACITANCES

$C_{ag1} < 0.006\ \mu\mu\text{F}$ $C_{g1k2} < 0.001\ \mu\mu\text{F}$

STATIC RATINGS

Anode voltage . . . . V_a = 250 V
Screen-grid voltage . . . . V_{g2} = 150 V
Secondary-cathode voltage . . . . V_{k2} = 150 V
Grid bias. . . . . V_{g1} = —2.5 V
Anode current . . . . I_a = 8 mA
Screen-grid current . . . . I_{g2} = 0.45 mA
Current to secondary cathode . . . . I_{k2} = —6.5 mA
Mutual conductance . . . . S = 17 mA/V
Internal resistance . . . . R_i = 50,000 ohms

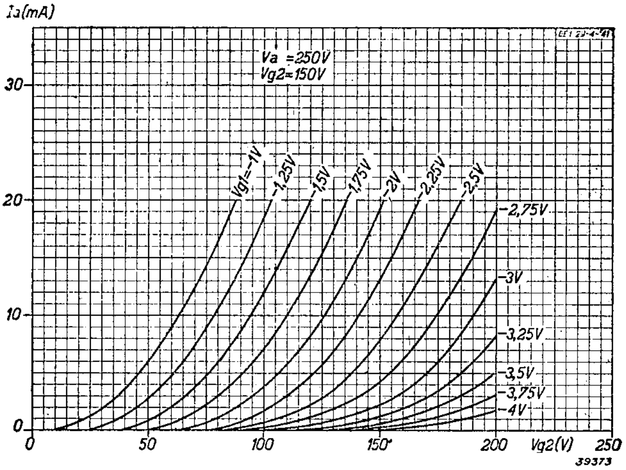


Fig. 10
Anode current as a function of the screen-grid voltage, for different values of grid bias.

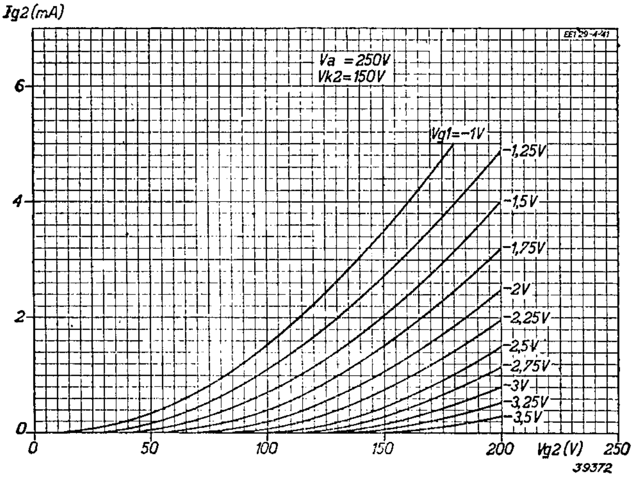


Fig. 11
Screen-grid current as a function of the screen voltage for different values of grid bias.

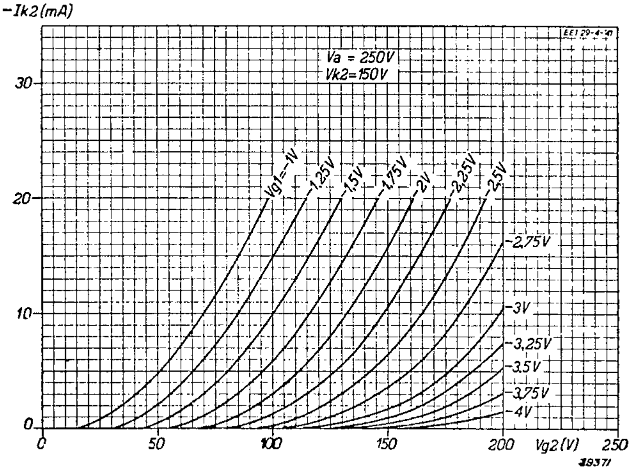
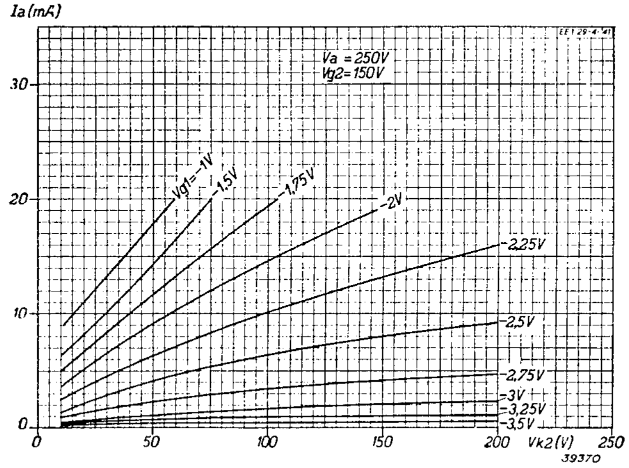
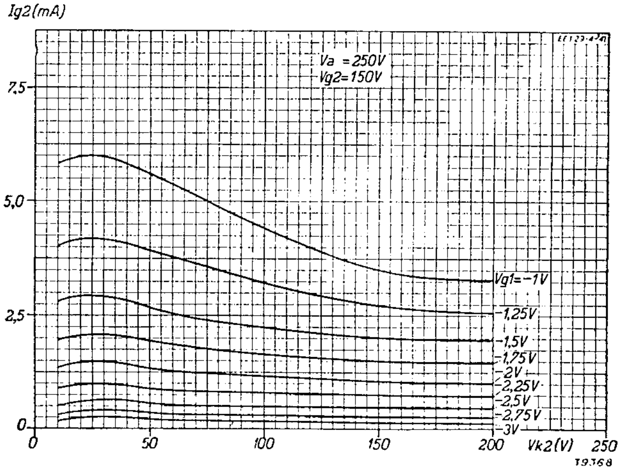


Fig. 12
Secondary-emission cathode current as a function of the screen-grid voltage, for different values of grid bias.



Anode current as a function of the secondary cathode potential at different values of grid bias.



g. 14
Screen-grid current as a function of the secondary cathode voltage at different values of grid bias.

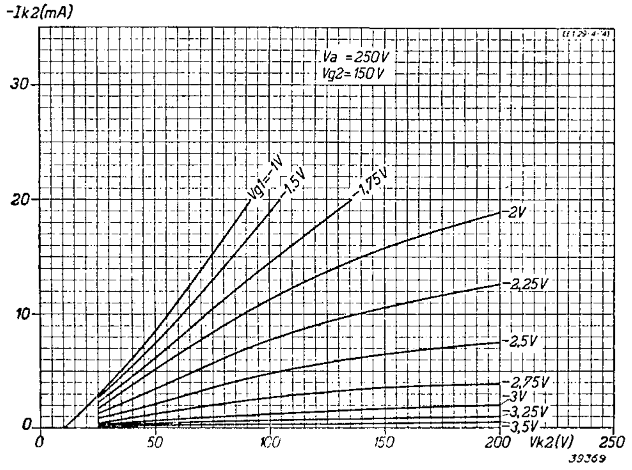


Fig. 15
Current flowing to the secondary cathode as a function of the potential of that cathode, for different values of grid bias.

OPERATING DATA: EEP 1 employed as pre-amplifier and phase-inverter in balanced ouput stages

(For resistance, current and voltage references see circuit, Fig. 16)

Supply voltage	V_b	=	400 V	500 V
Resistor	R_1	=	26,000 ohms	26,000 ohms
Resistor	R_2	=	208,000 ohms	208,000 ohms
Resistor	R_3	=	29,000 ohms	29,000 ohms
Resistor	R_4	=	85,000 ohms	105,000 ohms
Resistor	R_5	=	30,000 ohms	30,000 ohms
Resistor	R_6	=	9,000 ohms	9,000 ohms
Cathode resistor	R_7	=	6,900 ohms	6,000 ohms
Alternating output voltage per grid in output stage	V_o	=	10 30	10 30 V_{eff}
Alternating input voltage	V_i	=	34 114	31 96 mV_{eff}
Gain between grid of EEP 1 and grid of output stage	V_o/V_i	=	300 265	325 315
Total distortion	d_{tot}	=	1.4 4.6	0.9 3.2 %

MAXIMUM RATINGS

Anode voltage in cold condition	V_{ao}	=	max. 700 V
Anode voltage	V_a	=	max. 400 V
Anode dissipation	W_a	=	max. 2 W
Screen-grid voltage in cold condition	V_{g2o}	=	max. 400 V
Screen-grid voltage	V_{g2}	=	max. 150 V
Screen-grid dissipation	W_{g2}	=	max. 0.1 W
Voltage on sec. emission cathode in cold condition	V_{k2o}	=	max. 400 V
Voltage on sec. emission cathode	V_{k2}	=	max. 200 V
Dissipation of sec. cathode	W_{k2}	=	max. 2 W
Primary-cathode current	I_{k1}	=	max. 10 mA
Grid voltage at grid current start ($I_{g1} = +0.3\ \mu A$)	V_{g1}	=	max. —1.3 V
Resistance between grid and cathode	R_{g1k}	=	max. 0.7 M ohm
Resistance between filament and cathode	R_{fk}	=	max. 20,000 ohms
Voltage between filament and cathode (direct voltage or effective value of alternating voltage)	V_{fk}	=	max. 50 V

APPLICATIONS

In connection with the foregoing the following points should also be noted. The EEP 1 must be allowed to work only with automatic grid bias; normally the bias is obtained from a resistor connected to the cathode and the value of this resistor should be such that the potential difference corresponds exactly to the required bias. The working point A will then lie just on the point of intersection of the line OA with the characteristic (see Fig. 18). A slight displacement of the curve would, in the case of normal valves, produce only a small increase or decrease in the anode current. In the EEP 1, however, a very much greater variation in anode current results and, since the normal cathode resistor is of a fairly low value and offers only a small degree of compensation, special precautions have to be taken. Better automatic control of the cathode current is possible if the slope of the line OA in Fig. 18 is reduced and this effect can be obtained by using a higher resistance, due to the fact that the slope of the line in question is determined by the quotient of the cathode potential and the cathode

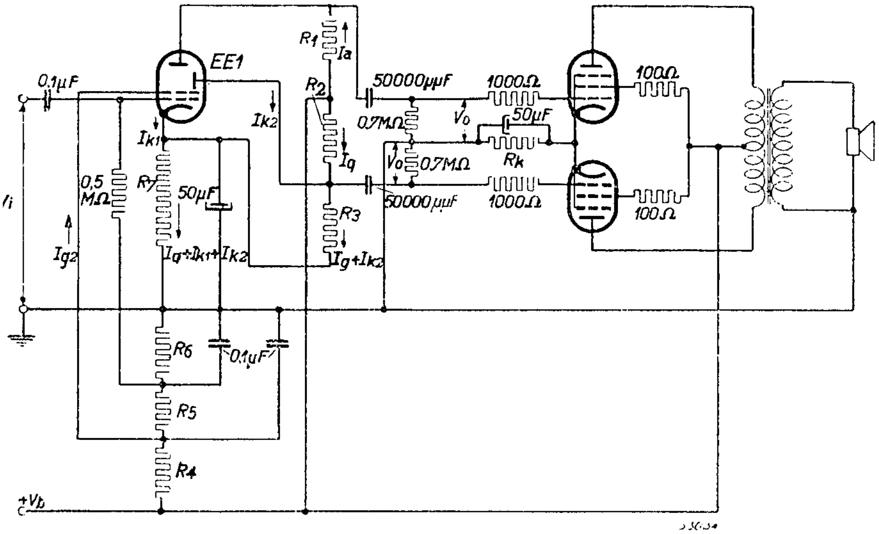


Fig. 16
Theoretical circuit diagram showing the EEP 1 used as driver valve without negative feed-back. The values of resistors R_1 to R_7 may be obtained from the operating data.

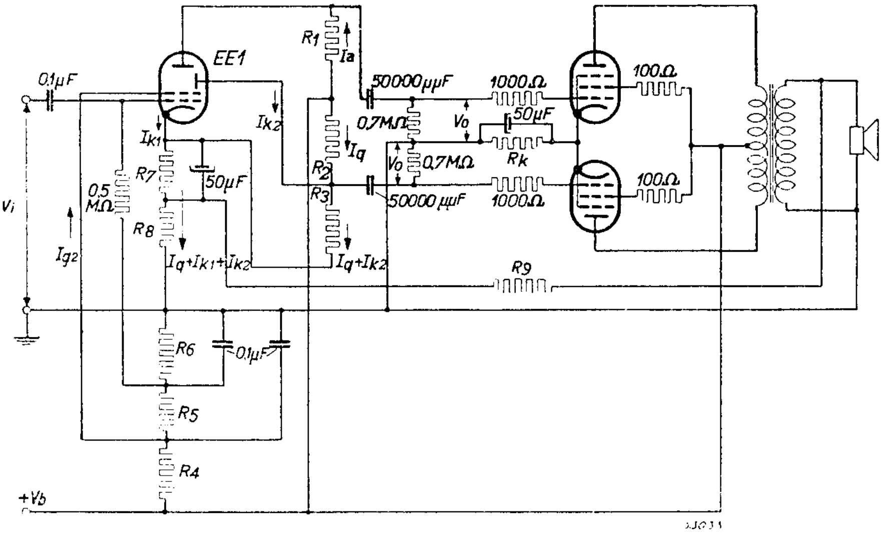


Fig. 17
The EEP 1 employed as driver, with negative feed-back. The circuit is the same as that of Fig. 16, with the exception of R_7 and R_8 of which the values depend on the required feedback; the sum of the values of R_7 and R_8 should correspond to the value of resistor R_7 in Fig. 16.

current. This, however, would make the grid bias too high, so that a positive potential has to be applied to the grid. In Fig. 18 this potential is represented by OB. From the point B the new line is drawn and the total grid bias as a function of the cathode current is then restored. It will be seen that the cathode current, regulated in this manner and indicated by the point of intersection with the curve, does not vary to any extent from the average value.

When the EEP 1 is employed as driver valve in a balanced circuit it is recommended that a supply voltage *Vb* of not less than 275 V be employed; otherwise the results will not be satisfactory.

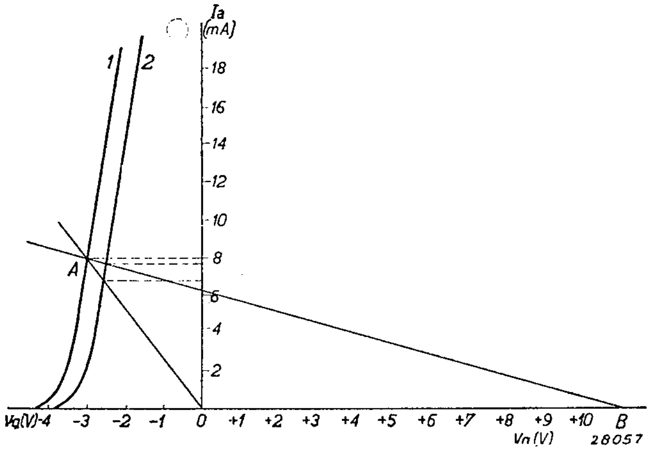


Fig. 18
Simplified diagram showing the effect of the cathode resistor on the constancy of the cathode current. The automatic control of the current is better according as the resistance line becomes flatter.

EF 5 Variable MU R.F. pentode

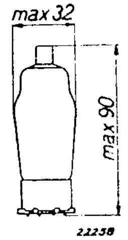


Fig. 1
Dimensions in mm.

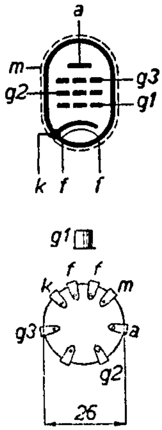


Fig. 2
Arrangement of electrodes and base connections.

The EF 5 is a variable-mu R. F. or I.F. pentode. Special care has been devoted in the design of this valve to the greatest possible reduction in cross-modulation and modulation hum. At a screen-grid voltage of 100 V the anode current of the EF 5 is 8 mA, when the mutual conductance is 1.7 mA/V, the control range being from —3 to —46.5 V. The control range is capable of modification by means of the screen voltage; at lower screen potentials, for the same grid bias, the mutual conductance drops sharply, but the cross-modulation conditions are then not so very good. With a screen voltage of 85 V the control range extends from —2 to —39 V only. Obviously, a lower screen potential will result in a lower screen current as well as a lower anode current and it is thus possible to reduce the bias at the working point from —3 to —2 V to increase the slope; the working value of the mutual conductance is then 1.85 mA/V.

With 60 V screen potential the conductance is still further reduced, to —2/—29 V.

The very greatly diminished modulation hum in this valve is of first importance in A.C./D.C. receivers, where alternating voltages at mains frequency can easily occur between heater and grid. The EF 5 is notable for its low inter-electrode capacitances and high internal resistance; excellent results are obtained on the short-wave range. Although on short waves the circuit magnification is usually only fair, the excellent properties of the EF 5 make it possible to achieve extremely good amplification in this range. On short waves, too, the mutual conductance is the same as on the other ranges (e.g. 200 m). The high impedance of anode and grid with respect to earth in the 12 to 60 metre band, as compared with the impedance values of practical tuned circuits, enables the EF 5 to produce in that range amplification values equal to the product of mutual conductance and impedance. On the short-wave bands the (feed-back) impedance, which takes the place of the anode-to-grid capacitance on the long waves, is unusually high and there is therefore no risk of parasitic oscillation, even with the maximum permissible amount of gain.

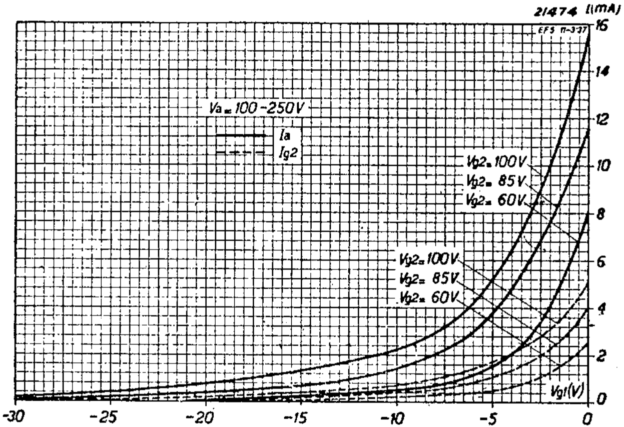


Fig. 3
Anode current and screen current as a function of the grid bias, for different values of screen potential, at 250 V anode. The curves also apply as an approximation to anode voltages of 100–250 V.

A factor contributing in no small degree towards the high properties of this valve is the use of side contacts (P-type base). The suppressor grid and metallizing, each with their own individual contacts, can be connected direct to earth to give the best possible results with short-wave reception.

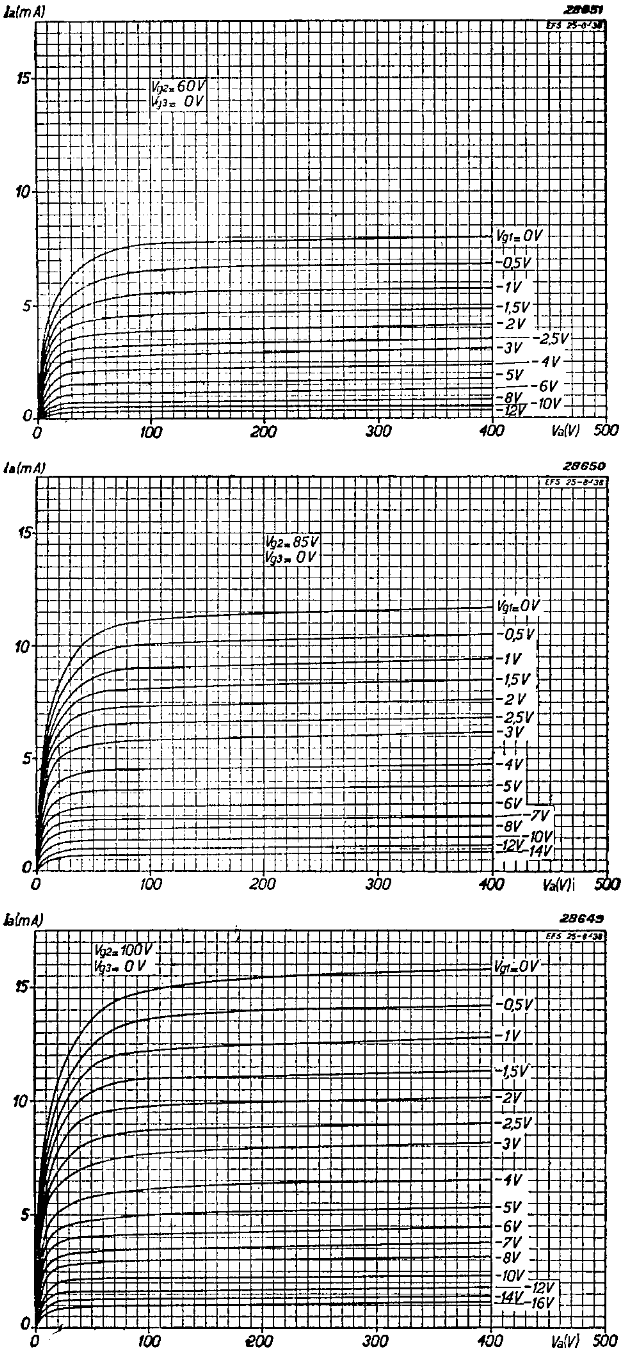


Fig. 4
Anode current as a function of the anode voltage, for different values of screen potential and grid bias.

HEATER RATINGS

Heating: indirect, A.C. or D.C., series or parallel supply
Heater voltage . . . . V_f = 6.3 V
Heater current . . . . I_f = 0.200 A

CAPACITANCES

$C_{ag1} < 0.003$ μμF
$C_{g1} = 5.4$ μμF
$C_a = 6.9$ μμF

OPERATING DATA: valve employed as R.F. or I.F. amplifier

Anode voltage V_a (V)		100			200			250	
Screen-grid voltage V_{g2} (V)		100			100			100	
Suppressor-grid voltage V_{g3} (V)		0			0			0	
Cathode resistor R_k (ohms)		170			180			180	
Grid bias V_{g1} (V)	-2.85$^{1)}$	-34$^{2)}$	-46.5$^{3)}$	-2.95$^{1)}$	-34$^{2)}$	-46.5$^{3)}$	-3$^{1)}$	-34$^{2)}$	-46.5$^{3)}$
Anode current I_a (A)	8	—	—	8	—	—	8	—	—
Screen current I_{g2} (mA)	2.6	—	—	2.6	—	—	2.6	—	—
Mutual conductance S (μA/V)	1700	17	2	1700	17	2	1700	17	2
Amplification factor μ	500	—	—	1600	—	—	2000	—	—
Internal resistance R_i (M ohms)	0.3	> 10	> 10	0.95	> 10	> 10	1.2	> 10	> 10

Anode voltage V_a (V)		100			200			250	
Screen-grid voltage V_{g2} (V)		85			85			85	
Suppressor-grid voltage V_{g3} (V)		0			0			0	
Cathode resistor R_k (ohms)		190			195			200	
Grid bias V_{g1} (V)	-1.9$^{1)}$	-29$^{2)}$	-39$^{3)}$	-1.95$^{1)}$	-29$^{2)}$	-39$^{3)}$	-2$^{1)}$	-29$^{2)}$	-39$^{3)}$
Anode current I_a (mA)	7.5	—	—	7.5	—	—	7.5	—	—
Screen current I_{g2} (mA)	2.45	—	—	2.45	—	—	2.45	—	—
Mutual conductance S (μA/V)	1850	18	2	1850	18	2	1850	18	2
Amplification factor μ	550	—	—	1750	—	—	2200	—	—
Internal resistance R_i (M ohms)	0.3	> 10	> 10	0.95	> 10	> 10	1.2	> 10	> 10

Anode voltage									
V_a (V)		100			200			250	
Screen-grid voltage									
V_{g2} (V)		60			60			60	
Supressor-grid voltage									
V_{g3} (V)		0			0			0	
Cathode resistor									
R_k (ohms)		360			370			380	
Grid bias									
V_{g1} (V)	-1.9[1]	-22[2]	-29[3]	-2.95[1]	-22[2]	-29[3]	-2[1]	-22[2]	29[3]
Anode current									
I_a (mA)	4	—	—	4	—	—	4	—	—
Screen-grid current									
I_{g2} (mA)	1.3	—	—	1.3	—	—	1.3	—	—
Mutual conductance									
S (μA/V)	1400	14	2	1400	14	2	1400	14	2
Amplification factor									
μ	1200	—	—	1900	—	—	2000	—	—
Internal resistance									
R_i (M ohms)	0.85	> 10	> 10	1.35	> 10	> 10	1.4	> 10	> 10

[1] Without control

[2] Mutual conductance reduced to one-hundredth of uncontrolled value.

[3] Extreme limit of control.

MAXIMUM RATINGS

V_{ao} = max. 550 V
V_a = max. 250 V
W_a = max. 2 W
V_{g2o} = max. 400 V
V_{g2} = max. 125 V
W_{g2} = max. 0.4 W
I_k = max. 15 mA
V_{g1} (I_{g1} = +0.3 μA) = max. —1.3 V
R_{g1} = max. 2.5 M ohms
R_{fk} = max. 20,000 ohms
V_{fk} = max. 100 V [1]

[1] Direct voltage or effective value of alternating voltage.

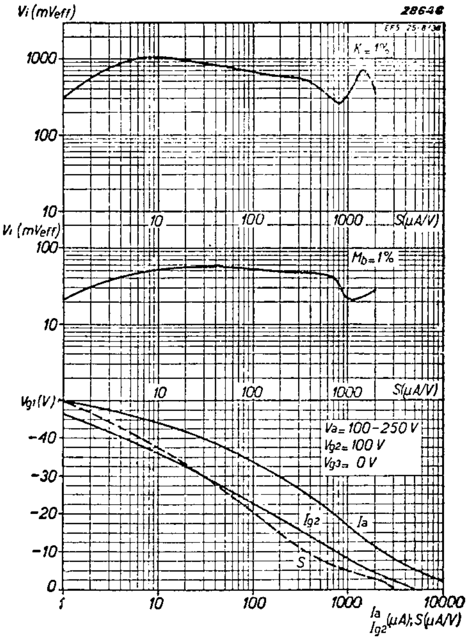


Fig. 5
At 100–250 V anode and 100 V screen;
Upper diagram. Alternating grid voltage as a function of the mutual conductance, with 1 % cross modulation.
Centre diagram. Alternating grid voltage as a function of the mutual conductance, with 1 % modulation hum.
Lower diagram. Mutual conductance S, anode current Ia and screen current Ig_2 as a function of the voltage on the first grid.

Due to the curvature of the characteristic, the uses of the EF 5 are restricted to R.F. and I.F. amplification. It can be employed as amplifier with either automatic or manual control. It is preferable to feed the screen through a potential divider; in many cases it would be found when using a series resistor that the screen voltage would become too high on full control and that the amplification control would be far too tardy.

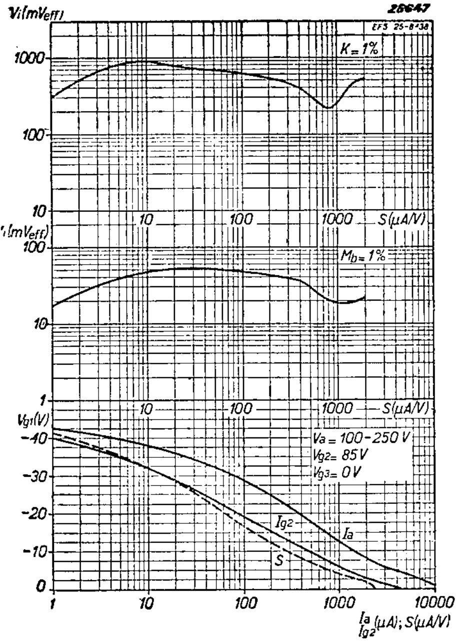


Fig. 6
At 100–250 V anode and 85 V screen;
Upper diagram. Effective alternating grid voltage as a function of the mutual conductance, with 1 % cross modulation.
Centre diagram. Effective alternating grid voltage as a function of the mutual conductance, with 1 % modulation hum.
Lower diagram. Mutual conductance *S*, anode current *Ia* and screen current Ig_2 as a function of the grid bias.

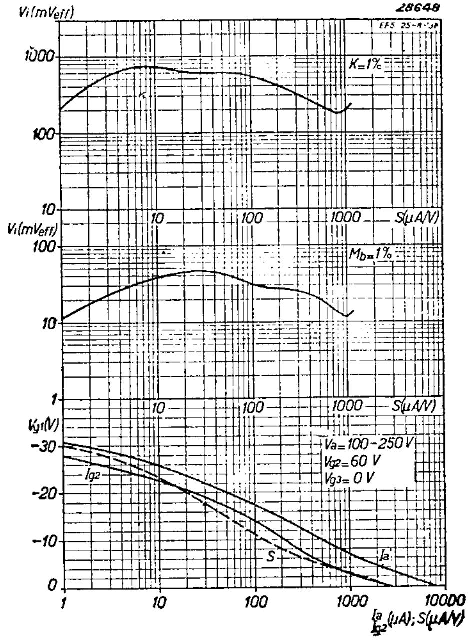


Fig. 7
At 100–250 V anode and 60 V screen:
Upper diagram. Effective alternating grid voltage as a function of the mutual conductance, with 1 % cross-modulation.
Centre diagram. Effective alternating grid voltage as a function of the mutual conductance, with 1 % modulation hum.
Lower diagram. Mutual conductance *S*, anode current *Ia* and screen current Ig_2 as a function of the grid bias.

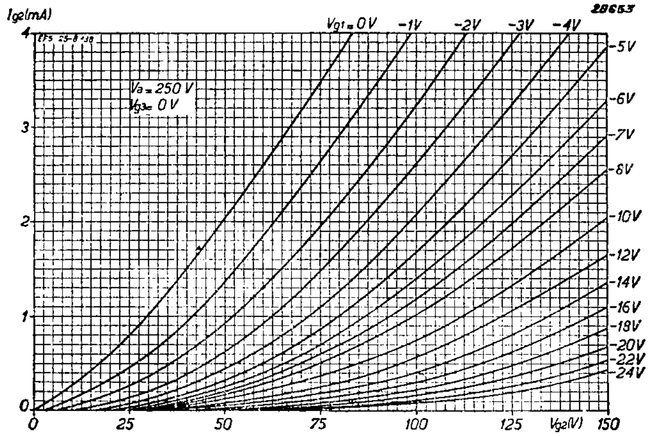


Fig. 8
Screen-grid current as a function of the screen voltage, for different values of grid bias.

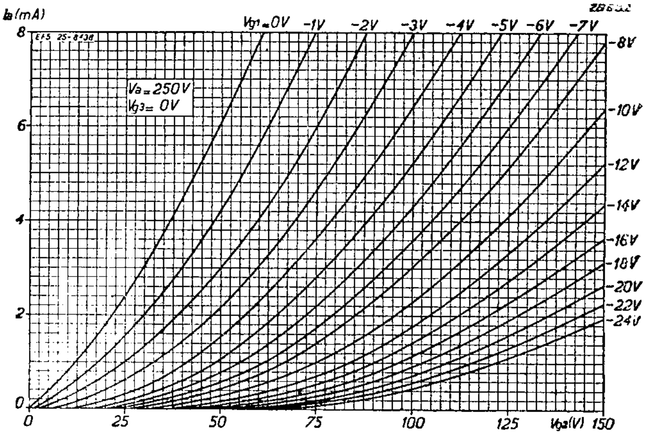


Fig. 9
Anode current as a function of the screen-grid voltage, for different values of grid bias.

EF 6 Pentode

This valve is particularly suitable for A.F. amplification and either anode-bend or grid detection. The EF 6 works only on a fixed bias and therefore finds no application in practice as an R.F. or I.F. amplifier. The degree of A.F. amplification, however, is very high indeed, the ultimate signal voltage on the anode being so great that practically distortionless modulation is possible in any kind of output stage. Used as a grid detector, this valve has many advantages when good reception of local stations is required.

It is also a very useful valve in special circuits, for instance as an amplifier for the control voltage in an automatic gain control circuit and so on. The EF 6 will also give very good results on the short-wave ranges, where the mutual conductance is the same as in the broadcast wave-bands.

As the R.F. impedance of anode and grid in the 12 to 60 m range, with respect to the impedance of normal tuned circuits, is extremely high, the gain obtainable from this valve is equal to the product of mutual conductance and impedance. In the short-wave range, the impedance, which replaces the anode-to-grid capacitance on long waves (anode feed-back), is also very high, so that the maximum permissible amplification may be obtained without risk of parasitic oscillation.

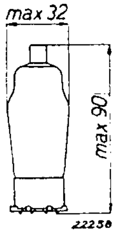


Fig. 1
Dimensions in mm.

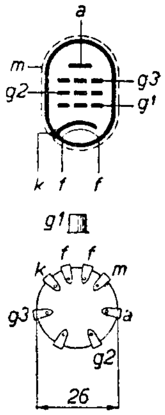


Fig. 2
Arangement of electrodes and base connections.

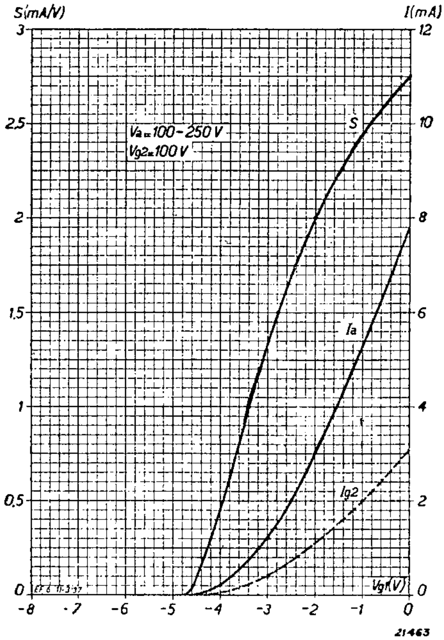


Fig. 3
Anode current, screen-grid current and mutual conductance as a function of the grid bias at V_{g2} = 100 V. The curves also apply as an approximation at all anode voltages from 100 V upwards.

In part, the excellent short-wave qualities of the EF 6 are due to the use of the P-type side-contact base and separate suppressor-grid connection. Cross-modulation and modulation hum are both very slight indeed, especially at the maximum permissible screen-grid voltage and, for this reason, the valve gives good results in A.C./D.C. receivers; in view of the high alternating voltages occurring between the heater and earth, and induced on the grid, in this type of receiver it is important that modulation hum should be as low as possible.

HEATER RATINGS

Heating, indirect, A.C. or D.C., parallel supply.

Heater voltage . . . . . V_f = 6.3 V
Heater current . . . . . I_f = 0.200 A

CAPACITANCES

$C_{ag1} < 0.003$ μμF
$C_{g1} = 5.2$ μμF
$C_a = 6.9$ μμF

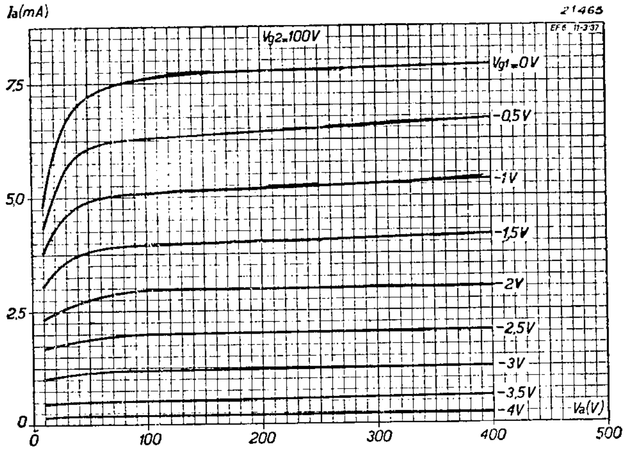


Fig. 4
Anode current as a function of the anode voltage at V_{g_2} = 100 V, for different values of grid bias.

OPERATING DATA

Anode voltage	V_a =	100 V	200 V	250 V
Screen-grid voltage	V_{g_2} =	100 V	100 V	100 V
Suppressor-grid voltage	V_{g_3}	0 V	0 V	0 V
Grid bias	V_{g_1} =	—2 V	—2 V	—2 V
Anode current	I_a =	3 mA	3 mA	3 mA
Screen grid current	I_{g_2} =	0.8 mA	0.8 mA	0.8 mA
Amplification factor	μ =	1800	3600	4500
Mutual conductance	S =	1.8 mA/V	1.8 mA/V	1.8 mA/V
Internal resistance	R_i =	1.0 M ohm	2.0 M ohms	2.5 M ohms

MAXIMUM RATINGS

V_{ao} . . . . = max. 550 V
V_a . . . . = max. 300 V
W_a . . . . = max. 1 W
V_{g_2o} . . . . = max. 550 V
V_{g_2} . . . . = max. 125 V
W_{g_2} . . . . = max. 0.3 W
I_k . . . . = max. 6 mA
V_{g_1} (I_{g_1} = + 0.3 μA) . . . . = max. —1.3 V
R_{g_1k} (auto. grid bias) . . . . = max. 1.5 M ohms
R_{g_1k} (fixed bias) . . . . = max. 1 M ohm
R_{fk} . . . . = max. 20,000 ohms
V_{fk} . . . . = max. 75 V [1]

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[1] Direct voltage or effective value of alternating voltage.

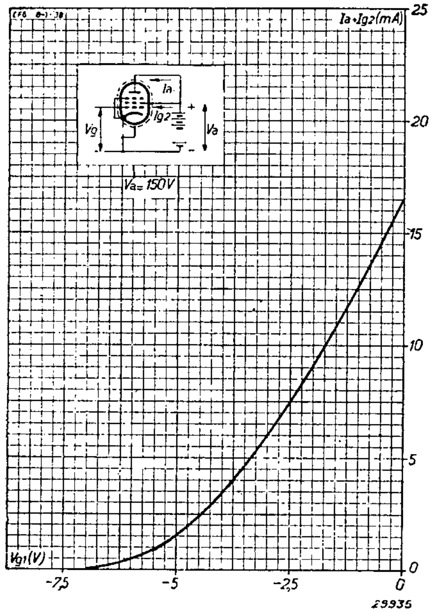


Fig. 5
EF 6 employed as triode. Anode current as a function of the grid bias for V_a = 150 V.

The valve is metallized and no additional screening is necessary, but the separate base contact to which the metallizing is connected internally must be effectively connected to the chassis. If in special circuits the cathode is negative with respect to the chassis, the metallizing should be connected to the cathode. The suppressor grid also has its own separate base contact for direct connection to earth.

Care must be taken when using the EF 6 as detector or A.F. amplifier in A.C./D.C. receivers, however, to see that the heater of the valve, in the heater circuit, is connected as closely as possible to the chassis end, in order to avoid hum.

1) GRID DETECTOR WITH RESISTANCE COUPLING

For grid detection it is advisable to feed the screen from a resistor and not from a potential divider, since in that case the grid swing will increase with signal strength. In A.C./D.C. receivers for use on 110 V mains the EF 6 is not generally satisfactory, as the output voltage is usually insufficient to load the output valve fully at low modulation depths. Table I gives the results to be obtained with the EF 6 when employed as grid detector.

2) A.F. AMPLIFIER WITH RESISTANCE COUPLING

The EF 6 is eminently suitable for A. F. amplification since it provides considerable gain with only very moderate distortion; the screen should preferably be fed through a resistor, for which a suitable value is indicated in tables II and III.

The A.F. signal applied to the grid must not be too strong, as this tends towards microphony when the loudspeaker used is of a sensitive type. This valve can be used only in circuits having not more than one stage of A.F. amplification and must therefore in every case be followed immediately by the output valve.

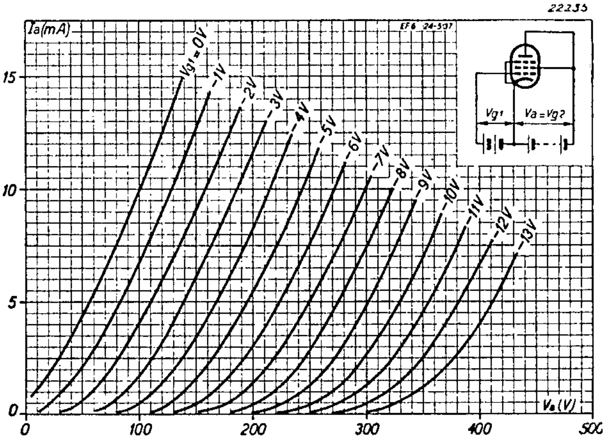
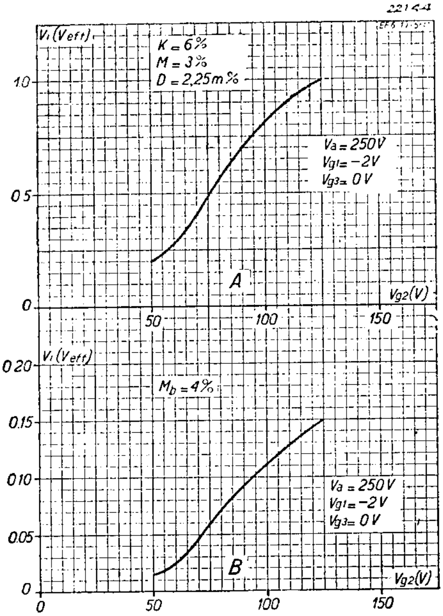


Fig. 6
EF 6 employed as triode. Anode current as a function of the anode voltage, for different values of grid bias.



Generally speaking, the A.F. sensitivity at the grid of the EF 6 should not be less than 5 mV.

Fig. 7
Curve A: Effective alternating grid voltage as a function of the screen-grid voltage of the EF 6, with 6 % cross-modulation (3 % increase in modulation depth + 2.25 *m* % modulation distortion, *m* = modulation depth). 6 % cross-modulation corresponds to 0.5 % third harmonic.
Curve B. Effective value of the alternating grid voltage as a function of the screen-grid voltage with 4 % modulation hum (corresponding to 1 % second harmonic).

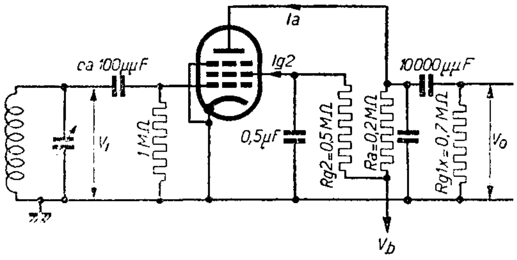


Fig. 8
Circuit driagram of the EF 6 employed as grid detector with resistance coupling.

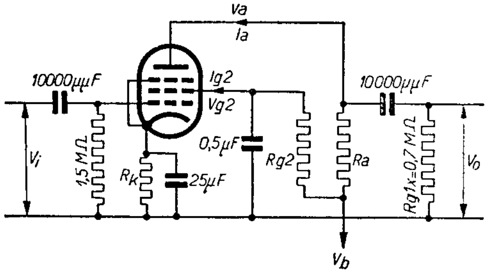


Fig. 9
Circuit diagram of the EF 6 employed as A. F. amplifier with resistance coupling.

TABLE I

EF 6 employed as grid detector with resistance coupling in A.C. receivers.

Heaters fed in parallel in A.C. receivers; detector grid leak = 1 megohm; grid capacitor = 100 $\mu\mu$F. Grid leak of next (output) valve Rg_{1x} = 0.7 megohm. Modulation depth m = 0.3 (30 %). Screen fed through series resistor; Ia and Ig_2 measured without signal.

Supply voltage	Anode Coupling res.	Anode current	Screen-grid series resistor	Screen current	Max. alternating output	Used with EL 2 as next (output) valve. $Va = Vg_2$ = 250 V				Used with EL 3 as next (output) valve. $Va = Vg_2$ = 250 V				Used with EL 5 as next (output) valve. Va = 250 V; Vg_2 = 275 V			
						For 50 mW output		For full excitation		For 50 mW output		For full excitation		For 50 mW output		For full excitation	
Vb (V)	Ra (M ohm)	Ia (mA)	Rg_2 (M ohm)	Ig_2 (mA)	Vomax[1] (Veff)	Output volts Vo (Veff)	Input volts Vi (mVeff)	Output volts Vo (Veff)	Input volts Vi (Veff)	Output volts Vo (Veff)	Input volts Vi (mVeff)	Output volts Vo (Veff)	Input volts Vi (Veff)	Output volts Vo (Veff)	Input volts Vi (mVeff)	Output volts Vo (Veff)	Input volts Vi (Veff)
300	0.2	1.35	0.6	0.45	19	0.9	63	11.2	0.35	0.33	35	3.7	0.14	0.5	43	8.5	0.27
300	0.2	1.15	0.8	0.35	17	0.9	58	11.2	0.35	0.33	33	3.7	0.13	0.5	41	8.5	0.26
300	0.2	1.0	1.0	0.30	15	0.9	58	11.2	0.42	0.33	33	3.7	0.14	0.5	41	8.5	0.28
250	0.2	1.15	0.6	0.35	16	0.9	60	11.2	0.35	0.33	33	3.7	0.14	0.5	40	8.5	0.27
250	0.2	0.95	0.8	0.28	14	0.9	60	11.2	0.35	0.33	33	3.7	0.13	0.5	40	8.5	0.26
250	0.2	0.8	1.0	0.23	11.5	0.9	65	11.2	0.42	0.33	33	3.7	0.14	0.5	40	8.5	0.28
300	0.1	2.6	0.3	0.85	23	0.9	58	11.2	0.43	0.33	38	3.7	0.14	0.5	50	8.5	0.35
300	0.1	2.2	0.4	0.65	20	0.9	58	11.2	0.43	0.33	38	3.7	0.14	0.5	50	8.5	0.35
300	0.1	1.8	0.5	0.55	17	0.9	58	11.2	0.48	0.33	38	3.7	0.15	0.5	50	8.5	0.35
250	0.1	2.1	0.3	0.7	19	0.9	70	11.2	0.43	0.33	38	3.7	0.14	0.5	50	8.5	0.35
250	0.1	1.8	0.4	0.55	16	0.9	70	11.2	0.43	0.33	38	3.7	0.14	0.5	50	8.5	0.35
250	0.1	1.5	0.5	0.45	14	0.9	70	11.2	0.48	0.33	38	3.7	0.15	0.5	50	8.5	0.35
300	0.05	4.6	0.15	1.5	24	0.9	77	11.2	0.6	0.33	44	3.7	0.25	0.5	56	8.5	0.45
300	0.05	3.9	0.2	1.2	20	0.9	77	11.2	0.6	0.33	44	3.7	0.25	0.5	56	8.5	0.45
300	0.05	2.9	0.3	0.9	15	0.9	79	11.2	0.7	0.33	46	3.7	0.25	0.5	59	8.5	0.60
250	0.05	3.7	0.15	1.3	18	0.9	80	11.2	0.6	0.33	42	3.7	0.25	0.5	55	8.5	0.45
250	0.05	3.1	0.2	1.0	16	0.9	80	11.2	0.6	0.33	42	3.7	0.25	0.5	55	8.5	0.45
250	0.05	2.4	0.3	0.65	12	0.9	84	11.2	0.7	0.33	45	3.7	0.25	0.5	60	8.5	0.60

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[1]) In these values for the alternating output the distortion in the detector is less than 5 %.

TABLE II

The EF 6 as resistance-coupled A.F. amplifier in A.C. mains receivers

For use in A.C. mains receivers with heaters in parallel; grid leak of the following (output) valve Rg_1v = 0.7 megohm; cathode decoupling capacitor = 50 μF. Screen grid fed through a resistor; Ia and Ig_2 measured without signal.

Supply voltage	Anode coupling resistor	Anode current	Screen-grid series resistor	Screen-grid current	Cathode resistor	Voltage gain	Used with EL 3 as output valve $Va = Vg_2 = 250$ V		Used with EL 5 as output valve $Va = 250$ V; $Vg_2 = 275$ V		Used with EL 2 as output valve $Va = Vg_2 = 250$ V		Used with AD 1 as output valve $Va = 250$ V	
							Output voltage	Total distortion	Output voltage	Total distortion	Output voltage	Total distortion	Output voltage	Total distortion
Vb (V)	Ra (megohm)	Ia (mA)	Rg_2 (megohm)	Ig_2 (mA)	Rk (ohms)	$\frac{Vo}{Vi}$	Vo 1) ($Veff$)	$d$tot 2) (%)	Vo 1) ($Veff$)	$d$tot 2) (%)	Vo 1) ($Veff$)	$d$tot 2) (%)	Vo 1) ($Veff$)	$d$tot 2) (%)
300	0.3	0.7	0.8	0.25	4,000	175	3.7	< 1.0	8.5	1.0	11.2	1.4	31	4.4
250	0.3	0.6	0.8	0.20	4,000	165	3.7	< 1.0	8.5	1.6	11.2	2.2	31	5.0
300	0.2	1.1	0.4	0.40	3,000	150	3.7	< 1.0	8.5	1.0	11.2	< 1.0	31	2.7
250	0.2	0.9	0.4	0.35	3,000	140	3.7	< 1.0	8.5	1.3	11.2	1.8	31	2.4
300	0.1	1.9	0.25	0.65	1,600	115	3.7	< 1.0	8.5	1.0	11.2	1.0	31	2.0
250	0.1	1.6	0.25	0.30	1,600	110	3.7	< 1.0	8.5	1.0	11.2	1.0	31	2.7

1) For the A.F. amplifier with fully loaded output valve.

2) In the A.F. amplifier with fully loaded output valve.

TABLE III

The EF 6 used as resistance-coupled A. F. amplifier in A.C./D.C. mains receivers

Used in A.C./D.C. receivers with heaters in series (heater current 200 mA); grid leak of the next (output) valve $Rg_{1x} = 0.7$ megohm. Cathode decoupling capacitor = 50 μF; screen fed through a resistor. Ia and Ig_2 measured without signal.

Supply voltage	Anode coupling resistor	Anode current	Screen-grid series resistor	Screen current	Cathode resistor	Voltage gain	Used with CL 1 as output valve $Va = Vg_2$ = supply voltage		Used with CL 2 as output valve Va = supply voltage; $Vg_2 = 100$ V		Used with CL 4 as output valve $Va = Vg_2$ = supply voltage	
							Output voltage	Total distortion	Output voltage	Total distortion	Output voltage	Total distortion
Vb (V)	Ra (Mohm)	Ia (mA)	Rg_2 (M ohm)	Ig_2 (mA)	Rk (ohm)	$\frac{Vo}{Vi}$	Vo [1] (Veff)	dtot [2] (%)	Vo [1] (Veff)	dtot [2] (%)	Vo [1] (Veff)	dtot [2] (%)
200	0.3	0.45	0.6	0.17	6,400	130	9.6	2.8	10	3.0	5.0	1.8
150	0.3	0.35	0.6	0.13	6,400	120	—	—	10	2.5	4.0	1.3
100	0.3	0.22	0.6	0.08	6,400	105	—	—	10	3.5	2.4	< 1.0
200	0.2	0.60	0.4	0.23	5,000	115	9.6	2.0	10	2.1	5.0	1.0
150	0.2	0.45	0.4	0.17	5,000	110	—	—	10	2.6	4.0	0.9
100	0.2	0.30	0.4	0.12	5,000	100	—	—	10	4.2	2.4	0.9
200	0.1	1.2	0.2	0.4	3,000	95	9.6	1.5	10	1.6	5.0	< 1.0
150	0.1	0.85	0.2	0.3	3,000	90	—	—	10	2.1	4.0	1.1
100	0.1	0.60	0.2	0.2	3,000	85	—	—	10	3.3	2.4	< 1.0

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1) For the A.F. amplifier with fully loaded output valve.

2) In the A.F. amplifier with fully loaded output valve.

EF 8 Low-noise variable-MU R.F. amplifier pentode

The EF 8 is a variable-mu R.F. amplifier the chief feature of which is its very low noise factor. As the noise produced in screen-grid and pentode valves is caused mainly by the distribution of the current between the screen and the anode — from which point of view a low screen current is advantageous — efforts have been made in the design of this valve to keep this current as low as possible. In principle, the construction of the EF 8 is similar to the conventional pentode, embodying control, screen and suppressor grids, but between the control grid and screen of this valve an additional grid has been introduced, wound with exactly the same pitch as the screen and normally connected to the cathode. The turns of this extra grid are situated exactly opposite those of the screen grid and this auxiliary electrode repels and bunches the electrons on their way towards the anode, the bunches thus passing just between the turns of the screen grid. In this way, the number of electrons actually arriving on the screen is very much smaller than when the auxiliary grid is not used. Fig. 3 illustrates the paths of the electrons through the different grids.

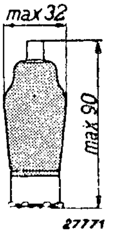


Fig. 1
Dimensions in mm

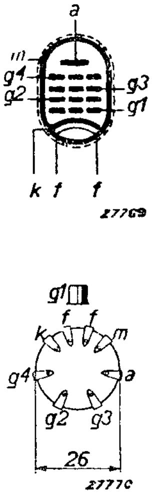


Fig. 2
Arrangement of electrodes and base connections.

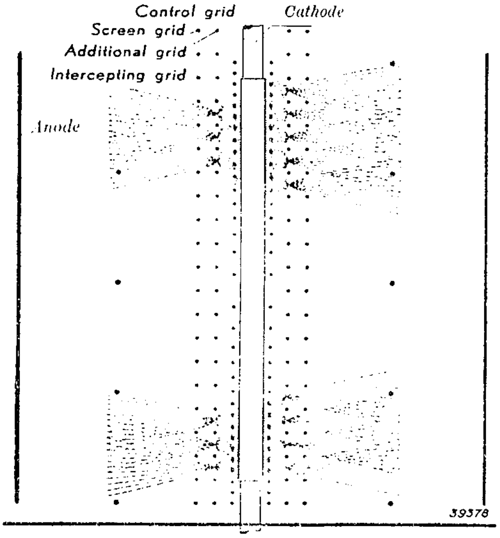


Fig. 3

Paths of the electrons from the cathode to the space between screen grid and anode. The second grid together with the third form a focusing device the actual focus of which lies roughly in front of grid 2. In this way the electrons are passed through the meshes of the third grid, resulting in a very low current to this grid.

The purpose of grid 3 is to draw from the cathode a sufficient number of electrons through the two grids (grids 1 and 2) with their low potential and this can take place only if the conductance of g_3 through g_2 is high enough, which means a wide pitch for grids 2 and 3. For the same reason it is necessary to increase the screen voltage, which in the EF 8 is 250 V instead of the usual 100 V. One drawback of this arrangement is that the dimensions of the various grids must be such as to permit the anode to exert sufficient attraction through the grids g_4, g_3 and g_2.

In consequence, the anode-to-grid capacitance is higher than usual in

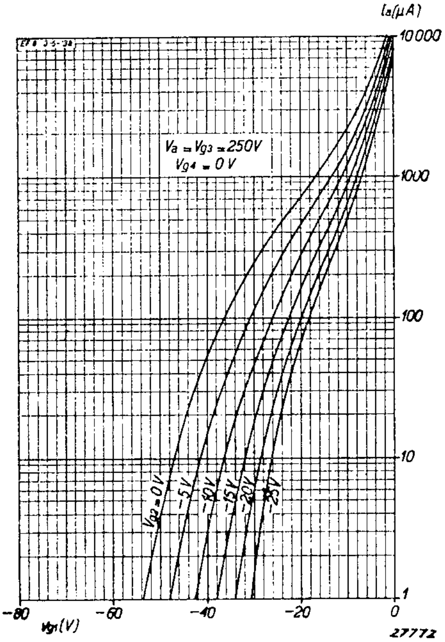


Fig. 4
Anode current as a function of the grid voltage, for different values of the bias on grid 2.

a pentode such as the EF 5 or EF 9, being max. 0.007 $\mu\mu$F, as against 0.003 $\mu\mu$F in the case of the EF 5. The impedance is therefore also lower, viz. 0.45 megohm. However, as the EF 8 finds practical application only as an R.F. amplifier, that is, as the input valve in a receiver, the higher C_{ag1} and lower impedance do not in themselves form an objection. In the short-wave range the circuit impedances are in any case on the low side, whilst in the normal broadcast bands the opportunities for amplification by means of this valve would, usually, not be fully utilized, since the signal input to the frequency-changer would then be too great.

Amplification is greatest behind the input valve of the receiver, but it is much less in the following stages and the latter therefore contribute in a very much smaller degree towards the general background noise. Usually the input valve is a frequency-changer and, as is generally known, this type of valve is fairly noisy, for which reason, in high-performance receivers where many different precautions are taken to suppress interference, including background noises, an R.F. pre-amplifier is employed.

The use of the EF 8 as R.F. amplifier ensures excellent characteristics from the point of view of the suppression of cross-modulation. The valve is generally provided with automatic gain control and its high performance should therefore be maintained especially on very strong signals, that is, with the full control applied to the valve. A very satisfactory cross-modulation curve is obtained on an anode current of 8 mA in the uncontrolled condition and the special design of the valve ensures that background noise, for which this high anode current would otherwise be an adverse factor, is kept at an extremely low level.

In connection with these features, the screen current has been effectively reduced to 0.2 mA,

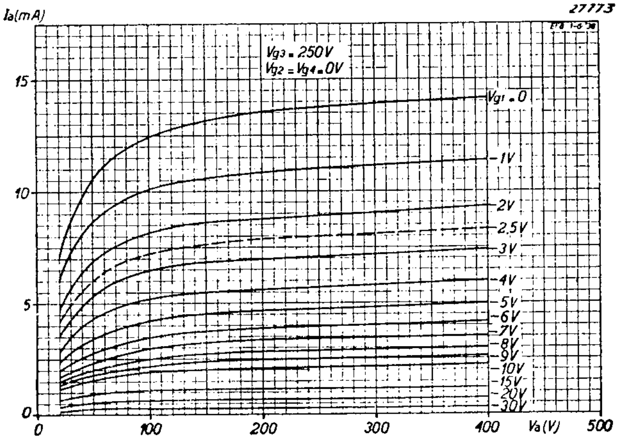


Fig. 5
Anode current as a function of the anode voltage, for various values of the bias on grid 1; grid 2 is connected to the cathode.

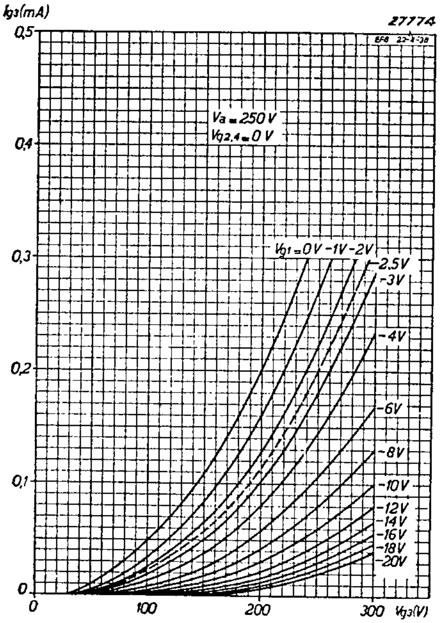


Fig. 6
Screen-grid current as a function of the screen voltage, for different values of grid bias; grid 2 connected to cathode.

in contrast with which that of the EF 5 is 2.6 mA and, due to this low current, the equivalent noise resistance does not exceed 3,200 ohms.

The corresponding value in the EF 5 is 15,000 ohms, which means that the EF 8 is five times better from the aspect of freedom from background noise.

At the same time, the valve, as such, is not the only source of noise; the circuits and resistors connected to the grid are also contributory factors and ultimate improvement in the signal-to-noise ratio is obtained more especially in certain particular cases. For example, if the impedance of the tuned circuit connected to the grid is, say, 10,000 ohms at 15 m, the arrangement may be regarded thus, that the noise in the first stage is produced by a resistance of 10,000 + 3,000 = 13,000 ohms; with the EF 5, the total noise resistance would be 10,000 + 15,000 = 25,000 ohms. Now the noise voltage of a resistance is proportional to the root of the resistance value, and this shows an improvement, in the case of EF 8, of $\sqrt{\frac{25,000}{13,000}} \cong 1.4$ times.

At the low-frequency end of the short-wave range, say at 50 m, the impedance of the circuit is usually much lower, being of the order of 3,000 ohms, and here the advantages of the EF 8 come more to the fore, since the total noise resistance, using that valve, becomes 6,000 ohms, as against 18,000 ohms in the case of the EF 5. This yields an improvement factor, with respect to freedom from noise, of $\sqrt{\frac{18,000}{6,000}} = 1.73$

On the other hand, in the medium- and long-wave ranges circuit impedances are much higher, being in the region of 100,000 ohms, and the preponderance of the noise, both with the EF 8 and the EF 5, is due to the circuit and not to the valve; the EF 8 then generally gives the better results. If, for any reason, the circuit impedances in these ranges are also comparatively low, the EF 8 will still ensure greater success.

In order to avoid an excessive signal

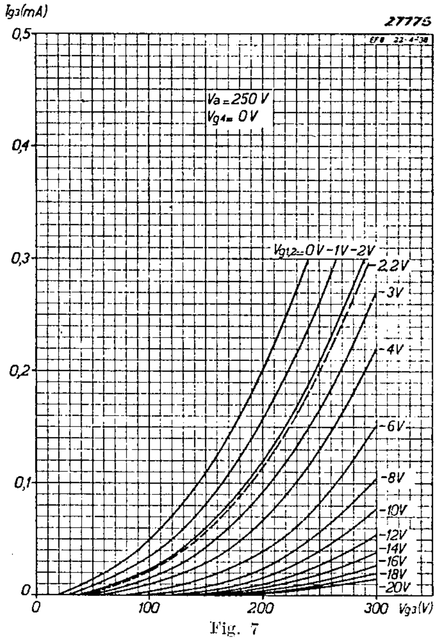


Fig. 7
Screen-grid current as a function of the screen voltage, for different values of grid bias; grid 2 connected to the bias of grid 1.

voltage being applied to the frequency-changer of a receiver employing R.F. amplification, the latter should not be too high, a factor of about 10 being quite sufficient. When "noisy" valves are used successive amplification should be suppressed somewhat to limit the noise, and this can be effected by taking a tapping from the second R.F. circuit. Conversely, if the valve is not noisy the amplification preceding the valve may be reduced so that also the R.F. valve will have weaker signals to handle, this being better from the point of view of reducing cross-modulation and modulation distortion. The signal on the R.F. valve is reduced by connecting the grid to a tapping in the circuit and this has the effect of considerably lessening the background noise.

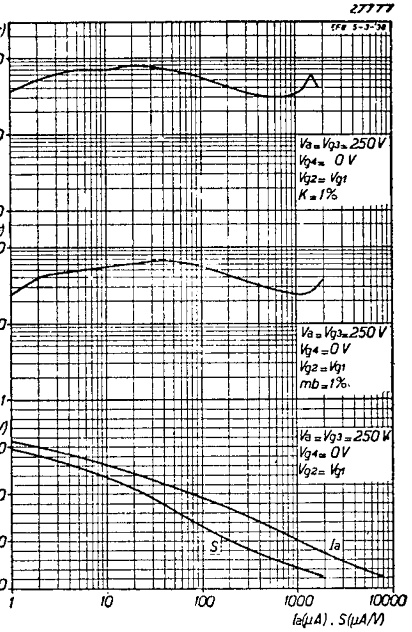


Fig. 9

Upper diagram. Effective alternating grid voltage as a function of the mutual conductance, with 1 % cross-modulation; grid 2 connected to control voltage on grid 1.

Centre diagram. Effective alternating grid voltage as a function of the mutual conductance, with 1 % modulation hum.

Lower diagram. Mutual conductance *S* and anode current *Ia* as a function of the grid bias.

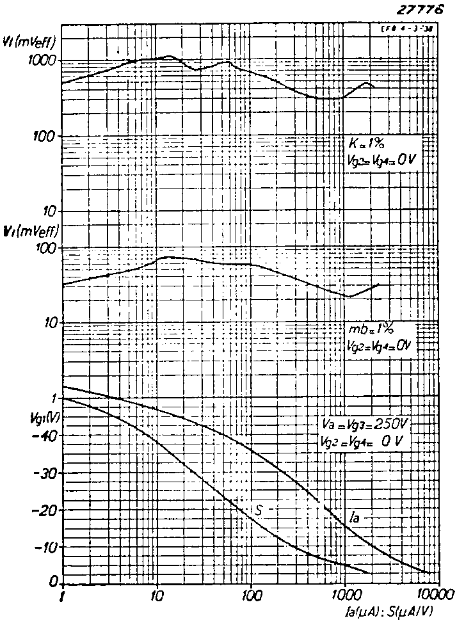


Fig. 8

Upper diagram. Effective alternating grid voltage as a function of the mutual conductance, with 1 % cross-modulation. Grid 2 connected to cathode.

Centre diagram. Effective alternating grid voltage as a function of the mutual conductance, with 1 % modulation hum.

Lower diagram. Mutual conductance *S* and anode current *Ia* as a function of the grid bias.

The noise resistance of the EF 8 increases according as the grid becomes more negative, but as a higher control voltage from the A.G.C. corresponds to a stronger signal the ratio of signal to noise is nevertheless improved.

On short waves the impedance values of the EF 8 are very good and ensure satisfactory amplification in this range: as the H.F. resistance between anode and grid, to earth, as compared with that of the ordinary practical circuit is quite high, amplification values can be obtained from the EF 8 in the short-wave range equal to the product of anode impedance and mutual conductance.

Grid 2 may be either connected direct to the cathode or it may be included with grid 1 in the automatic gain control circuit. In the latter case the control is more pronounced, but the cross-modulation curve is then not so good as when grid 1 is connected to the cathode: it is

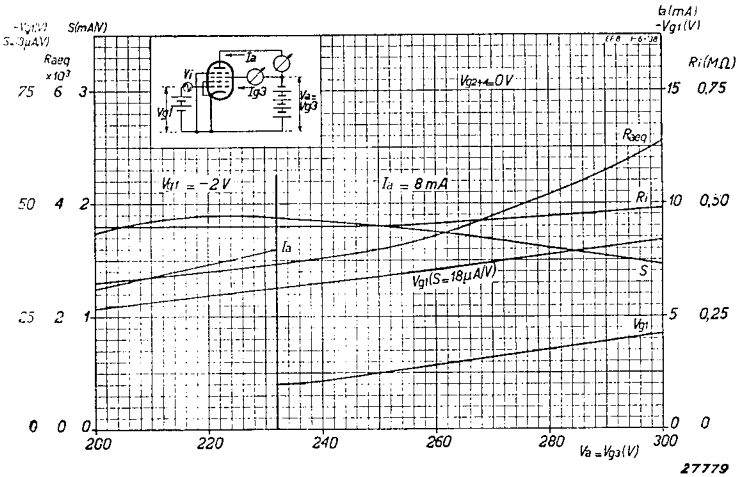


Fig. 10
Characteristics relating to various data as a function of the anode and screen-grid voltages; grid 2 connected to cathode. Left-hand side of the vertical line: at $Vg_1 = -2$ V; right-hand side: at $Ia = 8$ mA.

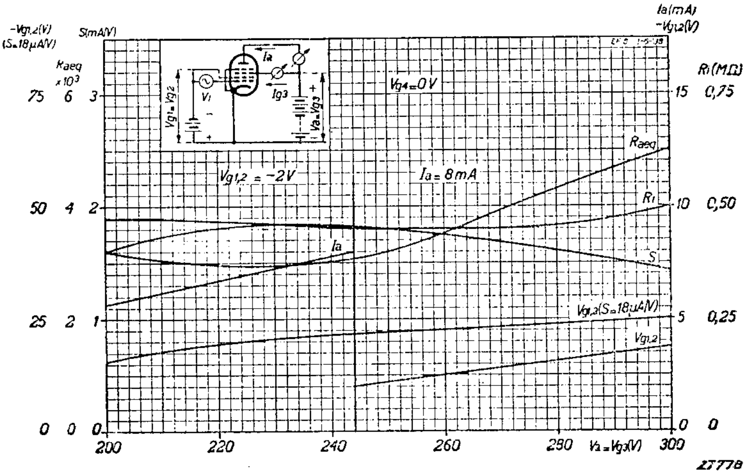


Fig 11.
Characteristics relating to various data as a function of the anode nda screen voltages. Grid 2 connected to control voltage on grid 1. Left-hand side of vertical line: $Vg_1 = Vg_2 = -2$ V. Right-hand side: $Ia = 8$mA

thus possible by means of the EF 8 to design A.G.C. circuits giving more, or less, control as required.

HEATER RATINGS

Heating: indirect, A.C. or D.C.; series or parallel supply.

Heater voltage	V_f	6.3 V
Heater current	I_a	= 0.200 A

CAPACITANCES

$C_{ag1} < 0.007\ \mu\mu F$
$C_{g1} = 4.6\ \mu\mu F$
$C_a = 7.8\ \mu\mu F$

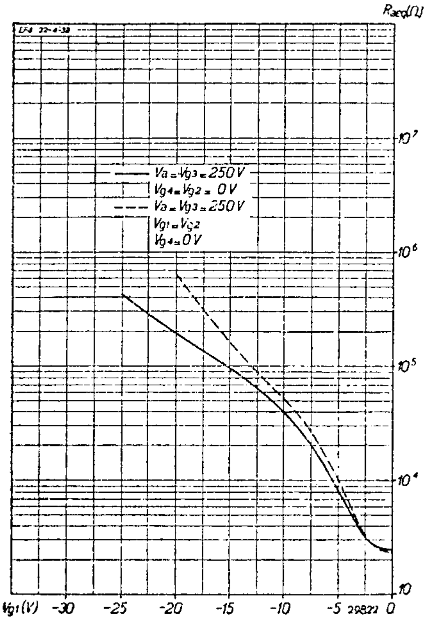


Fig. 12
Equivalent noise resistance as a function of the grid bias. The broken line refers to the case where grid 2 is connected to the control voltage on grid 1; the full line is for the grid connected to cathode.

OPERATING DATA: EF 8 employed as R.F. amplifier

(g_2 and g_4 connected to cathode).

Anode voltage	V_a	250 V		
Voltage on grid 2.	V_{g2}	0 V		
Screen-grid voltage	V_{g3}	250 V		
Voltage on grid 4.	V_{g4}	0 V		
Cathode resistor	R_k	305 ohms		
Grid bias.	V_{g1}	= —2.5 V ¹)	—34 V ²)	— 50 V ³)
Anode current	I_a	= 8 mA	—	—
Screen-grid current	I_{g3}	= 0,2 mA	—	—
Mutual conductance	S	= 1,800 μA/V	18 μA/V	1 μA/V
Internal resistance	R_i	= 0.45	> 10	> 10 M ohms
Equivalent noise resistance. . . .	R_{eq}	= 3,200 ohms	—	—

OPERATING DATA: EF 8 employed as R.F. amplifier

(g_2 connected to control voltage on grid 1; g_4 connected to cathode).

Anode voltage	V_a	= 250 V		
Screen-grid voltage	V_{g3}	= 250 V		
Voltage on grid 4.	V_{g4}	= 0 V		
Cathode resistor	R_k	= 265 ohms		
Grid bias (grids 1 and 2)	$V_{g1} = V_{g2}$	= —2.2 V ¹)	—22 V ²)	—28 V ³)
Anode current	I_a	= 8 mA	—	—
Screen-grid current	I_{g3}	= 0.2 mA	—	—
Mutual conductance	S	= 1,800 μA/V	18 μA/V	2.5 μA/V
Internal resistance.	R_i	= 0.45	> 10	> 10 M ohms
Equivalent noise resistance. . . .	R_{eq}	= 3,200 ohms	—	—

¹) Without control
²) Mutual conductance reduced to one - hundredth of uncontrolled value
³) Extreme limit of control.

MAXIMUM RATINGS

Anode voltage in cold condition	V_{ao}	= max. 550 V
Anode voltage	V_a	= max. 300 V
Anode dissipation	W_a	= max. 2.5 W
Screen voltage in cold condition	V_{g3o}	= max. 550 V
Screen voltage	V_{g3}	= max. 300 V
Screen dissipation	W_{g3}	= max. 0.08 W
Cathode current	I_k	= max. 12 mA
Grid voltage at grid current start ($I_{g1} = +0.3\,\mu$A)	V_{g1}	= max. —1.3 V
Grid voltage at grid current start ($I_{g2} = +0.3\,\mu$A)	V_{g2}	= max. —1.3 V
Resistance between grid 1 and cathode	R_{g1k}	= max. 3 M ohms
Resistance between grid 2 and cathode	R_{g2k}	= max. 3 M ohms
Resistance between filament and cathode	R_{fk}	= max. 20,000 ohms
Voltage between filament and cathode (direct voltage or effective value of alternating voltage)	V_{fk}	= max. 100 V

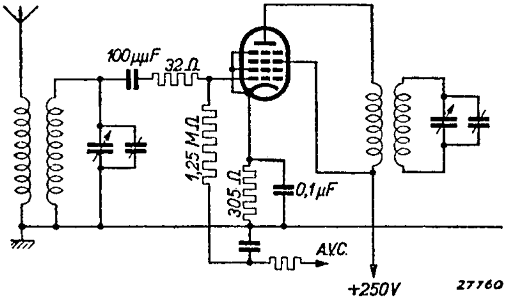


Fig. 13
Circuit diagram of the EF 8 used as R.F. amplifier in a superhet receiver with A.G.C. on grid 1 only.

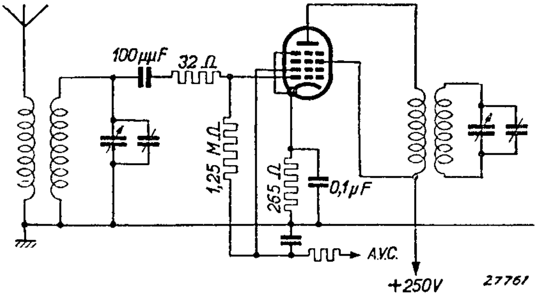


Fig. 14
As Fig. 13 but with A.G.C. on grids 1 and 2.

APPLICATIONS

The application of this valve is restricted to the first R.F. stage of a receiver. With respect to background noise it has outstanding properties in the short-wave range, as well as on medium and long waves. The very good cross-modulation characteristic, inter alia, is of considerable importance. Grid 3 may be connected direct or, better still, via a resistor of low value with decoupling capacitor, to the H.T. line. At voltages higher than 250 V it is necessary to increase the grid bias in order to avoid overstepping the scheduled maximum anode dissipation; this has the effect of reducing slightly the mutual conductance. Figs 10 and 11 give some useful data for this valve, at different values of anode and screen grid voltages.

EF 9 Variable-MU R.F. pentode

This is an R.F. or I.F. variable-mu pentode that can also be used as a resistance-coupled A.F. amplifier, with or without control of the amount of gain (A.G.C. operating also on the A.F. stage). The design of this valve differs from that of the EF 5 in that in place of a fixed screen potential the latter is made to vary on an increasing bias. Instead of taking the screen voltage from a potential divider the screen may be fed via a resistor. Without control the screen potential is adjusted, by means of the voltage drop across this resistor, to about 100 V. Due to the application of gain control the screen current drops and therefore also the potential difference across the resistor; the screen voltage thus rises again until, under full control, it approaches the value of the supply voltage. This varying voltage on the screen is referred to as "self-adjusting" or "sliding" screen voltage. The advantage of using a screen-grid series resistor is to be found in the fact that, assuming roughly equal cross-modulation conditions, the anode current without control is lower and the mutual conductance higher than in a valve with fixed screen voltage. For example, the anode current of the EF 9, at —2.5 V and 100 V screen, in the uncontrolled condition is 6 mA and the mutual conductance 2.2 mA/V, whereas in the case of the EF 5, at V_{g1} = —3 V and V_{g2} = 100 V, the anode current is 8 mA and the mutual conductance 1.7 mA/V.

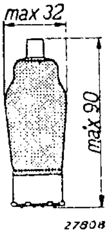


Fig. 1
Dimensions in mm.

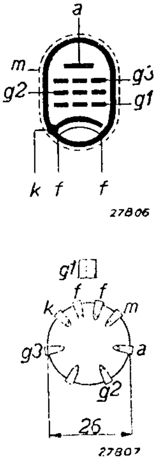


Fig. 2
Arrangement of electrodes and base connections.

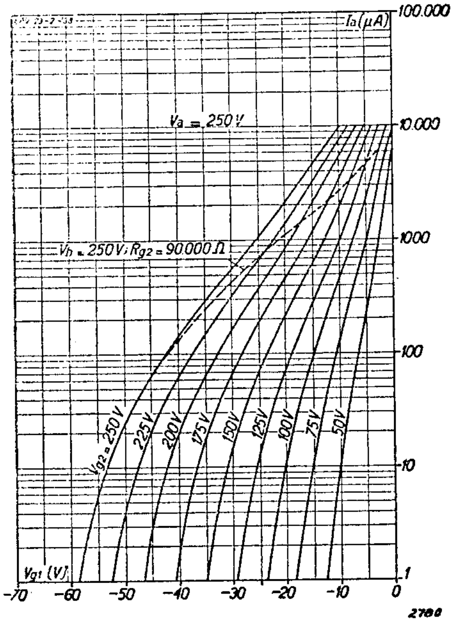


Fig. 3
I_a/V_{g1} characteristics using V_{g2} as parameter. The broken line shows the anode current with control applied to the valve, with the screen fed through a resistance of 90,000 ohms from a supply voltage of 250 V.

When the screen voltage rises the I_a/V_{g1} characteristic is displaced to the left and, if the curve has a short "tail" when the valve is in the uncontrolled condition, this will steadily increase in size as the screen voltage rises: the logarithmic I_a/V_{g1} characteristics with respect to different screen potentials shown in Fig. 3 will confirm this fact. Arising from these circumstances it may be said that, although the I_a/V_{g1} characteristic for the uncontrolled valve has only a short tail, the cross-modulation properties during the time that control is applied are considerably better than if the screen voltage were constant.

On a supply voltage of 250 V the screen-grid series resistor must be 90,000 ohms in order to obtain 100 V on the screen without control. As there is a different screen voltage for

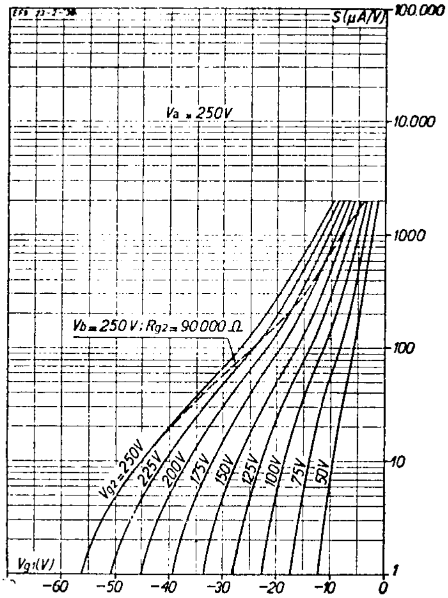


Fig. 4
Mutual conductance as a function of the grid bias, with V_{g2} as parameter. The broken line represents the mutual conductance of the valve when under control, with a screen-grid series resistor of 90,000 ohms and a supply voltage of 250 V.

every value of the grid bias, the anode current plotted against grid bias is shown by a broken line. An alternating grid voltage does not affect the screen voltage, since the screen is decoupled with a capacitor and in this case the anode current varies in accordance with the I_a/V_{g1} characteristic relating to the appropriate grid bias.

According to Fig. 3, the screen voltage at 12.5 V bias is 175 V, so that at this bias value the I_a/V_{g1} characteristic refers to $V_{g2} = 175$ V.

On other supply voltages the screen-grid resistor must be adjusted accordingly and the control curve is thereby slightly modified; for instance on a 200 V supply (as in A.C./D.C. sets) 60,000 ohms will be required to produce 110 V screen voltage without control. The anode voltage will then fall rather more rapidly. On a supply of 100 V, however, the sliding screen voltage no longer functions and the valve has therefore to be used with a fixed screen potential. In this case the I_a/V_{g1} characteristic for $V_{g2} = 100$ V shown in Fig. 3 applies. If a potential divider is used for feeding the screen it is possible to obtain a more rapid controlling effect than with fixed screen potential by a judicious arrangement of the resistance values in the network, but it should be borne in mind that the cross-modulation characteristic is then not quite so good. By means of the I_{g2}/V_{g2} curves in Fig. 10 the various values can be determined for each particular case in advance.

A suitable choice of control curve will also guarantee excellent modulation-hum characteristics, this being of especial importance when dealing with A.C./D.C. mains receivers.

A special feature of the EF 9 is the very low interelectrode capacitance; the anode-to-grid capacitance is less than 0.002 μμF and the valve therefore gives very good results

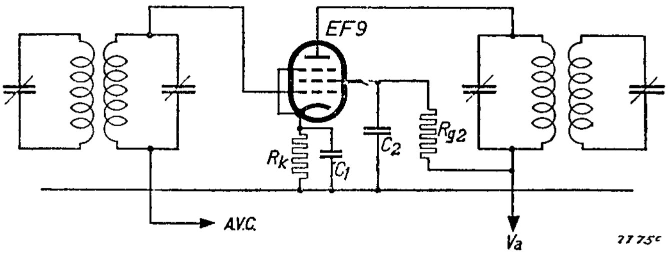


Fig. 5
Theoretical circuit diagram of an I.F. valve employing the principle of the "sliding" screen voltage.

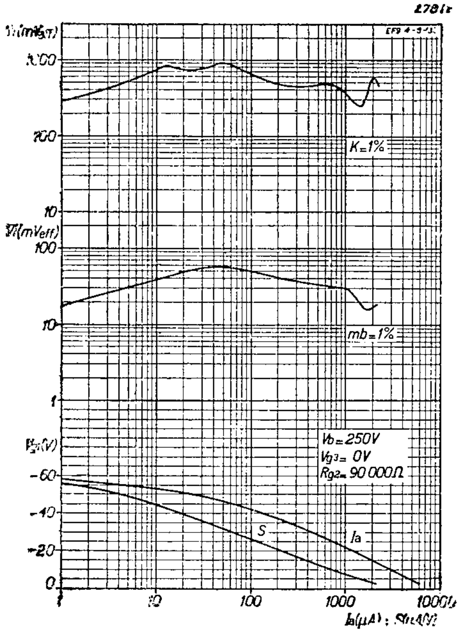


Fig. 6

Upper diagram. Effective alternating grid voltage as a function of the mutual conductance, with 1 % cross-modulation; screen fed via a resistor of 90,000 ohms from 250 V supply.
Centre diagram. Effective alternating grid voltage as a function of the mutual conductance, with 1 % modulation hum.
Lower diagram. Mutual conductance S and anode current Ia as a function of the grid bias.

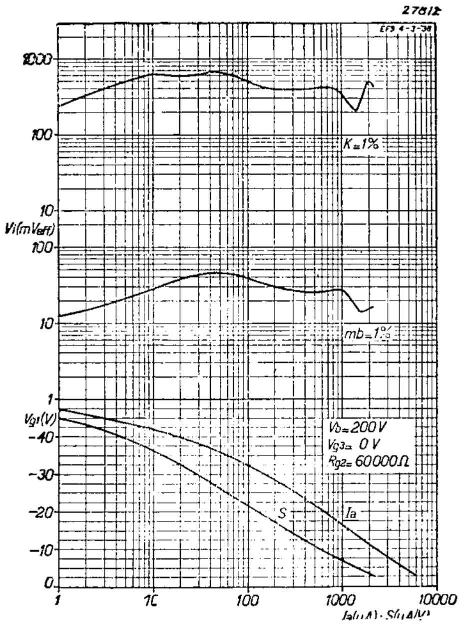


Fig. 7

Upper diagram. Effective alternating grid voltage as a function of the mutual conductance with 1 % cross-modulation; screen grid fed via a resistor of 60,000 ohms from a 200 V supply.
Centre diagram. Effective alternating grid voltage as a function of the mutual conductance, with 1 % modulation hum.
Lower diagram. Mutual conductance S and anode current Ia as a function of the grid bias.

in the short-wave range. Although in this range the magnification of the circuits is usually only fair, the EF 9 will ensure a high degree of amplification.

As already mentioned, the EF 9 can also be employed as a resistance-coupled A.F. amplifier; by applying a control voltage to the grid the amplifier may be so regulated that the performance of the A.G.C. of the receiver is enhanced by the A.F. stage. The relevant data will be found in the table on page 276.

HEATER RATINGS

Heating: indirect, A.C. or D.C., series or parallel supply.
Heater voltage . . . . $V_f = 6.3$ V
Heater current . . . . $I_f = 0.200$ A

CAPACITANCES

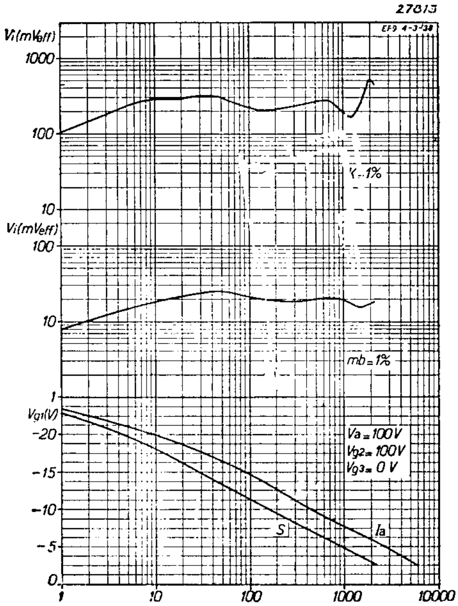
$C_{ag1} < 0.002\ \mu\mu\text{F}$
$C_{g1} = 5.5\ \mu\mu\text{F}$
$C_a = 7.2\ \mu\mu\text{F}$

Fig. 8

Upper diagram. Effective alternating grid voltage as a function of the mutual conductance with 1 % cross-modulation, at $Va = 100$ V, $Vg_2 = 100$ V (fixed).

Centre diagram. Effective alternating grid voltage as a function of the mutual conductance with 1 % modulation hum.

Lower diagram. Mutual conductance S and anode current Ia as a function of the grid bias.



OPERATING DATA: EF 9 used as R.F. or I.F. amplifier

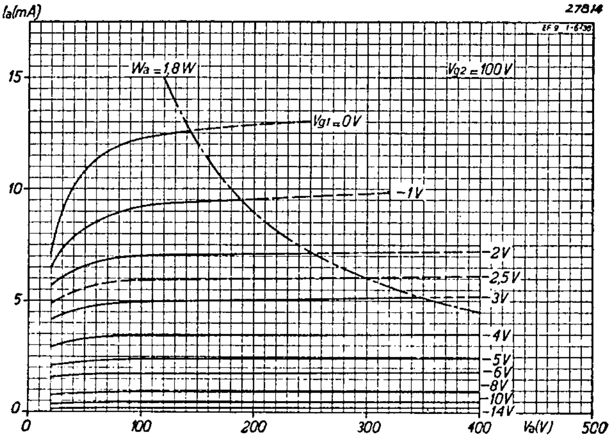
Anode voltage	V_a	= 250 V		
Suppressor grid voltage	V_{g3}	= 0 V		
Screen-grid series resistor	R_{g2}	= 90,000 ohms		
Cathode resistor	R_k	= 325 ohms		
Grid bias	V_{g1}	= —2.5 V ¹)	—39 V ²)	—49 V ³)
Screen voltage	V_{g2}	= 100 V	—	250 V
Anode current	I_a	= 6 mA	—	—
Screen current	I_{g2}	= 1.7 mA	—	—
Mutual conductance	S	= 2,200	22	4.5 μA/V
Internal resistance	R_i	= 1.25	> 10	> 10 M ohms

Anode voltage	V_a	= 200 V		
Suppressor grid voltage	V_{g3}	= 0 V		
Screen-grid series resistor	R_{g2}	= 60,000 ohms		
Cathode resistor	R_k	= 325 ohms		
Grid bias	V_{g1}	= —2.5 V ¹)	—32 V ²)	—39 V ³)
Screen voltage	V_{g2}	= 100 V	—	200 V
Anode current	I_a	= 6 mA	—	—
Screen current	I_{g2}	= 1.7 mA	—	—
Mutual conductance	S	= 2,200	22	5.5 μA/V
Internal resistance	R_i	= 0.9	> 10	> 10 M ohms

Anode voltage	V_a	= 100 V		
Suppressor-grid voltage	V_{g3}	= 0 V		
Screen-grid voltage	V_{g2}	= 100 V		
Cathode resistor	R_k	= 325 ohms		
Grid bias	V_{g1}	= —2.5 V ¹)	—16 V ²)	—19 V ³)
Anode current	I_a	= 6 mA	—	—
Screen current	I_{g2}	= 1.7 mA	—	—
Mutual conductance	S	= 2,200	22	7 μA/V
Internal resistance	R_i	= 0.4	> 10	> 10 M ohms

¹) Without control. ²) Mutual conductance reduced to one-hundredth of uncontrolled value. ³) Extreme limit of control range.

Fig. 9
Anode current as a function of the anode voltage at different values of the grid bias, with a fixed screen voltage of 100 V.



MAXIMUM RATINGS

Anode voltage in cold condition . . . . V_{ao} = max. 550 V
Anode voltage . . . . V_a = max. 300 V
Anode dissipation . . . . W_a = max. 2 W
Screen voltage in cold condition . . . . V_{g2o} = max. 550 V
Screen voltage at I_a = 6 mA . . . . V_{g2} = max. 125 V
Screen voltage at I_a = 3 mA . . . . V_{g2} = max. 300 V
Screen-grid dissipation . . . . W_{g2} = max. 0.3 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
Resistance between grid and cathode . . . . R_{g1k} = max. 3 M ohms
Resistance between filament and cathode . . . . . R_{fk} = max. 20,000 ohms
Voltage between filament and cathode (direct voltage or effective value of alternating voltage) . . . . V_{fk} = max. 100 V

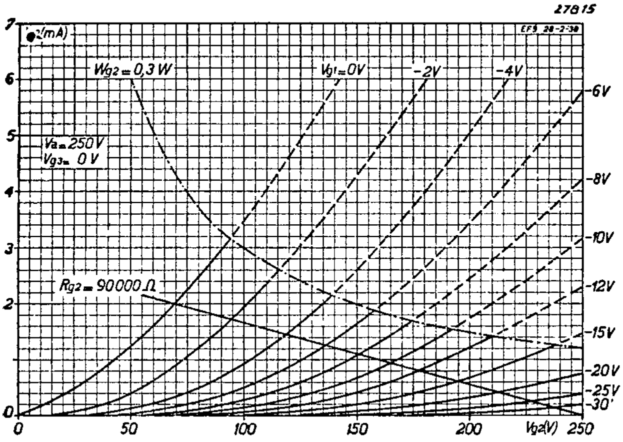


Fig. 10
Screen current as a function of the screen voltage at different values of the grid bias. These curves also apply as an approximation to anode voltages between 100 and 250 V.

For data referring to the use of the valve as a resistance-coupled A. F. amplifier see Table on p. (272).

The EF 9 is used as amplifier valve with manually or automatically controlled amplification. The heating-up time is shorter than usual and the cathode insulation is rated to carry 100 V direct voltage or effective value of the alternating voltage; this value should not be exceeded.

EFM 1 A.F. Amplifier and electronic indicator

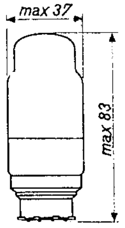


Fig. 1
Dimensions in mm.

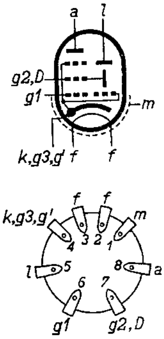


Fig. 2
Arrangement of electrodes and base connections.

The EFM 1 combines a variable-mu A.F. amplifier pentode with an electronic indicator, the former being the lower of the two assemblies in the envelope; a conical fluorescent screen, of the type used in the EM 1, is mounted above the pentode unit, so as to be visible at the top of the envelope. The cathode extends into the space formed by the fluorescent screen and is screened off, so that the light emitted by the cathode will not be visible; this screen is supported on two rods, arranged in such a manner that they are invisible from the outside. Between the cathode and the screen, a grid and two deflectors are mounted; the grid is wound without backbones and is supported only at the ends. A space charge thus occurs in front of the grid and this promotes a more uniform flow of electrons to the fluorescent screen. Further, on very weak signals, when the fluorescing areas are only small, the electron stream is thus confined to a relatively small working area of the screen. The two deflector rods are connected to the screen grid of the pentode unit and two fluorescent spots appear on the screen.

The pentode section is designed on the sliding screen-voltage principle, the screen, therefore, being fed through a resistor. When the A.G.C. voltage is applied to the grid the screen current drops and the voltage on the screen, and therefore also on the deflectors, increases. The fluorescent screen being connected directly to the supply voltage, the difference between the potential of the deflector electrodes and that of the fluorescent screen decreases, as also the deflecting effect of the two electrodes, in consequence of which the fluorescent areas are increased and the dark sections decreased in size. As the screen grid is decoupled by a capacitor, it is possible simultaneously to apply A.F. voltages to the grid, without affecting the size of the luminous sectors. The anode circuit may be resistance-coupled to the next valve for further amplification of the A.F. signal.

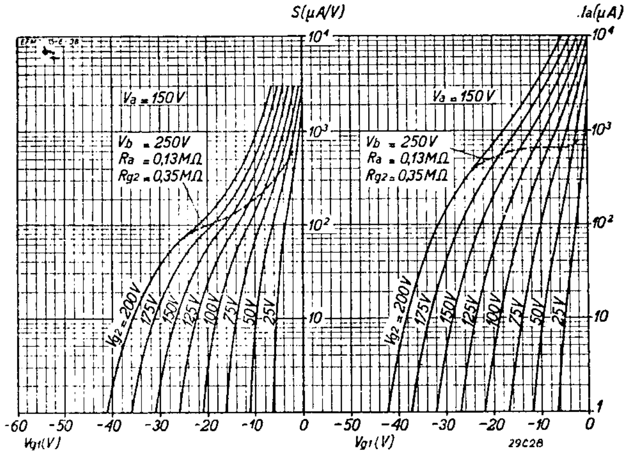


Fig. 3

Right-hand diagram. Anode current as a function of the grid bias, with screen voltage as parameter. These curves relate to an anode voltage of 150 V. The broken line represents the dynamic characteristic at Vb = 250 V, Rg_2 = 0.35 M Ohm and Ra = 0.13 M Ohm.

Left-hand diagram. Mutual conductance as a function of the grid bias, with screen voltage as parameter. These curves are in respect of an anode voltage of 150 V. The broken line refers to the mutual conductance as a function of the grid bias, using a screen-grid resistor of 0.35 M Ohm and an anode resistor of 0.13 M Ohm, both on a 250 V supply.

To produce the desired indication of the correct receiver tuning, the direct voltage from the detector diode, or the A.G.C. control vol-

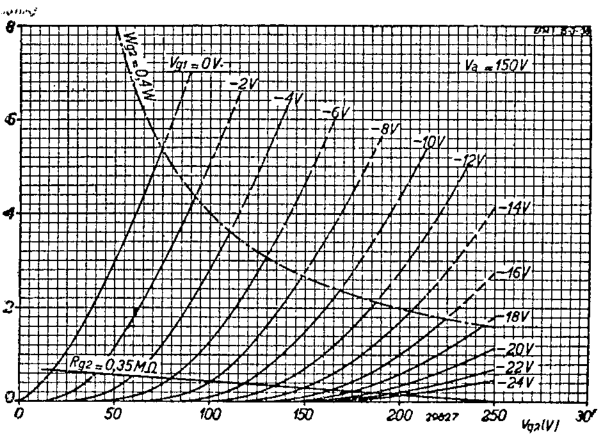


Fig. 4
Screen-grid current as a function of the screen voltage, with grid bias as parameter: resistance-line for Rg_2 = 350,000 ohms.

tage is applied to the grid. When a strong signal arrives at the diode the grid of the EFM 1 is rendered strongly negative and the amplification is reduced, which means, of course, that the A.F. amplification stage is included in the A.G.C. This combination of electronic indicator and A.F. pentode thus virtually automatically furnishes a variable-mu A.F. amplifier, and a pentode of this type must necessarily meet the requirement that distortion shall remain low throughout the whole range of control. The pentode part of the EFM 1 is designed to give an amplification factor of about 60 with an anode resistor of 130,000 ohms and a screen series resistor of 350,000 ohms, with —2 V grid bias. By increasing the bias from —2 to —20 V the amplification is reduced from 60 to roughly 13, giving a control of 1: 4.5, and this extra amount of control can be put to good use where effective automatic gain control is required.

The above variation in grid bias just corresponds to the full deflection of the fluorescent bands and the construction of the screen grid is such as to ensure a constant anode current over the whole of the range. The amount of distortion is therefore also fairly constant and, at the same time, well within the ordinary practical limits. In order to suppress distortion, a fairly high control voltage is needed for the amplifier section of the valve, so that per degree of deflection in the indicator a greater voltage variation must be established on the grid of the EFM 1 than is the case with, say, the tuning indicator EM 1.

The use of the combined amplifier — indicator makes it possible to reduce the total number of valves required for many different types of radio receiver, without dispensing with electronic indication, or reducing the sensitivity. As this valve is necessarily a compromise, however, it must not be expected that it will give results in every way comparable

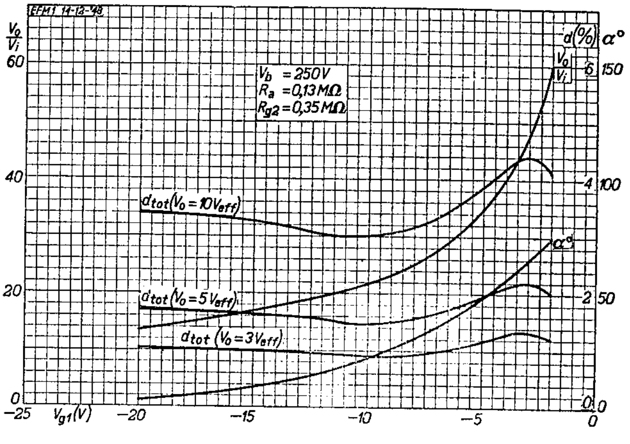


Fig. 5
Distortion as a function of the grid bias, with alternating output voltage as parameter, at Rg_2 = 350,000 ohms, Ra = 130,000 ohms and Vb = 250 V; also shadow angle α as a function of the grid bias.

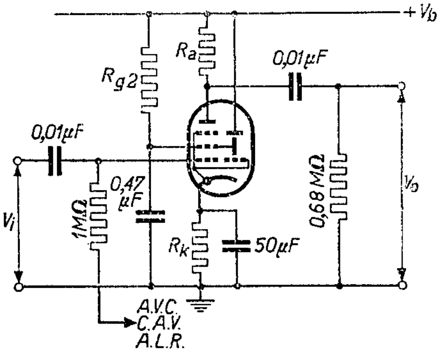


Fig. 6
Circuit diagram illustrating the symbols used in the relevant data.

with those of an A.F. amplifier with separate indicator.

The EFM 1 has no diodes for detection and will therefore be frequently used in conjunction with the double-diode I.F. pentode EBF 2; it can also be employed successfully with a separate diode such as the EAB 1 or EB 4.

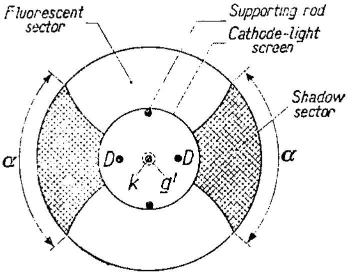


Fig. 7
Sketch of the fluorescent screen, showing the light and dark sectors.

HEATER RATINGS

Heating: indirect, A.C. or D.C., series or parallel supply.

Heater voltage	V_f	= 6.3 V
Heater current	I_f	= 0.200 A

OPERATING DATA

Supply and fluorescent screen voltage	$V_b = V_l$ =	250 V	
Anode resistor	R_a =	130,000 ohms	
Screen-grid series resistor	R_{g2} =	350,000 ohms	
Cathode resistor	R_k =	980 ohms	
Grid bias in uncontrolled condition	V_{g1} =	—2 V	—
Grid bias with full control	V_{g1} =	—	—20 V
Anode current	I_a =	0.8 mA	0.5 mA
Screen-grid current	I_{g2} =	0.6 mA	0.2 mA
Current on fluor. screen	I_l =	0.65 mA	0.8 mA
Screen-grid voltage	V_{g2} =	40 V	180 V
Anode voltage	V_a =	146 V	185 V
Voltage gain	V_o/V_i =	60	13
Distortion at 5V (eff) A.C. anode	d_{tot} =	2 %	1.7 %
Shadow angle of single sector, measured at edge of screen	α	> 70°	< 5°

MAXIMUM RATINGS

Anode voltage in cold condition	V_{ao}	= max. 550 V
Anode voltage	V_a	= max. 300 V

Anode dissipation	W_a	= max. 0.4 W
Screen-grid voltage in cold condition	V_{g2o}	= max. 550 V
Screen-grid voltage	V_{g2}	= max. 300 V
Screen-grid dissipation	W_{g2}	= max. 0.4 W
Voltage on fluorescent screen in cold condition	V_{lo}	= max. 550 V
Voltage on fluorescent screen	V_l	= max. 300 V
Voltage on fluorescent screen	V_l	= min. 200 V
Cathode current	I_k	= max. 5 mA
Grid voltage at grid current start (I_{g1} = + 0.3 μA)	V_{g1}	= max. —1.3 V
Screen-grid current under same conditions	I_{g2}	= min. 0.53 mA
Resistance between grid and cathode	R_{g1k}	= max. 3 M ohms
Resistance between filament and cathode	R_{fk}	= max. 20,000 ohms
Voltage between filament and cathode (direct voltage or effective value of A.C. voltage)	V_{fk}	= max. 100 V

APPLICATIONS

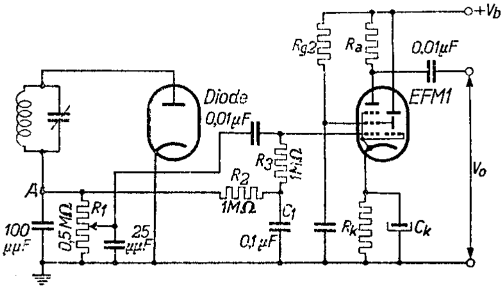


Fig. 8
Circuit diagram showing EFM 1 used as variable A. F. amplifier and electronic indicator, following a diode-detector stage.

The EFM 1 can be used only as an A.F. amplifier combined with an electronic indicator, and Fig. 8 shows the theoretical circuit of the valve in conjunction with a preceding, detector, valve. The R.F. signal from the diode resistor R_1 is fed through a capacitor to the grid of the EFM 1 and the negative D.C. voltage across the grid leak is fed from A, by way of resistors R_2 and R_3, also to this grid. Resistor R_2 and capacitor C_1 make up a smoothing filter for the A.F. voltage occurring across the diode resistor, to ensure that only direct voltage reaches the grid of the EFM 1 along this path. R_3 is the grid leak.

The negative D.C. voltage for the control of the EFM 1 is usually taken from the detector diode; it can be derived also from the A.G.C. diode, but in the case of delayed automatic gain control the cathode-ray indication, on signals of the strength less than that of the delay voltage, will then not function.

In view of possible microphony, the A. F. sensitivity at the grid of the EFM 1 should not be too great and care should be taken when mounting the valve itself that no trouble can occur through acoustic vibration. If a steep-slope output valve such as the EL 3 is used in the next stage, it is advisable to reduce the sensitivity by applying sufficient negative feed-back. To prevent hum, the direct voltage applied to the anode coupling resistor must in every case be smoothed by an R.C. filter, but no allowance has been made for this filter in the data and characteristics, since these will depend on each individual case and will also differ according to the supply voltage employed.

Practical applications of the EFM 1 are confined to two possibilities. One is the improvement of the A.G.C. of a receiver, by virtue of the fact that the control voltage applied to the grid is also operative on the EFM 1. As already stated, the A.F. gain in the case of a high-mutual-conductance output valve may be reduced by means of negative feed-back; if the cathode capacitor of the EL 3 be omitted, the negative feed-back factor will be about $2^1/_2$, but this does not represent a sufficient reduction in the sensitivity and the only alternatives are to use a higher value of cathode resistor for the output valve, or to reduce the gain of the EFM 1 in the uncontrolled condition. To ensure the proper amount of grid bias the grid of the EL 3 should, in the first instance, be connected to a tapping on the cathode resistor; a value of 500 ohms for the latter gives a feed-back factor of about $4^1/_2$ and will ensure sufficient reduction in the sensitivity. Naturally, however, this amount of feed-back is obtained at the expense of the optimum output power; with a resistor of R_k = 500 ohms, the maximum obtainable output is not more than about 3.3 W and for this reason preference is usually given to a reduction in the amplification of the EFM 1. This can also be achieved by using a higher value for the cathode resistor, but it will result in a smaller variation in the shadow angle of the indicator (see also Fig. 5). A cathode resistor of, say, 2,000 ohms provides a bias of about —4 V; the corresponding amplification factor is then 40 instead of 60 and the range of deflection of the indicator is thereby reduced from 5—75° to 5—65°.

Another method consists in the use of a lower anode coupling resistor than the value of 130,000 ohms suggested; a smoothing resistor is then connected in series with it to bring the value up to 130,000 ohms, or the appropriate higher value in the case of higher supply voltages.

One result of the limited feed-back when using high-mutual-conductance output valves (EL 5 or EL 6) is that the A.F. sensitivity is still quite high. As the reader will be aware, the strength of the I.F. signal to be applied to the detector diode and, therefore, also the delay voltage for the A.G.C. is determined by the amount of A.F. gain. When the A.F. sensitivity is high it is not necessary to have a large signal strength at the detector and this leaves only small voltages available for controlling the EFM 1; this means, in effect, that the dark sectors will be reduced only on very weak signals, or that the electronic indicator will be relatively insensitive.

A still greater reduction in the A.F. sensitivity than by means of simple feed-back in a steep-slope output valve may be obtained by means of a valve having low A.F. sensitivity, such as the triode AD 1, in which case the sensitivity of the indicator will be greatly improved.

Notwithstanding the higher alternating output voltage of the EFM 1 necessary to load fully the AD 1, the distortion is extremely slight; on an average, the distortion from the combination of EFM 1 + AD 1 is less than in the AD 1 alone, this being due to the compensation of the second harmonics.

The second course open in the application of the EFM 1 consists in shifting the point of equilibrium of the sensitivity of the indicator unit in such a way that it will contribute less towards the A.G.C. In this case a higher D.C. voltage is required at the detector and therefore also a stronger I.F. signal, with less A.F. amplification; the latter may be reduced by means of strong negative feed-back. Since negative feed-back produced by the omission of the cathode capacitor from the output valve results in a considerable loss of output power, it is necessary to feed back from the loudspeaker to the grid of the EFM 1. Voltage feed-back to the EFM 1 has the advantage that the A.F. gain can be reduced at will by increasing the amount of coupling, whilst, further, the internal resistance of the output stage is reduced instead of increased, as in the case of current-coupling by omission of the cathode capacitor. In this way it is possible to include in the feed-back circuit components which are dependent on the frequency, so as to improve the frequency characteristic.

The object of this voltage feed-back, then, is to stabilize the amount of gain, but a great part of the A.F. gain control is thereby lost. On a strong carrier wave the EFM 1 can be fully controlled, in which case the amplification is lower and the negative feed-back weaker; there is also less distortion.

COMBINATION OF EFM 1 and EBF 2

When the EFM 1 is used as L.F. amplifier the EBF 2 will often be selected to serve as I.F. amplifier and detector, and this arrangement opens two possibilities:

1) EFM 1 as A.F. amplifier with weak negative feed-back on the output valve; the electronic indicator is then more or less insensitive.

2) EFM 1 as A.F. amplifier with strong feed-back from the loudspeaker to this valve. It has already been mentioned that the A.F. gain must be on the low side if a good tuning indication is to be obtained; in this case the delay voltage should be somewhat higher (5 to 6 V). The most suitable circuit is shown in the diagram of Fig. 9; the cathode voltage of the EBF 2 is 5—6 V and the cathode of the EFM 1 is connected to that of the EBF 2 through a resistor R_3 the voltage drop of which supplies the grid bias for the EFM 1. This resistor is not capacitively decoupled and it serves also as part of the potential divider for the negative feed-back.

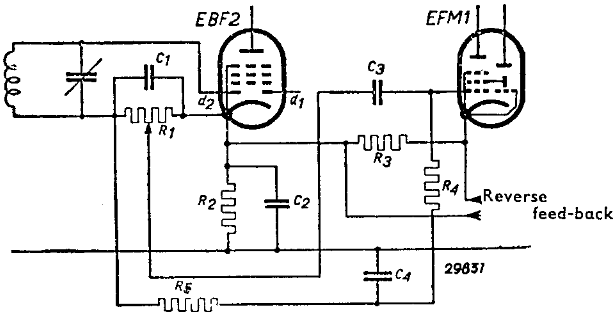


Fig. 9
Circuit diagram showing the EFM 1 used in conjunction with the EBF 2 with negative feed-back to the former.

When the EFM 1 is employed with negative feed-back the delay voltage from the A.G.C. must be higher than the normal cathode voltage of the EBF 2 (2 V), firstly in order to load fully the output valve and secondly so as not to limit the operation of the electronic indicator on weak signals. For, if the A.G.C. comes into operation before the output valve is fully loaded the direct voltage on the detector, for the same signal, is restricted and the sensitivity of the indicator reduced. A delay of 5 to 6 V is in most cases sufficient.

One complication to be taken into account is as follows. If efforts are directed towards less A.F. amplification, not by means of negative feed-back, but by using an output stage of lower sensitivity (e.g., the AD 1), the increased control on the EFM 1 will mean that the total A.F. gain on increasing signal strengths will again be reduced. In consequence, a very much stronger signal is needed at the detector to load fully the output valve on strong incoming signals than would be the case if the A.F. control were compensated by the negative feed-back, i.e., the delay voltage of the A.G.C. should be higher than the value suggested, and this in turn introduces still greater obstacles in the control of the EBF 2. It will therefore be appreciated that the use of negative feed-back is much to be preferred in reducing the A.F. gain subsequent to the detector stage.

EH 2 Heptode

This pentagrid valve can be employed very successfully on very short wavelengths as a controlled modulator in conjunction with a separate oscillator, and also as R.F. or I.F. amplifier with limited control range.

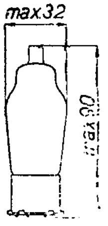


Fig. 1
Dimensions in mm

The action of this valve is similar to that of a hexode in that, when used as modulator, the input signal is applied to the first grid and the oscillator signal to the third. The 2nd and 4th grids are screen grids having their own separate contacts on the base of the valve. The fifth grid which, regarded superficially, constitutes the main point of difference with the earlier type of hexode, is a suppressor grid, whose purpose is to improve the internal resistance and to ensure satisfactory performance when the valve is used in A.C./D.C. receivers with 100 V on the anode.

When the EH 2 is employed as frequency-changer a separate oscillator has many advantages; a triode such as the EBC 3 has an initial mutual conductance (at $Vg = 0$, $S = 3.0$ mA/V) that will guarantee stability of oscillation also in the short-wave range. A variable-mu modulator valve should meet the following requirements:

1) Conversion conductance should be sufficiently high.
2) Required oscillator voltage should be as low as possible.
3) Currents due to transit-time must not occur.

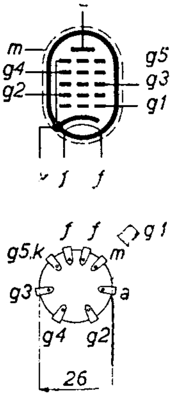


Fig. 2
Arrangement of electrodes and base connections.

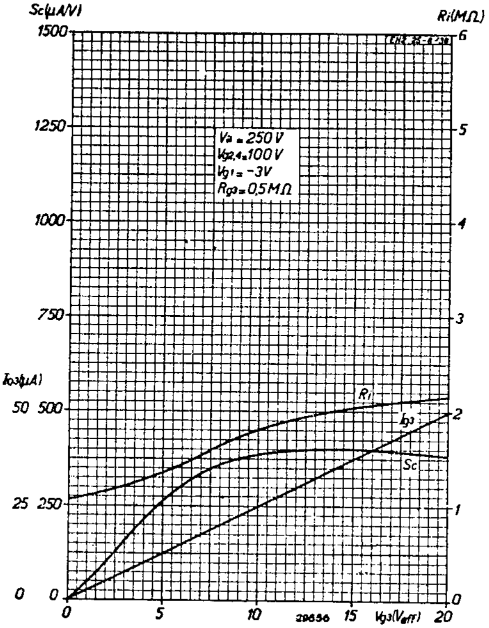


Fig. 3
Conversion conductance, internal resistance and oscillator-grid current as a function of the oscillator voltage on grid 3, at 250 V anode, 100 V screen and -3 V bias on grid 1.

4) Parallel input impedance should remain as high as possible, down to the very shortest wavelengths.
5) A satisfactory compromise between the least possible background noise, narrow range of bias for full control of the valve and also least possible cross-modulation.
6) Negligible frequency drift arising from the automatic gain control or from mains voltage variations.
7) Least possible coupling between input and oscillator circuits (inductive effect).

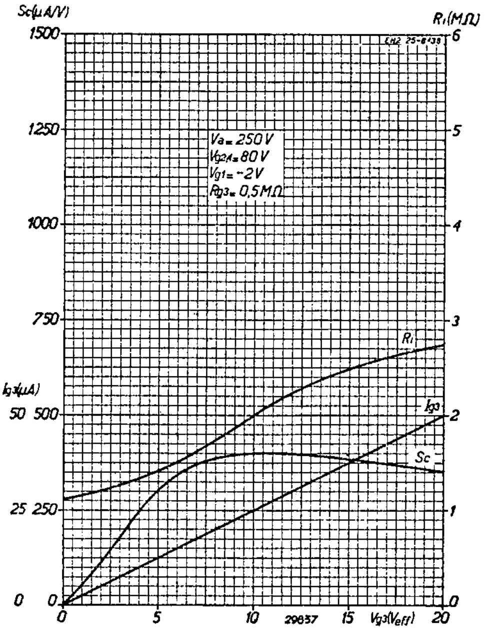


Fig. 4
Conversion conductance, internal resistance and oscillator current as a function of the oscillator voltage on grid 3, with 250 V anode, 80 V screen and –2 V bias on grid 2.

1) In the EH 2 the required conversion conductance is ensured by the high conductance of the 1st grid with respect to the anode current (when using this valve as a straight amplifier and at $V_{g3} = 0$). This conductance is 1.8 mA/V.

2) With regard to the required oscillator voltage, the characteristic of the conductance of the first grid in relation to the anode current, as a function of the voltage on the 3rd grid, is the deciding factor. The more steeply this characteristic drops when the bias on the 3rd grid (V_{g3}) is increased, the lower the peak oscillator voltage on the grid. Due to the particular construction of the first grid, this conductance is so high that when grids 2 and 4 are given a potential of 100 V the oscillator voltage necessary for the normal conversion conductance is approximately 14 V_{eff}, which can be supplied by any ordinary oscillator. Figs 3 and 4 reproduce the conversion conductance as a function of the oscillator voltage and these figures show that the values at very much lower oscillator voltages are still quite reasonable. This is important for short-wave reception.

3) The question of transit time current has also been satisfactorily dealt with. The electrons encounter a certain amount of delay in the field between grids 2 and 3, but at very high frequencies some of them, as a result of the alternating field produced by the oscillator voltage on grid 3, acquire so much kinetic energy that, despite the negative bias on grid 1,

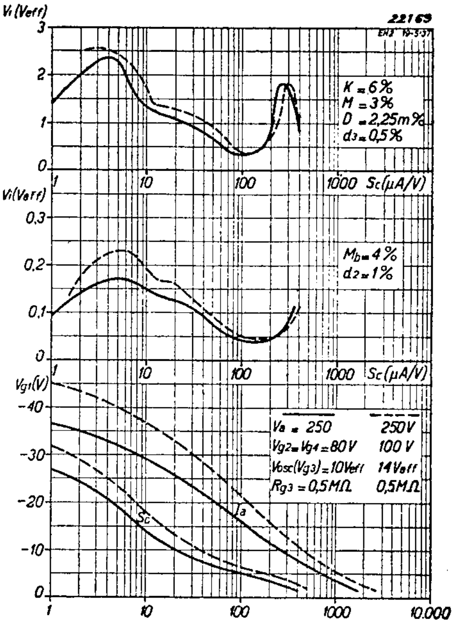


Fig. 5
Upper diagram. EH 2 used as a frequency changer. Alternating input voltage as a function of the conversion conductance as controlled by the bias on grid 1, with 6 % cross-modulation.
Centre diagram. Alternating input voltage as a function of the conversion conductance as controlled by the bias on grid 1, with 4 % modulation hum.
Lower diagram. Conversion conductance and anode current as a function of the bias on grid 1

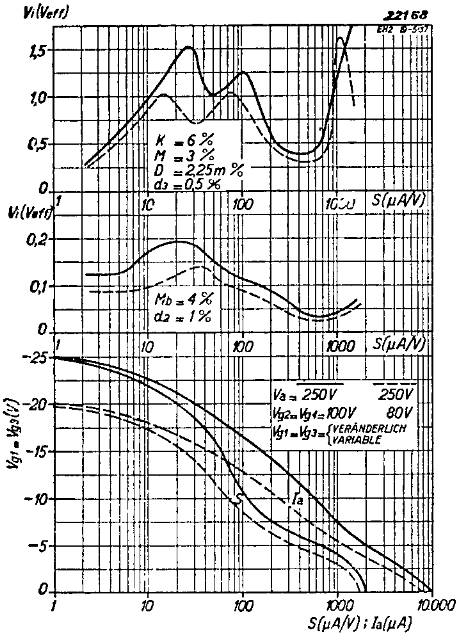


Fig. 6

EH 2 used as an R.F. or I.F. amplifier.
Upper diagram. Alternating input voltage as a function of the mutual conductance when controlled by a similar bias on grids 1 and 3, with 6 % cross-modulation.
Centre diagram. Alternating input voltage as a function of the mutual conductance when controlled by the bias on grids 1 and 3, with 4 % modulation hum.
Lower diagram. Mutual conductance and anode current as a function of the bias on grids 1 and 3.

they return in the direction of this grid: this will take place when the period of the alternating field corresponds in order of size to that of the transit time required by the electron between these grids. This transit time is reduced by making the space between grids 3 and 2 small, but normally this procedure has an adverse effect on other properties of a heptode and in this respect the EH 2 represents the best possible compromise.

4) The parallel input impedance in the short-wave range shows a considerable improvement over other types, by reason of the very small spacing of $g_1 - k$ and $g_2 - g_1$. At 15 metres and on a signal frequency of 500 kc/s above the oscillator frequency ($f_{osc} = f_i + 500$ kc/s) the following values of input impedance and capacitance were obtained by actual measurement:

R_{input} = 30,000 ohms
C_{input} = 6.3 $\mu\mu$F

5) In the development of the EH 2 every effort has been made to keep the noise factor as low as possible, whether the valve be used as frequency-changer or as R.F. amplifier. As will be seen from Figs 5 and 6, the alternating input voltage with 6 % cross-modulation, when under the effect of control, is in either case less than 0.3 V_{eff}.

6) When used with a separate oscillator valve, the valve has a frequency drift due to mains voltage flectuations that may be regarded as extremely slight. The drift arising from variations in the mutual conductance is also very small, since this is caused by differences in the capacitance of grid 3 which in themselves are negligible.

7) The heptode EH 2 will not produce any electrical coupling effects between oscillator and input grids, because grid 3 in no way influences the electrons in the neighbourhood of grid 1;

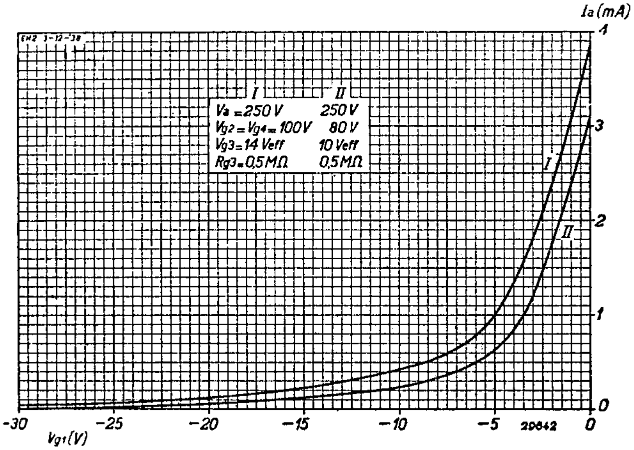


Fig. 7

Anode current as a function of the voltage on grid 1. EH 2 used as a frequency-changer.

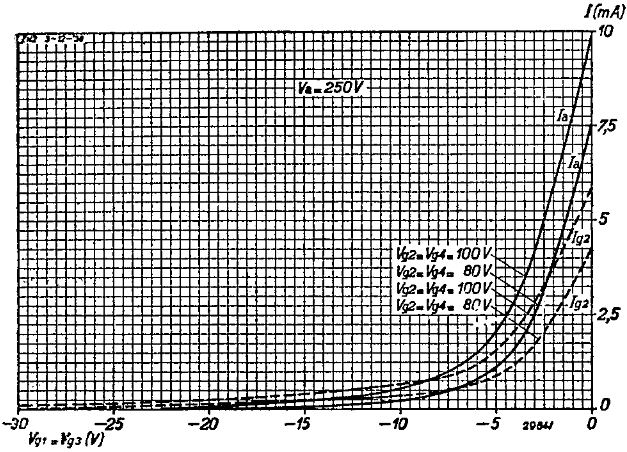


Fig. 8
Anode and screen-grid current as a function of the voltage on grids 1 and 3 when using the EH 2 as R.F. or I.F. amplifier.

there is therefore no negative capacitance between grids 1 and 3. The normal capacitance exists between the electrodes mutually, this being about 0.2 μμF, which on very short waves does result in retroaction from the oscillator voltage to the input circuit, although if the oscillator frequency is taken higher than the input frequency this will not affect the performance of the valve.

HEATER RATINGS

Heating: indirect, A.C. or D.C., series or parallel supply.
Heater voltage . . . . $V_f = 6.3$ V
Heater current . . . . $I_f = 0.200$ A.

CAPACITANCES

$C_{ag1} < 0.0015$ μμF
$C_{g1} = 5$ μμF
$C_a = 11$ μμF
$C_{g1g3} = 0.2$ μμF

OPERATING DATA: EH 2 used as frequency-changer

Anode voltage	$V_a =$	250		250 V	
Screen-grid voltage	$V_{g2+4} =$	100		80 V	
Grid leak, oscillator	$R_{g3} =$	0.5		0.5 M ohm	
Oscillator voltage, grid 3	$V_{osc} =$	14		10 V_{eff}	
Cathode resistor	$R_k =$	530		380 ohms	
Grid bias.	$V_{g1} =$	—3	—25	—2	—20 V
Anode current	$I_a =$	1.85	—	1.8	— mA
Screen current	$I_{g2} + I_{g4} =$	3.8	—	3.5	— mA
Conversion conductance	$S_c =$	400	< 10	400	< 10 μA/V
Internal resistance	$R_i =$	2	> 10	2	> 10 M ohms

OPERATING DATA: EH 2 used as R.F. or I.F. amplifier

Anode voltage	$V_a =$	250		250 V	
Screen-grid voltage	$V_{g2} = V_{g4} =$	100		80 V	
Cathode resistor	$R_k =$	430		310 ohms	
Grid bias.	$V_{g1} = V_{g3} =$	—3	—25	—2	— 20 V
Anode current	$I_a =$	4.2	—	4	— mA
Screen current	$I_{g2} + I_{g4} =$	2.8	—	2.5	— mA
Mutual conductance	$S =$	1400	< 2	1400	< 2 μA/V
Internal resistance	$R_i =$	1	> 10	1	> 10 M ohms

MAXIMUM RATINGS

V_{ao} = max. 550 V
V_a = max. 250 V
W_a = max. 1.5 W
$V_{g2o} = V_{g4o}$ = max. 400 V
$V_{g2} = V_{g4}$ = max. 125 V
$W_{g2} = W_{g4}$ = max. 0.5 W

V_{g1} ($I_{g1} = +0.3\ \mu A$) = max. —1.3 V
V_{g3} ($I_{g3} = +0.3\ \mu A$) = max. —1.3 V
$R_{g1} = R_{g3}$ = max. 2.5 M ohms
I_k = max. 10 mA
R_{fk} = max. 5,000 ohms
V_{fk} = max. 100 V 1)

APPLICATIONS

A) R.F. OR I.F. AMPLIFIER WITH VARIABLE SLOPE

A potential divider should be given preference for feeding the screen grids (grids 2 and 4) and the slope is best controlled by applying the same control voltage to both grids 1 and 3; if the latter grid is controlled by an attenuator (potential divider) giving a lower voltage, the control range is increased, but as the cross-modulation characteristic is identical in both instances this arrangement offers no advantages.

The metallizing of the envelope is connected to a separate contact on the base of the valve and, generally speaking, this should be earthed. The usual care must be taken with respect to the screening of the leads and the arrangement of the wiring, and the supply lines should be decoupled by means of filters. Fig. 9 shows the circuit diagram of this valve employed as a variable-mu I.F. amplifier.

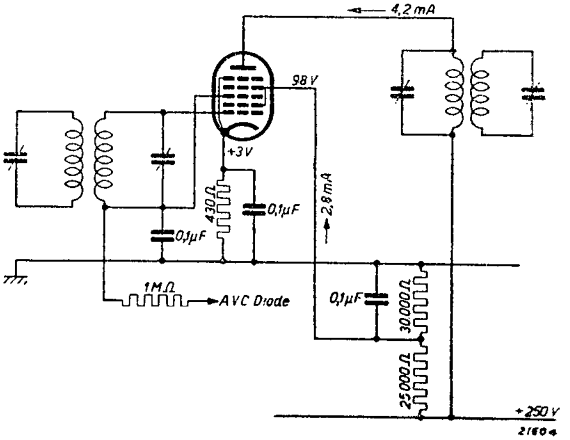


Fig. 9
Circuit diagram of the EH 2 used as an I.F. amplifier, with the same control voltage applied to grids 1 and 3.

B) VARIABLE-MU MODULATOR

Fig. 10 shows the circuit of the EH 2 used as a modulator, with the EBC 3 as oscillator, although the EF 6, connected as a triode, can also be employed for this purpose. This circuit will give satisfactory results at wavelengths of 5 m; it is preferable to couple the tuned oscillator circuit to the anode of the oscillator valve. The oscillator is coupled to grid 3 of the heptode EH 2 through a capasitor of 20 to 50 μμF, the latter being the best value for "all-wave" reception.

For wavelengths of 5 to 12 metres the oscillator coil may be made from about $4^1/_2$ turns of wire on an inside diameter of approximately 10 mm, not too closely wound and without an iron core. Tinned copper wire must not be used for this purpose and the leads from the coils to the tuning capacitor should be as short as possible. The coupling coil may also consist of $4^1/_2$ turns of silk-covered wire about 0.1 mm in diameter, wound directly on the anode-circuit coil. A resistor of 40 ohms in series with the grid of the oscillator will prevent over-oscillation at the lower end of the wave-range.

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1) direct voltage or effective value of the alternating voltage.

When the EF 6 is used as oscillator the oscillator voltage will be somewhat higher and, in the short-wave range, in contrast with octodes such as the EK 2, the oscillator frequency should be higher than the input frequency, as is usual on the medium and long waves. The other coupling, established by the capacitance between g_1 and g_3, then provides a voltage across the input circuit of the same frequency as the oscillator, and the phase of this voltage is such that it tends to augment the conversion amplification. In the uncontrolled condition the bias on grid 1 should be —2 V with 80 V on screens 2 and 4, or —3 V with 100 V on the screens. The control voltage from the A.G.C. is in this case applied only to the first grid. The two screens (2 and 4) should be fed from a generously proportioned potential divider.

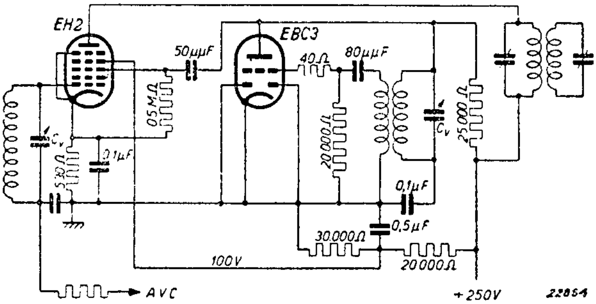

Fig. 10
Circuit diagram of the EH 2 used as frequency-changer with the EBC 3 as oscillator

EK 2 Octode

The EK 2 is a six-grid frequency-changer, employing the principle of electronic mixing; the small dimensions and particular internal construction of this valve provide the following advantages:

1) The electronic coupling effect met with especially on short waves is for the greater part counteracted by a capacitor between the first and fourth grids, the object of this capacitor being to compensate, with a positive capacitance, the apparent negative capacitance produced by electronic coupling.

2) Small dimensions and narrow spacing of the electrodes practically eliminates transit-time effects in the range of very short waves.

3) The parallel input resistance between control grid and cathode is very high, even on the very short waves, and its effect on the amplification may therefore be ignored.

4) Background noise, which is proportional to the root of the anode current divided by the mutual conductance, is only very slight.

5) The performance of the valve from the point of view of absence of whistles is extremely good.

6) Interference due to cross-modulation or modulation-distortion when control is applied to the valve is a minimum.

7) The internal resistance is more than 1 megohm and permits the use of very good quality I. F. circuits, giving a high degree of gain.

8) Microphony is so slight that it may be ignored in the design of a receiver.

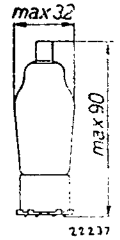

Fig. 1
Dimensions in mm.

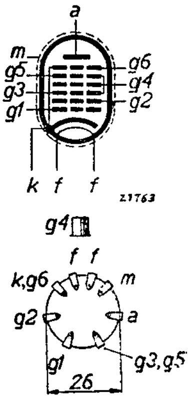

Fig. 2
Arrangement of electrodes and base connections.

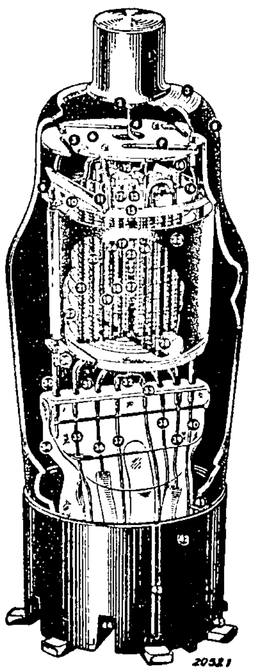

Fig. 3
Construction of the new octode EK 2. The capacitor for the compensation of inductive effect is shown at 12.

HEATER RATINGS

Heating: indirect; A.C. or D.C., series or parallel supply.
Heater voltage . . . . $V_f = 6.3$ V
Heater current . . . . $I_f = 0.200$ A

CAPACITANCES

$C_{ag4} < 0.07$ μμF
$C_a = 10$ μμF
$C_{g1} = 6.0$ μμF
$C_{g1g4} = 1.1$ μμF

$C_{g2} = 4.5$ μμF
$C_{g2g4} < 0.25$ μμF
$C_{g4} = 8.8$ μμF

OPERATING DATA (for medium- and long-wave operation)

Anode voltage	V_a =	100 V			200—250 V		
Screen-grid voltage	$V_{g3,5}$ =	50 V			50 V		
Oscillator-anode voltage	V_{g2} =	100 V			200 V		
Oscillator grid leak	R_{g1} =	50,000 ohms			50,000 ohms		
Oscillator voltage, grid 1	V_{osc} =	9 V_{eff}			15 V_{eff}		
Oscillator grid current	I_{g1} =	200 μA			300 μA		
Cathode resistor	R_k =	570 ohms			490 ohms		
Bias, grid 4	V_{g4} =	—2 V 1)	—15 V 2)	—20 V 3)	—2 V 1)	—15 V 2)	—20 V 3)
Anode current	I_a =	1 mA	—	—	1 mA	—	—
Screen-grid current	$I_{g3} + I_{g5}$ =	1 mA	—	—	1.1 mA	—	—
Oscillator-anode current	I_{g2} =	1.5 mA	—	—	2.5 mA	—	—
Conversion conductance	S_c =	550	5.5	2	550	5.5	2 μA/V
Internal resistance	R_i =	1.2	> 10	> 10	2	> 10	> 10 M ohms
Conductance, grid 1 with respect to grid 2 ($V_{osc} = 0$)	S_{g1g2} =	0.3 mA/V	—	—	0.4 mA/V	—	—
Direct current, oscillator anode at commencement of oscillation ($V_{osc} = 0$)	I_{g2} =	3.2 mA	—	—	5.5 mA	—	—

1) Without control
2) Conductance reduced to one-hundredth of uncontrolled value
3) Extreme limit of control

OPERATING DATA (for reception on all wavelengths) 4)

Anode voltage						
V_a =	100 V			200—250 V		
Screen-grid voltage						
$V_{g3,5}$ =	80 V			80 V		
Oscillator-anode voltage						
V_{g2} =	100 V			200 V		
Oscillator grid leak						
R_{g1} =	16,000 ohms			50,000 ohms		
Oscillator voltage, grid 1						
V_{osc} =	6 V_{eff}			9 V_{eff}		
Oscillator grid current						
I_{g1} =	300 μA			200 μA		
Cathode resistor						
R_k =	395 ohms			525 ohms		
Bias, grid 4						
V_{g4} =	—3 V 1)	—26 V 2)	—40 V 3)	—4 V 1)	—26 V 2)	—40 V 3)
Anode current						
I_a =	2.5 mA	—	—	1.7 mA	—	—
Screen-grid current						
$I_{g3} + I_{g5}$ =	2.8 mA	—	—	1.3 mA	—	—
Oscillator-anode current						
I_{g2} =	2.3 mA	—	—	4 mA	—	—
Conversion conductance						
S_c =	550 μA/V	5.5	1	550	5.5	1 μA/V
Internal resistance						
R_i =	0.65	> 10	> 10	1.4	> 10	> 10 M ohms
Conductance grid 1 with respect to grid 2 ($V_{osc} = 0$)						
S_{g1g2} =	0.35	—	—	0.9	—	— mA/V
Direct current, oscillator anode at commencement of oscillation ($V_{osc} = 0$)						
I_{g2} =	4 mA	—	—	9 mA	—	—

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1) Without control 2) Conductance reduced to one-hundredth of uncontrolled value 3) Extreme limit of control 4) In view of the possibility of frequency drift, the valve should not be controlled in the short-wave range.

MAXIMUM RATINGS

V_{ao} = max. 550 V
V_a = max. 250 V
W_a = max. 1.0 W
$V_{g3,5o}$ = max. 550 V
$V_{g3,5}$ = max. 125 V
$W_{g3,5}$ = max. 0.3 W
V_{g2o} = max. 550 V
V_{g2} = max. 225 V

W_{g2} = max. 1.3 W
I_k = max. 12 mA
V_{g4} ($I_{g4} = +0.3\ \mu$A) = max. —1.3 V
R_{g4k} = max. 2.5 M ohms
R_{g1k} = max. 100,000 ohms
R_{fk} = max. 5,000 ohms
V_{fk} = max. 100 V 1)

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1) Direct voltage or effective value of alternating voltage.

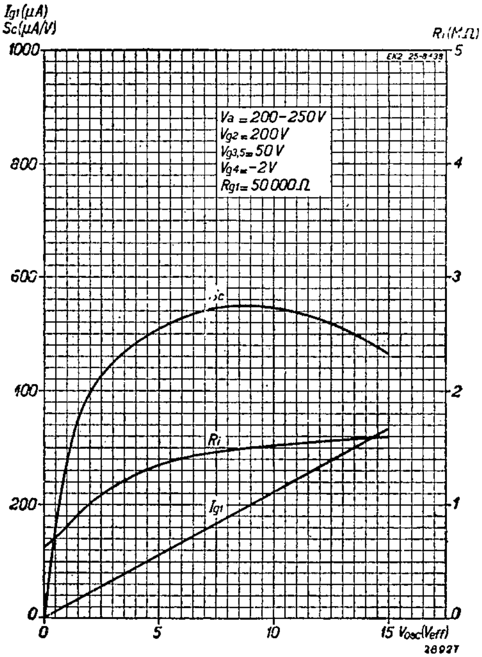


Fig. 4
Conversion conductance Sc, internal resistance Ri and oscillator-grid current Ig_1 as a function of the oscillator voltage, with $Vg_2 = 200$ V and $Vg_{3,5} = 50$ V.

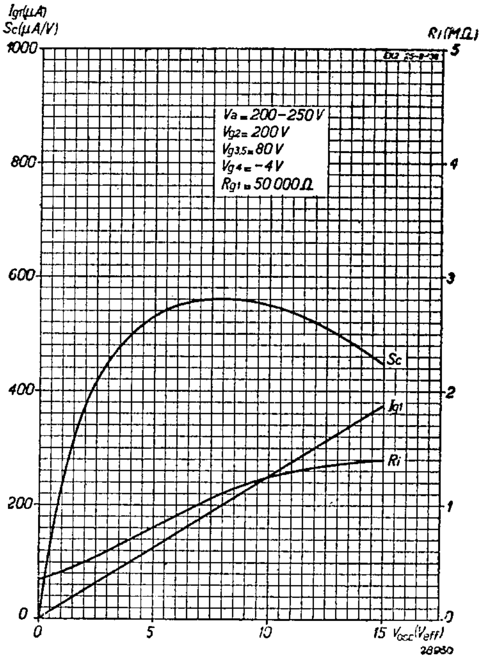


Fig. 5
Conversion conductance Sc, internal resistance Ri and oscillator-grid current Ig_1 as a function of the oscillator voltage, with $Vg_2 = 200$ V and $Vg_{3,5} = 80$ V.

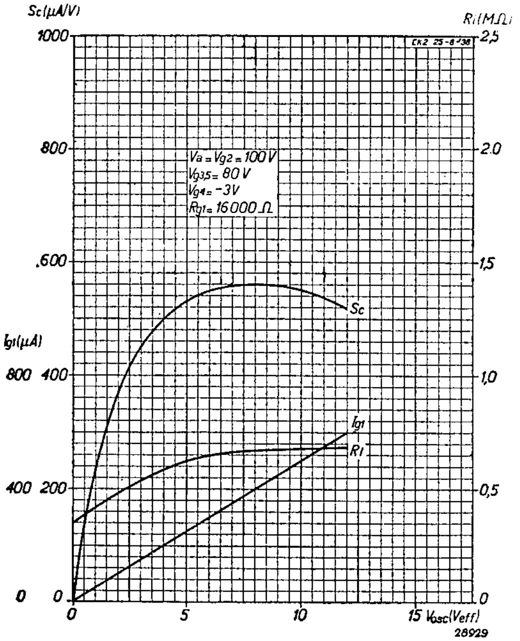


Fig. 6
Conversion conductance Sc, internal resistance Ri and oscillator-grid current Ig_1 as a function of the oscillator voltage, with $Vg_2 = 100$ V and $Vg_{3,5} = 80$ V.

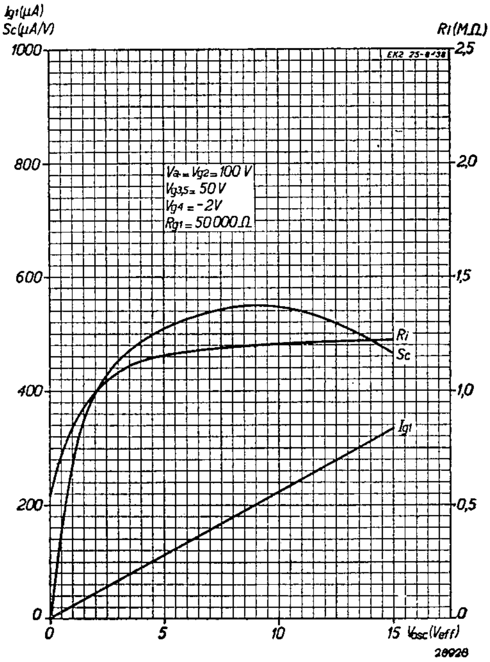


Fig. 7
Conversion conductance Sc, internal resistance Ri and oscillator-grid current Ig_1 as a function of the oscillator voltage, with $Vg_2 = 100$ V and $Vg_{3,5} = 50$ V.

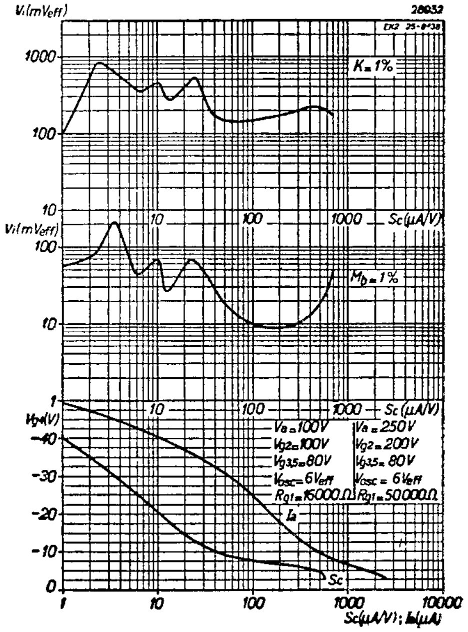


Fig. 8

Upper diagram. Alternating input voltage as a function of the conversion conductance controlled by the bias on grid 4, with 1 % cross-modulation.

Centre diagram. Alternating input voltage as a function of the conversion conductance controlled by the bias on grid 4, with 1 % modulation hum.

Lower diagram. Anode current and conversion conductance as a function of the bias on grid 4.

The supply for the various electrodes should be derived preferably from a high-value potential-divider network, although, naturally, it is also possible to apply the voltages through series resistors of sufficiently high value. As the oscillator unit functions just as easily without bias (i.e. $V_{g1} = 0$), the grid leak of the EK 2 can be connected directly to the cathode. A value of 15 V_{eff} for the oscillator voltage guarantees efficient working with very little back-ground noise and, in the medium- and long-wave ranges, this value can usually be attained without any difficulty. It is possible, however, that the reaction at 600 metres may need to be so tight that at 200 metres the oscillator voltage would be twice as much and this may tend to cause periodical interruption of the oscillation (squegging). This effect was formerly met with in simple types of receiver with reaction, manifesting itself as a troublesome variation in reception, or else a host of whistles when the set was being tuned to certain stations, this being actually due to very rapid cessation and recommencement of the oscillation. Squegging may be prevented by, inter alia, reducing the number of turns on the reaction coil; the oscillator voltage at the upper end of the wave-range will then certainly be slightly lower than normal, but from the characteristic of the conversion conductance as a function of the oscillator voltage (Fig. 4) it will be seen that at about 9 or 10 V_{eff} the slope is even better than at 15 V_{eff}. In order to stabilize the oscillator voltage throughout the whole range a damping resistor is frequently connected in parallel with the coupling coil.

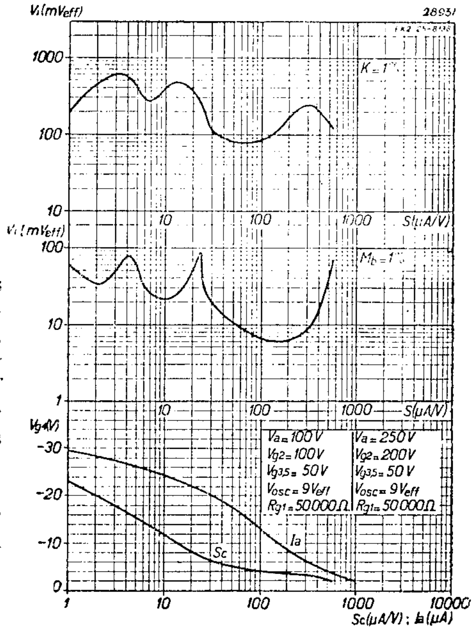


Fig. 9

Upper diagram. Alternating input voltage as a function of the conversion conductance controlled by the bias on grid 4, with 1 % cross-modulation.

Centre diagram. Alternating input voltage as a function of the conversion conductance with 1 % modulation hum.

Lower diagram. Anode current and conversion conductance as a function of the bias on grid 4.

Another remedy is to employ lower values of grid capacitor and leak for the oscillator section of the valve and this gives excellent results in the short-wave range; satisfactory values are about 50 $\mu\mu$F for the grid capacitor and 50,000 ohms for the leak. Since 50 $\mu\mu$F is really too low for good long-wave reception (a value of about 200 to 1000 $\mu\mu$F is usually preferred), the value of the grid leak may be reduced in all-wave receivers, instead of using a smaller capacitor, e.g., 10,000 or 16,000 ohms (see also data relevant to the latter value).

At the same time this resistor must not be in parallel with the oscillator circuit, as this damps the latter too much; Fig. 11 illustrates the proper arrangement, whilst Fig. 12 shows a circuit in which a lower value of grid leak is employed with the padding capacitor serving also as grid capacitor; this again results in less damping of the oscillator circuit. If the value of the padding capacitor C_p is too low, however, damping will still occur and in "all-wave" receivers the circuit depicted in Fig, 13 is recommended.

Here a grid leak of 50,000 ohms is used for the broadcast range and 10,000 ohms for the short waves. If a padding capacitor C_p is also to be included on short waves this will generally be of a high value, to provide adequate earthing of the circuit.

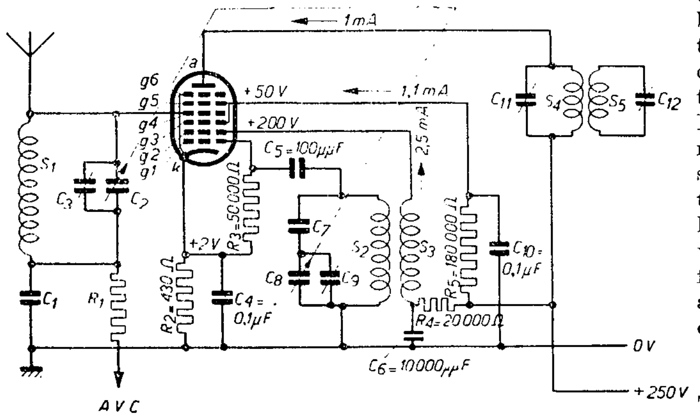


Fig. 10
Circuit diagram showing the application of the EK 2.

In the short-wave range it is not so simple to obtain a sufficiently high oscillator voltage, and the following values are recommended:

V_{g2} = 200 V
$V_{g3,5}$ = 80 V

This generally provides an oscillator voltage of 5 to 6 V_{eff}, but if the magnification of the circuits is very good this potential will be higher. It is not good practice to aim at producing extra high voltages for short-wave reception, as the tuned input circuit of the octode will then tend to oscillate; an oscillator voltage of 5 to 6 V_{eff} is quite good and the valve can best be made to operate on this value.

Frequency drift is especially troublesome in the short-wave range; whilst theoretically almost negligible in the broadcast bands, this factor must certainly be taken into account in short-wave operation. Drift due to mains voltage fluctuations is so slight as to make no difference on short-waves; at a wavelength of 13 metres it is only 5 kc/s. On the other hand, frequency drift in the 13—50 m band caused by variations in the bias on the

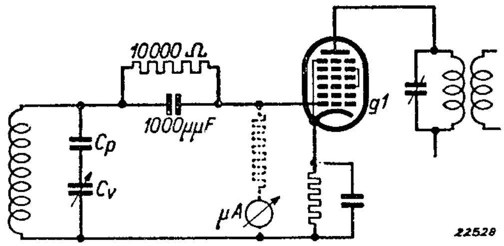


Fig. 11
Circuit employing a low value of grid leak (10,000 ohms). The method of measuring the amplitude of the oscillator voltage by means of the grid current is also shown.

fourth grid is so great that control must not be applied in that range. If, despite this fact, control is to be employed, it is essential to use a separate triode as oscillator, although it is much better to omit the control from the mixing valve and precede the octode by a variable-mu R.F. amplifier pentode, applying the control to that valve. Without this R.F. amplifier the sensitivity in the short-wave range is not very high and it is therefore sufficient to control the I.F. valve only.

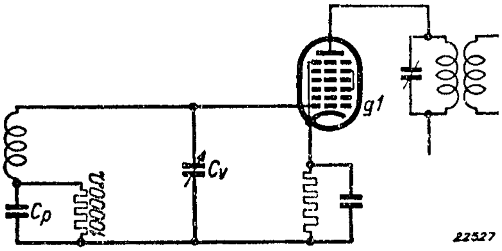


Fig. 12
Circuit for low value of grid leak, with padding capacitor in series with the coil.

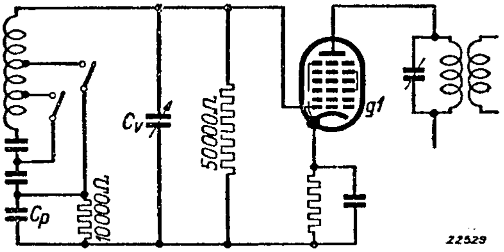


Fig. 13
Diagram of oscillator circuit with low-value grid leak, and low-value padding capacitor for medium and long-wave reception.

Since suppression of the image-frequency in short-wave reception (due to the lower magnification of the R.F. circuits in that range) is more difficult than in the broadcast wave-bands, it is advisable in receivers for short-wave reception to employ a high intermediate frequency (450—475 kc/s), which is, moreover, advantageous in suppressing electronic coupling. At lower intermediate frequencies it is good practice, in order to simplify balancing of the circuits, to detune the input stage by about 500 kc/s at the lower end of the wave-range, i.e., to increase the difference between the oscillator and input frequencies by 500 kc/s. This has practically no effect on the sensitivity, but it does facilitate the trimming. In the broadcast range the oscillator frequency should be higher than that of the input, or it will not be found possible to cover the whole of the range, but on short waves, in view of electronic coupling, the situation should be reversed.

The inclusion of a small compensating capacitor definitely reduces the inductive effect but does not entirely eliminate it, since too much compensation causes the input circuit to oscillate. In the 13—50 m band the padding capacitor is often omitted, the difference in frequency being obtained from differences in the self-inductance and trimming capacitor; the oscillator frequency can therefore be lower than the input frequency also in this range.

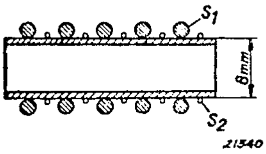


Fig. 14
Oscillator coil for use on very short waves (6 to 8 metres). S_1 = 5 turns of 2 mm bare copper wire (not tinned). S_2 = 5 turns of 0.1–0.2 mm enamelled copper wire.

The tuned oscillator circuit must be coupled to the first grid and the reaction coil to the second (oscillator anode). The EK 2 may also be used successfully as a self-oscillating mixer valve in the 5—13 m wave-band, but this range cannot be fully covered without the use of switches. The oscillator can be maintained in oscillation only over a small part of this range, for instance from 6 to 8 metres, but for that matter it would be difficult to include the whole range of from 5 to 15 m on a single scale. Fig. 14 shows the construction of a coil suitable for use between 6 and 8 metres and, for the rest, extreme accuracy and simplicity of controls are essential features.

EK 3 Octode

The EK 3 is an octode frequency-changer the characteristics of which show a considerable improvement over those of the EK 2; certain forms of interference are here reduced to a minimum by means of electronic bunching.

This valve gives an equally high conversion amplification in the short-wave band and in the ordinary broadcast ranges. In comparison with other frequency-changers the EK 3 offers many advantages. The principle of electronic bunching makes it possible to separate the oscillator unit from the mixing section as completely as though two separate valves were involved. Four electron bunches are formed, two for generating the oscillation and two for the mixing, and the two functions are to such an extent independent of each other that interaction is practically impossible. Fig. 3 shows a cross-section through the system of electrodes, together with the different electron streams. The advantages of this 4-channel system are as follows:

1) Frequency drift caused by mains voltage fluctuations, or variation of the bias on grid 4, is extremely slight.

2) Constant oscillator slope on very short wavelengths.

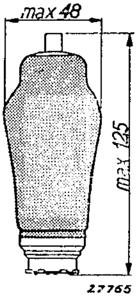


Fig. 1
Dimensions in mm.

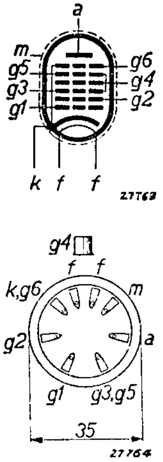


Fig. 2
Arrangement of electrodes and base connections.

The almost perfect screening of the oscillator section of the EK 3 means that electrons returned to the 4th grid as a result of the control have no effect whatever on the space charge and slope of the oscillator unit; frequency drift arising from control on the valve is thus avoided and the EK 3 can therefore be included in the A.G.C., even on the short-wave range.

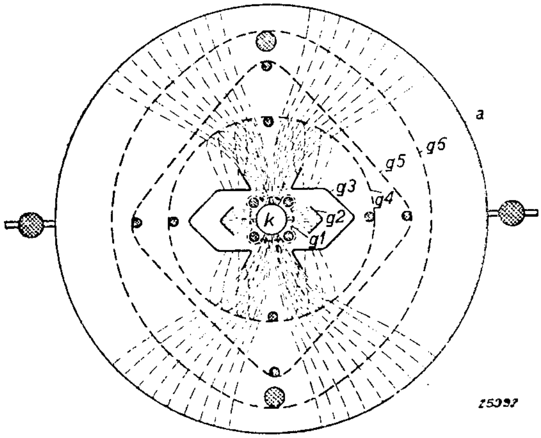


Fig. 3
Cross-section of the system of electrodes in the EK 3, showing the electron streams. The two bunches to left and right serve to generate the oscillation. The oscillator voltage thus occurs on grid 1 and the two streams flowing upwards and downwards are modulated by this voltage. The oscillator section is surrounded by a screen having in it two slots through which the bunches of electrons are directed; this screen is maintained at a positive potential and functions as a third octode grid. Electrons leaving the oscillator section are deflected to a certain extent before they reach the 4th grid. Any electrons that may be repelled back cannot re-enter the oscillator section but return to the screen surrounding the oscillator.

This screening of the oscillator unit is accompanied by the following advantages:

a) the space charge between grid 1 and the cathode, and between grids 2 and 1, does not vary when the bias on grid 4 is altered.

b) The mutual conductance of grid 1 with respect to grid 2 is not affected by the bias on grid 4.

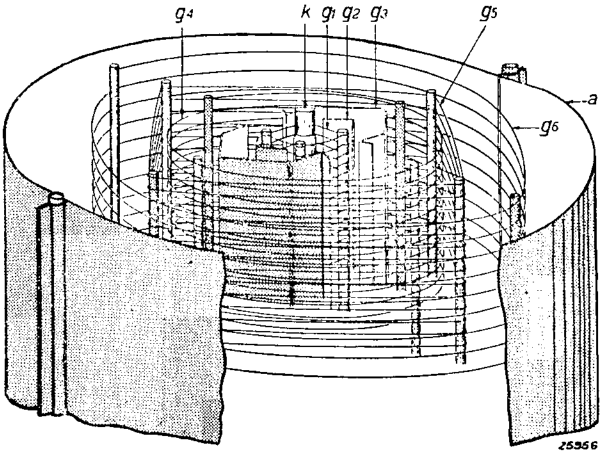


Fig. 4
Details of construction of the 4-channel octode.

c) The mutual conductance of grid 4 with respect to grid 2 may be entirely ignored. Interference due to undesired coupling between the input circuit and the oscillator is thus avoided; coupling of this kind will often set up an oscillation in the input circuit of the valve as well as relaxation oscillations caused by frequency drift.

The oscillator anode consists of two V-shaped plates and the electron streams directed towards these are held by them, variations in the direct voltage on grid g_3 being prevented from influencing the oscillator unit in any way. The short path of the electrons from the cathode to the auxiliary anode plates ensures very short transit-times in the oscillator section; this effect is so pronounced that the oscillator conductance corresponds to the statically measured slope, even at very short wavelengths.

The static conductance of grid 1 with respect to grid 2 is extremely high, being 4 mA/V at the threshold of oscillation, for which reason the coupling of the components in the oscillatory circuit may be fairly loose; the valve capacitances then only play a very small part in the detuning of the oscillator frequency. Measures have been taken in the design of the valve to reduce the inductive effect (electronic coupling between grids 1 and 4) and the amount of interference met with under this head is extremely small. A capacitor in series with a resistor is connected between grids 1 and 4, the function of the resistor being to make the phase angle of the alternating voltage, as applied to grid 4 through the capacitor, exactly equal to that of the induced voltage arising from the transit time of the electrons passing from grid 1 to grid 4; the conversion amplification at the lower end of the different wave-

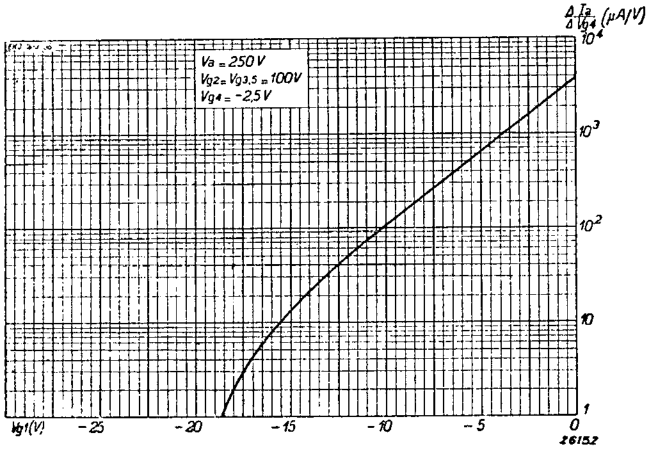


Fig. 5
Conversion of the 4th grid as a function of the direct voltage on grid 1

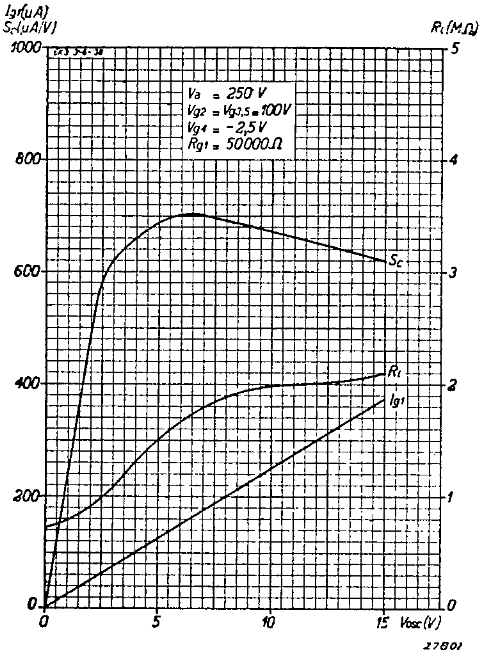


Fig. 6
Internal resistance, conversion conductance and oscillator-grid current as a function of the oscillator voltage when a grid leak of 50,000 ohms is used.

ranges is hardly influenced at all by the effect in question.

The input impedance of the EK 3 in the short-wave bands is very high in comparison with the impedance of the normal receiver circuit, and its effect on the amplification may therefore be ignored. At a wavelength of 14 metres the impedance is about 60,000 ohms. The input capacitance is different for every value of control voltage applied to the grid, because variations are produced in the density of the space charge in front of the grid and these variations tend to detune the circuit coupled to the grid and reduce the sensitivity of the receiver. Furthermore, the R.F. signal in this case does not occur at the centre of the resonance curve and the amplification of the sidebands is not uniform; the resultant asymmetry tends to cause considerable distortion in the detector.

In the EK 3 such capacitive variations are very small, namely only 0.2 $\mu\mu$F, and the consequent detuning effect is only slight, in any case within the limits for the normal broadcast bands.

If a better cross-modulation characteristic is required it should be noted that the conductance of the EK 3 drops less sharply when a control voltage is applied to the 4th grid.

The high conductance of the oscillator unit and increased conversion conductance necessitate a high power cathode and the heater current is accordingly well above 200 mA, being actually 0.6 A; this valve cannot therefore be used in A.C./D.C. receivers, for which purpose a special valve with a 200 mA filament for series operation has been developed.

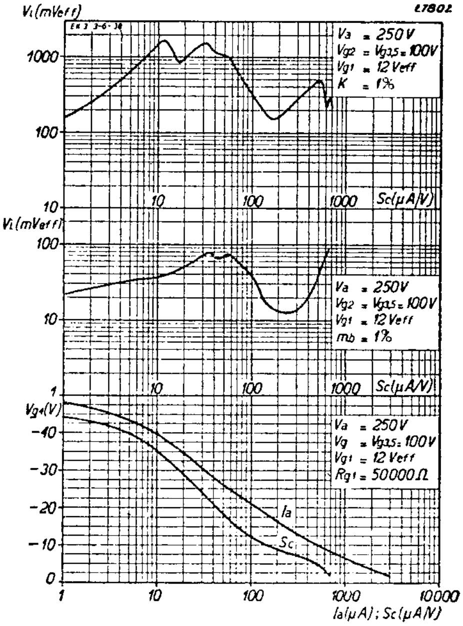


Fig. 7
Upper diagram. Alternating input voltage as a function of the conversion conductance controlled by the bias on grid 4, with 1 % cross-modulation.
Centre diagram. Alternating input voltage as a function of the conversion conductance controlled by the bias on grid 4, with 1 % modulation hum.
Lower diagram. Anode current and conversion conductance as a function of the bias on grid 4.

HEATER RATINGS

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

Heater voltage	V_f	= 6.3 V
Heater current	I_f	= 0.6 A

CAPACITANCES

$C_{ag_4} < 0.07\ \mu\mu F$
$C_a = 16.5\ \mu\mu F$
$C_{g_1} = 14\ \mu\mu F$
$C_{g_1g_4} = 1.1\ \mu\mu F$
$C_{g_2} = 8.6\ \mu\mu F$
$C_{g_4} = 15.2\ \mu\mu F$

OPERATING DATA: EK 3 employed as a frequency-changer for "all-wave" reception

Anode voltage	V_a	= 250 V		
Screen-grid voltage	$V_{g3,5}$	= 100 V		
Oscillator-anode voltage	V_{g2}	= 100 V		
Oscillator grid leak	R_{g1}	= 50,000 ohms		
Oscillatory voltage, grid 1	V_{osc}	= 12 V_{eff}		
Oscillator-grid current	I_{g1}	= 300 μA		
Cathode resistor	R_k	= 190 ohms		
Bias, grid 4	V_{g4}	= —2.5 V 1)	—38 V 2)	—42 V 3)
Anode current	I_a	= 2.5 mA	—	—
Screen-grid current	$I_{g3,5}$	= 5.5 mA	—	—
Oscillator-anode current	I_{g2}	= 5 mA	—	—
Conversion conductance	S_c	= 650	6.5	3 μA/V
Internal resistance	R_i	= 2	> 10	> 10 M ohms
Mutual conductance, grid 1 with respect to grid 2 ($V_{osc} = 0$)	S_{g1g2}	= 4 mA/V	—	—
Direct current, oscillator anode at threshold of oscillation ($V_{osc} = 0$)	I_{g2}	= 18 mA	—	—

1) Without control
2) Conversion conductance reduced to one-hundredth of uncontrolled value
3) Extreme limit of control

MAXIMUM RATINGS

Anode voltage in cold condition	V_{ao}	= max. 550 V
Anode voltage	V_a	= max. 300 V
Anode dissipation	W_a	= max. 1 W
Screen voltage in cold condition	$V_{g3,50}$	= max. 550 V
Screen voltage	$V_{g3,5}$	= max. 150 V
Screen dissipation	$W_{g3,5}$	= max. 1 W
Oscill. anode voltage in cold condition	V_{g2o}	= max. 550 V
Oscill. anode voltage	V_{g2}	= max. 150 V
Oscill. anode dissipation	W_{g2}	= max. 1 W
Cathode current	I_k	= max. 23 mA
Grid voltage at grid current start ($I_{g4} = + 0.3\ \mu$A)	V_{g4}	= max. —1.3 V
Resistance in circuit of grid 4	R_{g4k}	= max. 3 M ohms
Resistance in circuit of grid 1	R_{g1k}	= max. 100,000 ohms
Resistance between filament and cathode	R_{fk}	= max. 20,000 ohms
Voltage between filament and cathode (direct voltage or effective value of alternating voltage)	V_{fk}	max. 50 V

Because of the steep slope of the oscillator section it is not a difficult matter to establish and maintain the oscillation; the grid leak can therefore be connected to the cathode. The triode unit also oscillates readily and the reaction may with advantage be fairly loose; over-oscillation or squegging will then not occur. A grid leak of 50,000 ohms with a grid capacitor of 50 $\mu\mu$F is recommended and will serve for all wavelengths.

In the EK 3 the inductive effect is counteracted by a form of compensation between grids 1 and 4, to which end it is necessary for the oscillator voltage at the lower end of the short-wave range to be 12 V (effective), (300 μA grid current passes through the 50,000 ohm grid leak). On other wavelengths the oscillator voltage will, of course, be different and the compensation not quite so complete, but outside the short-wave range the inductive effect is so slight that it may otherwise be ignored.

The principle of electron bunching ensures that frequency drift is kept as low as possible; only the potential of the 3rd grid has any effect on the capacitance of the first, but this is to be expected, as the former surrounds the latter. If frequency drift is to be minimized the voltage on the screen ($V_{g3,5}$) must be stabilized by means of a potential divider passing a fairly considerable current; for practical purposes, however, there is a limit to this stabilization of the screen voltage. A useful method of eliminating any residual frequency drift consists in coupling the oscillator circuit to the anode circuit of the triode. Capacitive variations in the 1st grid then have less effect upon the tuning, provided that the reaction is not too tight, since the grid capacitance is induced in the oscillator circuit by way of this coil. This demonstrates clearly the importance of the high mutual conductance of this valve, since the coupling may be made extremely loose.

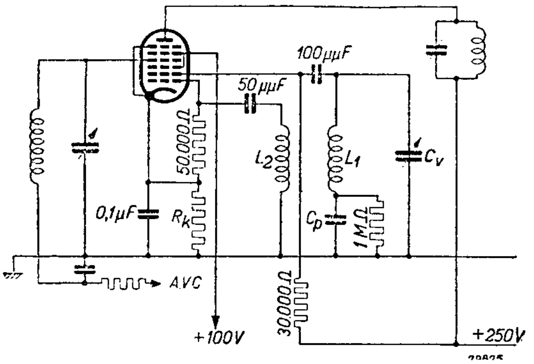


Fig. 8
Circuit diagram showing the oscillatory circuit in the oscillator-anode circuit of the EK3, with the anode fed through a resistor of 30,000 ohms. The oscillator circuit is not accessible to the direct voltage.

The circuit to be recommended from the point of view of frequency drift is that shown in Fig. 8, in which the oscillator circuit is not coupled directly to the anode circuit but by means of a capacitor of 100 $\mu\mu$F. In this way the direct voltage of 100 V does not reach the plates of the tuning capacitor. The circuit is a simple one, but it has the drawback that it is damped by the feed resistor of 30,000 ohms, whereas damping of this circuit is the very thing to be avoided, since:

1) the coupling in the short-wave range should preferably be as loose as possible to avoid frequency drift;

2) on long waves extra damping is often provided in series with the padding capacitor on medium waves, expressly to prevent parasitic oscillation. In the great majority of cases the circuit depicted in Fig. 8 will present no difficulties.

If a padding capacitor C_p is connected in series with the oscillator coil (on the medium and long wave ranges), this should actually be bye-passed by a high value resistor, to prevent a direct voltage from occurring across the tuning capacitor C_v.

Another method of feeding the oscillator anode is shown in Fig. 9, where the voltage is applied through the oscillator coil; the padding capacitor then serves simultaneously to block the voltage from the variable capacitor C_v. This circuit also has a disadvantage, in that extra contacts are required on the wave-change switch for connection to the padding capacitor C_p; on the other hand, the damping of the oscillator circuit is not so heavy as in the circuit in Fig. 8. The latter, in which 5 turns of wire are used for the reaction coil, grids 3 and 5 being fed through a resistor, has given an actual measured frequency-drift value of only 4.5 kc/s at 15 m, this measurement being taken with control applied to the 4th grid, of from —2 to —20 V, in other words, under extremely adverse conditions. When the voltage for the screen $V_{g3,5}$ is taken from a potential divider the frequency drift is even less.

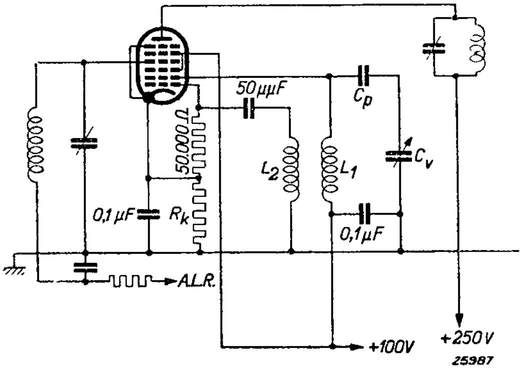


Fig. 9
Circuit diagram of oscillatory circuit in the oscillator-anode circuit, this anode being fed through the coil. The padding capacitor also serves to isolate the variable capacitor C_v from the direct voltage.

EL 2 Output pentode

The EL 2 is an indirectly-heated, 8 W output pentode for use in car-radio receivers; the low heater-power consumption makes this valve very suitable for this purpose. With an anode and screen potential of 250 V, the mutual conductance is 2.8 mA/V at the working point. The cathode attains its full working temperature in a very short time, namely 18 seconds. The control-grid connection is at the top of the envelope.

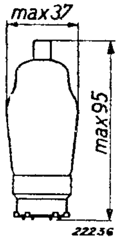


Fig. 1
Dimensions in mm.

HEATER RATINGS

Heating: Indirect by battery current; series or parallel supply.
Heater voltage . . . . $V_f = 6.3$ V
Heater current . . . . $I_f = 0.2$ A

CAPACITANCES

Anode to grid 1 . . . . $C_{ag1} < 0.6$ $\mu\mu$F

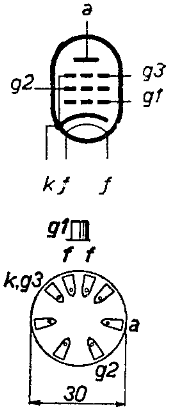


Fig. 2
Arrangement of electrodes and base connections.

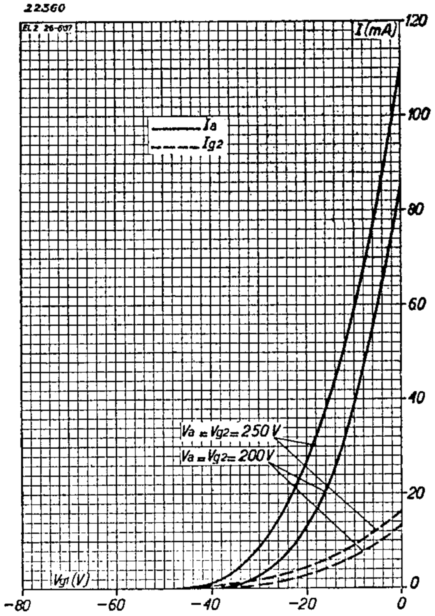


Fig. 3
Anode and screen current as functions of the grid bias for equal anode and screen voltages of 200 V and 250 V.

OPERATING DATA: EL 2 used as Class A output valve (single valve)

Anode voltage	V_a	= 200 V	250 V
Screen-grid voltage	V_{g2}	= 200 V	250 V
Cathode resistor	R_k	= 480 ohms	485 ohms
Grid bias	V_{g1}	= —14 V	—18 V
Anode current	I_a	= 25 mA	32 mA
Screen-grid current	I_{g2}	= 4 mA	5 mA
Mutual conductance	S	= 3 mA/V	2.8 mA/V
Internal resistance	R_i	= 70,000 ohms	70,000 ohms
Load resistor	R_a	= 8,000 ohms	8,000 ohms
Output with 10 % distortion	W_o	= 2.3 W	3.6 W
Alternating grid voltage with 10 % distortion	V_i	= 8.5 V_{eff}	10 V_{eff}
Alternating grid voltage for 50 mW output	V_i	= 1 V_{eff}	0.9 V_{eff}

OPERATING DATA: EL 2 used as output valve in balanced circuit (2 valves)

		Automatic grid bias	
Anode voltage	V_a	= 200 V	250 V
Screen-grid voltage	V_{g2}	= 200 V	250 V
Common cathode resistor	R_k	= 320 ohms	305 ohms
Anode current (without signal)	I_{ao}	= 2 × 21 mA	2 × 27.5 mA
Anode current at full modulation	I_{amax}	= 2 × 24.5 mA	2 × 32.5 mA
Screen current (without signal)	I_{g2o}	= 3.5 mA	2 × 4.5 mA
Screen current at full modulation	I_{g2max}	= 2 × 6 mA	2 × 8 mA
Load resistor between the two anodes	R_{aa}	= 9,000 ohms	8,000 ohms
Output power	W_{omax}	= 5 W	8 W
Total distortion at full modulation	d_{tot}	= 1.5 %	1.4 %
Alternating grid voltage at full modulation	V_i	= 14 V_{eff}	17 V_{eff}

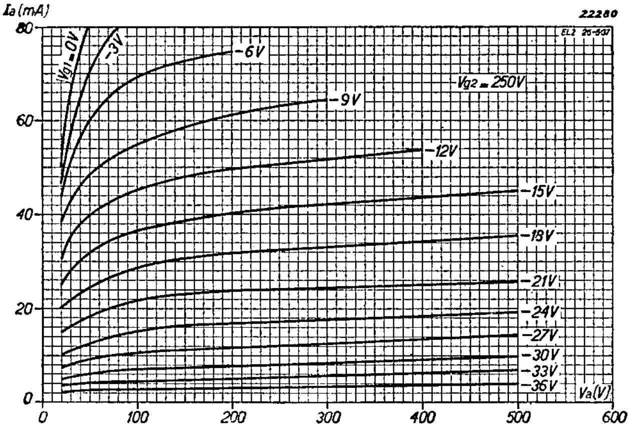


Fig. 4
Anode current as a function of the anode voltage with V_{g1} as parameter, at V_{g2} = 250 V.

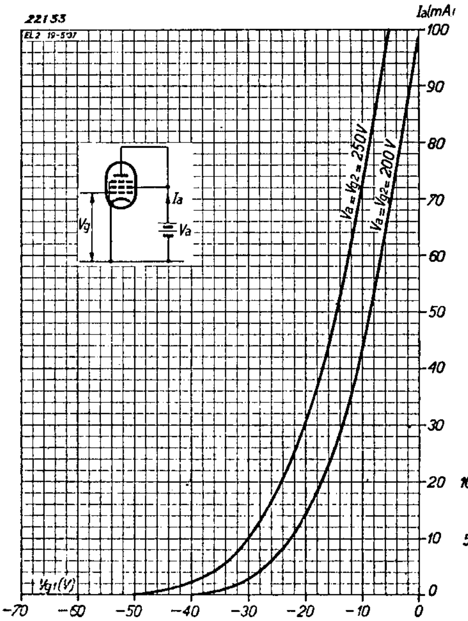


Fig. 5
EL 2 used as triode. Anode current as a function of the grid bias at *Va* = 200 and 250 V.

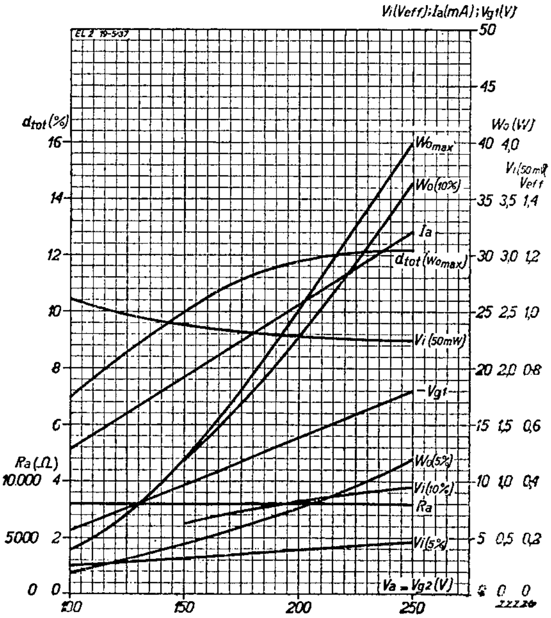


Fig. 6
EL 2 used as triode. Anode current as a function of the anode voltage for different values of grid bias.

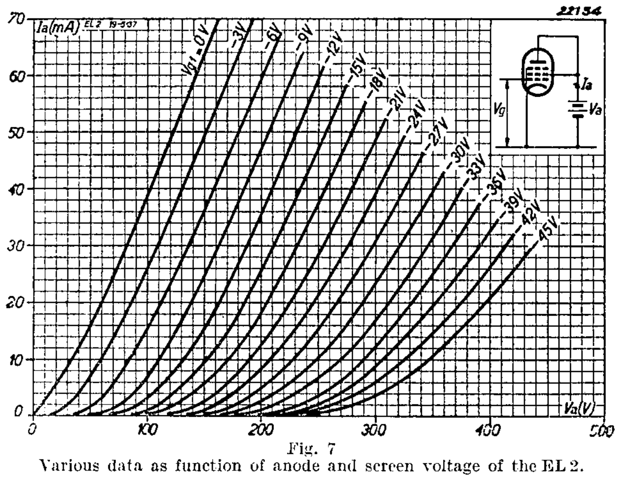


Fig. 7
Various data as function of anode and screen voltage of the EL 2.

OPERATING DATA: EL 2 used as triode (grid 2 connected to anode)

Anode and screen-grid voltage	V_a	= 250 V	250 V
Grid bias	V_{g1}	= —27 V	—20 V
Anode current	I_a	= 15 mA	30 mA
Mutual conductance	S	= 1.7 mA/V	2.6 mA/V
Internal resistance	R_i	= 4,100 ohms	3,100 ohms
Amplification factor	μ	= 7	8

MAXIMUM RATINGS

Anode voltage in cold condition	V_{ao}	= max. 550 V
Anode voltage	V_a	= max. 250 V
Anode dissipation	W_a	= max. 8 W
Screen-grid voltage in cold condition	V_{g2o}	= max. 550 V
Screen-grid voltage	V_{g2}	= max. 250 V
Screen-grid dissipation	W_{g2}	= max. 1.6 W
Cathode current	I_k	= max. 45 mA
Grid voltage at grid current start (I_{g1} = + 0.3 μA)	V_{g1}	= max. —1.3 V
Resistance between grid and cathode with automatic bias	R_{g1k}	= max. 1 M ohm
Resistance between grid and cathode with fixed bias	R_{g1k}	= max. 0.6 M ohm
Resistance between filament and cathode	R_{fk}	= max. 5,000 ohm
Voltage between filament and cathode (direct voltage or effective value of alternating voltage)	V_{fk}	= max. 50 V

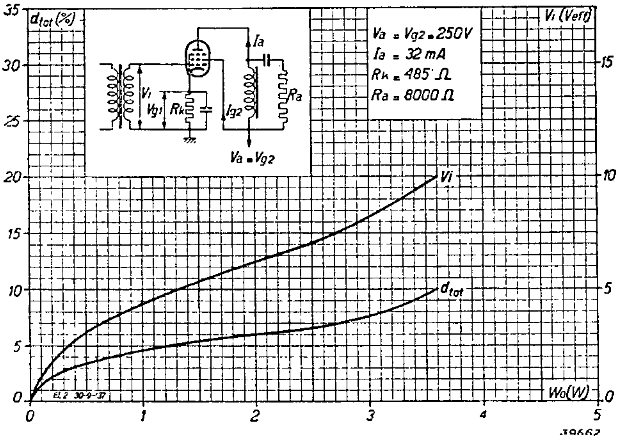


Fig. 8
Alternating grid voltage and total distortion as a function of the output power. EL 2 used as single output valve, with $V_a = V_{g2} =$ 250 V.

This valve can be used in a single or balanced output stage in car radio sets. For 12 V batteries the heaters of two of these valves can be connected in series, or, alternatively, one EL 2 may be placed in series with another valve in the same series, for example the EBC 3 or EF 6. The cathode must be decoupled with respect to the earth line through a capacitor of at least 2 μF, but an even higher capacitor of 25 or 50 μF is better. When used in balanced output circuits (two valves), the bias should preferably be automatic and the EBC 3 or EL 2, connected as triode, may be employed as driver. Bearing in mind the cost of the driver transformer and the required reproduction of low audio frequencies, the designer will find a transformation ratio of 1 : (2 + 2) quite suitable, but if the EL 2 is used, connected as triode, the ratio may be somewhat higher.

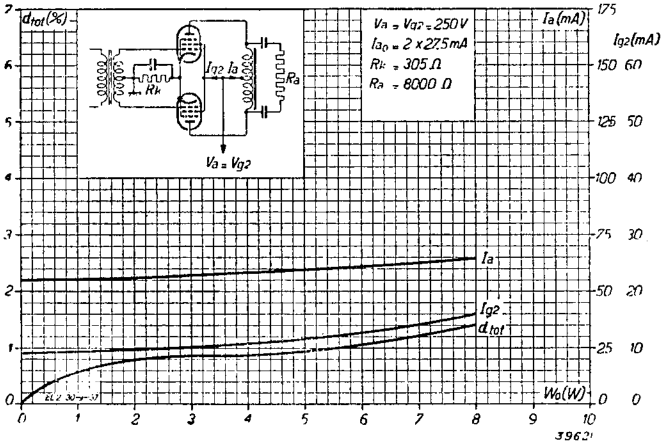


Fig. 9
Anode current, screen current and total distortion as a function of the output power for two EL 2 valves in a balanced circuit, with automatic grid bias, with $V_a = V_{g_2} = 250$ V.

Tables I and II furnish particulars of the EL 2 for the single output valve, allowing for the voltage drop across the output transformer; the values for output power refer to the effective power at the output side of the valve and in this case the transformer losses should be deducted.

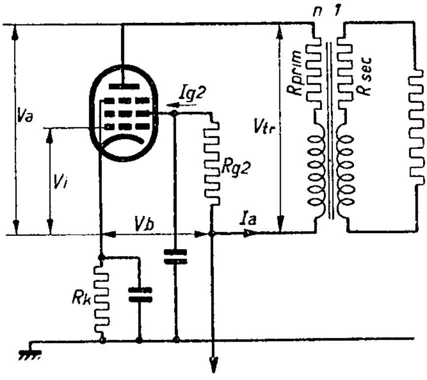


Fig. 10
Circuit diagram of the EL 2 as employed for the measurements the results of which are given in Table I. Loading resistance
$Ra = Rprim + n^2 Rsec + n^2 Rl = Rtr + n^2 Rl.$
Output power
$Wo = ia^2 (Rprim + n^2 Rsec + n^2 Rl)$
$= ia^2 (Rtr + n^2 Rl) = ia^2 Ra.$
Direct voltage on the anode = $Va = Vb - Ia\ Rprim$.
Power loss in output transformer =
$ia^2 (Rprim + n^2\ Rsec) = ia^2\ Rtr = Wo\ \frac{Rtr}{Ra}$

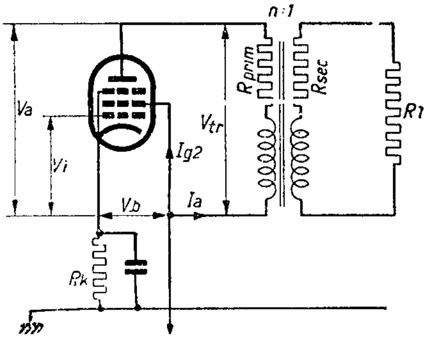


Fig. 11
Circuit diagram of the EL 2 as used for the measurements the results of which are given in Table II. For the symbols and formulae employed see text, Fig. 10

TABLE I

EL 2. Output power and alternating voltage across grid leak as a function of the voltage drop across the output transformer, at an anode voltage of 250 V.

$I_a = 32$ mA

Anode voltage V_a (V)	Supply voltage V_b (V)	Screen resistor R_{g_2} (ohm)	Voltage drop in output transf. V_{tr} (V)	With 10 % distortion			At 5 % distortion			Power loss in output transformer $\frac{W_{tr}}{W_o}$ 100 %
				Anode load resistor R_a (ohm)	Alternating grid voltage V_i (V_{eff})	Output power W_o (W)	Anode load resistor R_a (ohm)	Alternating grid voltage V_i (V_{eff})	Output power W_o (W)	
250	250	0	0	8,000	9.4	3.65	8,000	4.7	1.3	—
250	260	1,600	10	8,000	9.4	3.5	8,000	4.5	1.1	8
250	270	3,300	20	8,000	9.3	3.3	8,000	4.4	1.1	16
250	280	4,900	30	8,000	9.0	3.2	8,000	4.4	1.1	24
250	300	8,400	50	8,000	8.5	2.95	8,000	4.3	1.0	40

TABLE II

EL 2. Output power and peak alternating grid voltage as a function of the voltage drop across the output transformer at 250 V supply and screen voltages.

$I_a = 32$ mA

Anode voltage V_a (V)	Supply voltage V_b (V)	Screen voltage V_{g_2} (V)	Voltage drop in output transf. V_{tr} (V)	With 10 % distortion			At 5 % distortion			Power loss in output transformer $\frac{W_{tr}}{W_o}$ 100 %
				Anode load resistor R_a (ohm)	Alternating grid voltage V_i (V_{eff})	Output power W_o (W)	Anode load resistor R_a (ohm)	Alternating grid voltage V_i (V_{eff})	Output power W_o (W)	
250	250	250	0	8,000	9.4	3.65	8,000	4.7	1.3	—
250	250	250	10	7,500	9.6	3.55	7,500	4.7	1.2	8
250	250	250	20	7,000	9.6	3.35	7,000	4.7	1.1	18
250	250	250	30	7,000	9.5	3.15	7,000	5.2	1.3	27
250	250	250	50	6,000	9.8	2.9	6,000	5.1	1.1	52

Note: In calculating the power loss due to the resistance of the output transformer windings, it was assumed that the losses in primary and secondary windings were equal.

EL 3 Output pentode

This is a high-mutual-conductance, indirectly-heated 9 W output pentode which, owing to its accuracy of construction, is capable of delivering 4.5 W with 10 % distortion (i.e., efficiency 50 %). The mutual conductance is 9 mA/V and the valve lends itself well to reception incorporating A.F. feed-back; the grid input signal for full modulation is 4.2 V. In balanced output stages it is possible to obtain an output of 8.2 W at $V_a = V_{g2} = 250$ V, in which case the distortion is 3.1 % whilst the input signal need only be 6.7 V (per half of the secondary winding of the driver transformer). At a screen potential of 265 V, with 250 V applied to the anode and allowing for a voltage drop of 15 V in the output transformer, an output power of 9 W is developed, with 6.8 % distortion, on a grid input of 5.6 V (effective). The special construction of the cathode imparts to this valve its very high mutual conductance with a comparatively low heater power; at the heater voltage of 6.3 V the current is only 0.9 A.

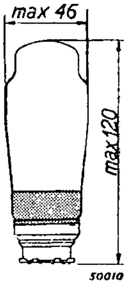


Fig. 1
Dimensions in mm

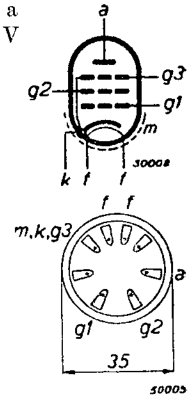


Fig. 2
Arrangement of electrodes and base connections.

HEATER RATINGS

Heating: indirect, A.C. or D.C. parallel supply.

Heater voltage . . . . $V_f = 6.3$ V

Heater current . . . . $I_f = 0.9$ A

CAPACITANCES

Anode-to-grid . . . . $C_{ag1} = < 0.8$ μμF

OPERATING DATA: EL 3 employed as single output valve

Anode voltage	V_a	= 250 V
Screen-grid voltage	V_{g2}	= 250 V
Grid bias	V_{g1}	= —6 V
Cathode resistor	R_k	= 150 ohms
Anode current	I_a	= 36 mA
Screen-grid current	I_{g2}	= 4 mA
Mutual conductance	S	= 9 mA/V
Internal resistance	R_i	= 50,000 ohms
Load resistor	R_a	= 7,000 ohms
Output power with 10 % distortion	W_o	= 4.5 W
Alternating grid voltage at $W_o = 4.5$ W	V_i	= 4.2 V_{eff}
Sensitivity ($W_o = 50$ mW)	V_i	= 0.33 V_{eff}
Amplification factor; grid 2 with respect to grid 1	μ_{g2g1}	= 23

OPERATING DATA: EL 3 used in balanced output stage (2 valves)

(automatic grid bias)

Anode voltage	V_a	= 250 V	250 V
Screen-grid voltage	V_{g2}	= 250 V	250 V
Cathode resistor	R_k	= 140 ohms	190 ohms [1]
Anode current (without signal)	I_{ao}	= 2 × 24 mA	2 × 31 mA
Anode current at max. modulation	$I_{a\,max}$	= 2 × 28.5 mA	2 × 34 mA
Screen current (without signal)	I_{g2o}	= 2 × 2.8 mA	2 × 3.6 mA
Screen current at max. modulation	$I_{g2\,max}$	= 2 × 4.6 mA	2 × 5.8 mA
Load resistor between anodes	R_{aa}	= 10,000 ohms	10,000 ohms
Output power	W_o	= 8.2 W	9 W
Distortion	d_{tot}	= 3.1 %	6.8 %
Alternating input voltage (per grid)	V_i	= 6.7 V_{eff}	5.6 V_{eff}

[1] separate cathode resistor per valve.

OPERATING DATA: EL 3 employed as triode (Grid 2 connected to anode)

Anode voltage	V_a	= 250 V
Grid bias	V_{g1}	= —8.5 V
Cathode resistor	R_k	= 425 ohms
Anode current	I_a	= 20 mA
Amplification factor	μ	= 20
Mutual conductance	S	= 6.5 mA/V
Internal resistance	R_i	= 3,000 ohms
Load resistor	R_a	= 7,000 ohms
Output power with 5 % distortion	W_o	= 1.1 W
Alternating grid voltage	V_i	= 5.9 V_{eff}
Sensitivity (W_o = 50 mW)	V_i	= 1.1 V_{eff}

MAXIMUM RATINGS

Anode voltage in cold condition	V_{ao}	= max. 550 V
Anode voltage	V_a	= max. 250 V
Anode dissipation	W_a	= max. 9 W
Screen-grid voltage in cold condition	V_{g2o}	= max. 550 V
Screen voltage	V_{g2}	= max. 275 V
Screen dissipation (V_i = o)	W_{g2}	= max. 1.2 W
Screen dissipation (W_o = max.)	W_{g2}	= max. 2.5 W
Cathode current	I_k	= max. 55 mA
Grid voltage at grid current start (I_{g1} = + 0.3 μA)	V_{g1}	= max. —1.3 V
External resistance between grid and cathode	R_{g1k}	= max. 1 M ohm
External resistance between filament and cathode	R_{fk}	= max. 5,000 ohms
Voltage between filament and cathode (D.C. voltage or effective value of alternating voltage)	V_{fk}	= max. 50 V

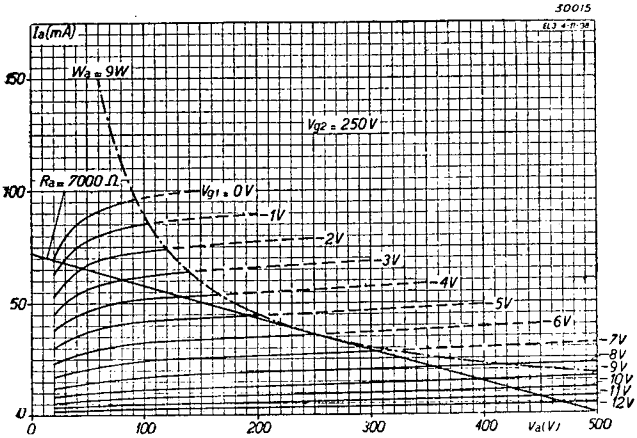


Fig. 3
Anode current as a function of the anode voltage at different values of grid bias, at $Vg_2 = 250$ V

As there is normally a voltage drop across the output transformer, it is necessary to allow for this in determining the supply voltage if the maximum output is to be obtained from the valve. Usually, the screen grid is connected directly to the supply line and, in order to ensure maximum anode voltage (250 V), the screen potential should be slightly higher, this being limited to 275 V maximum (see maximum ratings). Fig. 7 gives a number of useful data as plotted against the screen voltage within a range of 250—275 V and these curves furnish the main operating data with respect to any voltage drop of from 0 to 25 V in the output transformer.

Fig. 8 supplies additional data as a function of the screen voltage for the case where the receiver supply is less than 250 V and the anode potential is less than the screen voltage by 15 V (equal to the voltage drop across the output transformer).

Grid bias may be of the automatic type only (cathode resistor); semi-automatic bias is permissible provided that the cathode current of the EL 3 exceeds 50 % of the total current flowing through the biasing resistor. The maximum value for the grid leak, as shown in the maximum ratings, should then be reduced in accordance with the formula: (cathode current of output valve/total current in the resistance) × R_{g1k}. Furthermore, the fact must be taken into account that the current of any valves controlled by A.G.C. will affect the bias on the output valve, so that, if A.G.C. is to be employed, the bias may be too low and the anode current therefore too high. In the design of a receiver it is essential to take the high mutual conductance into consideration, as it may otherwise give rise to feed-back and parasitic oscillation. Leads to the valve holders must be as short as possible and a resistor of 1,000 ohms in the control-grid lead is in many cases necessary.

When this valve is to be used in balanced output circuits the following should also be borne in mind. If the standing anode current is more than 25 mA a separate resistor must be used for each valve; differences in the anode currents might be the cause of overloading, due to the fact that one valve carrying a high current would receive too little bias from another with too low a current. It is advisable to watch this point in all cases where the removal of one of the valves would cause damage to another. The data supplied in respect of this valve when used as a triode give a clear idea of its performance as a pre-amplifier in balanced output circuits.

To prevent oscillation it is advisable not to connect the screen directly to the anode but to interpose a resistor of 100 ohms, without any decoupling; for the rest, the same precautions must be taken as for a pentode, such as short leads, etc. The EL 3 coupled as a triode will also give good results when employed as a driver valve in balanced output stages operating with grid current.

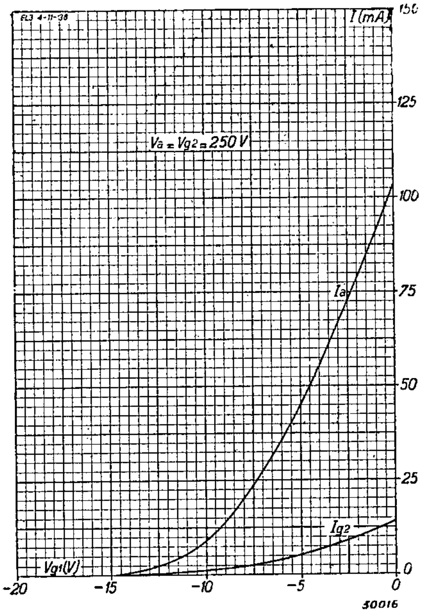


Fig. 4
Anode and screen-grid current as a function of the grid bias at $Va = Vg_2 = 250$ V.

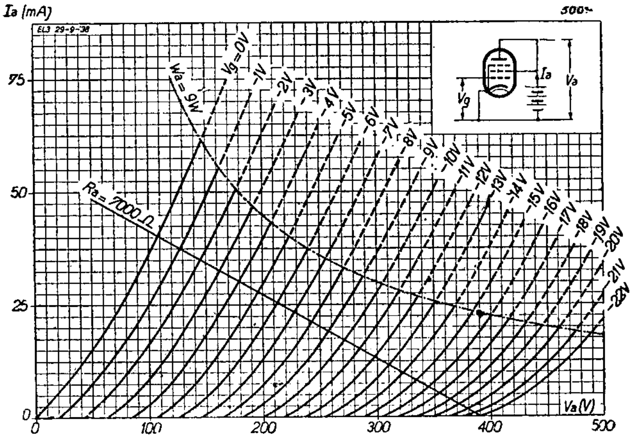


Fig. 5
Anode and screen-grid current as a function of the anode voltage, with Vg as parameter. EL 3 used as a triode.

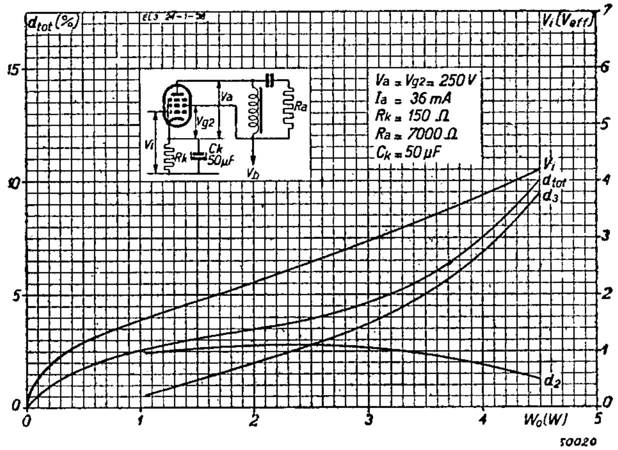


Fig. 6
Total distortion, 2nd and 3rd harmonic distortion and alternating grid voltage as a function of the output power. EL 3 used as single output valve with automatic bias ($V_a = V_{g_2} = 250$ V).

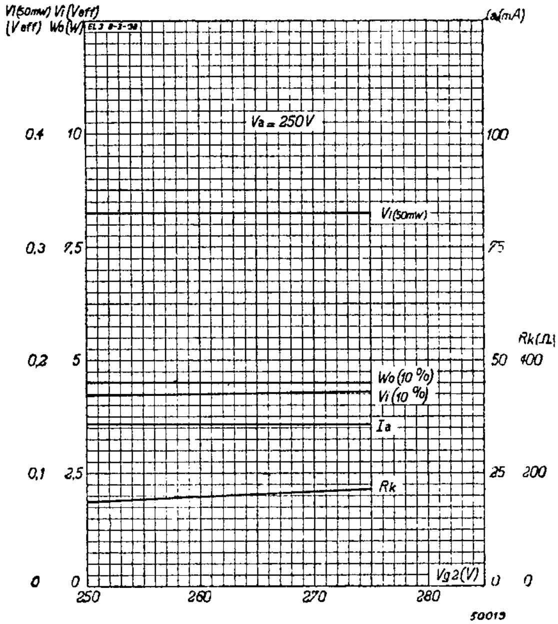


Fig. 7

Output power with 10 % distortion . . . *Wo* (10 %)
Alternating grid voltage . . *Vi* (10 %)
Sensitivity . . . . *Vi* (50 mW)
Cathode resistor . . . . . . *Rk*
Anode current . . . . *Ia*

as a function of the screen-grid voltage (in the range 250–275 V), at constant anode voltage (V_a = 250 V)

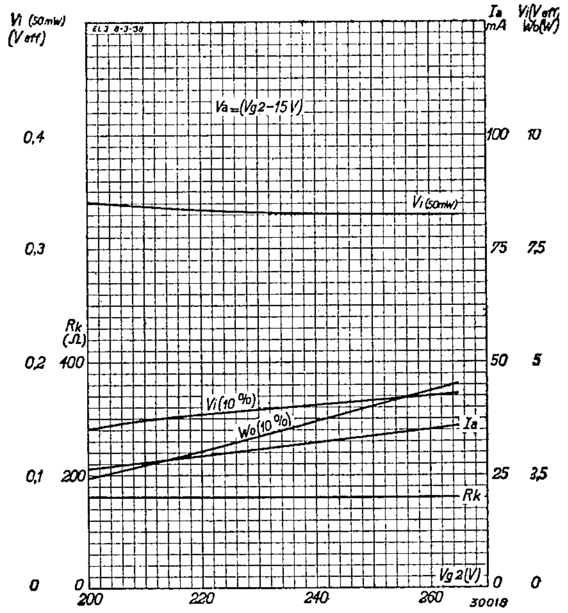


Fig. 8

Output power with 10 % distortion. . .	*Wo* (10 %)
Alternating grid voltage . .	*Vi* (10 %)
Sensitivity	*Vi* (50 mW)
Cathode resistor	*Rk*
Anode current.	*Ia*

as a function of the screen-grid voltage (in the range 200–265 V) and at an anode voltage of 15 V less than the screen potential.

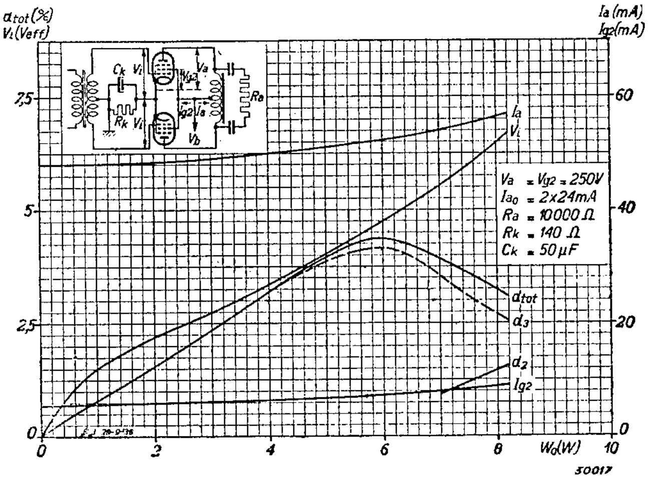
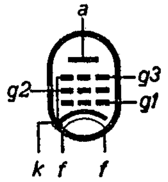


Fig. 9

Anode current I_a, screen current I_{g_2}, total distortion, 2nd and 3rd harmonic distortion and alternating grid voltage V_i as functions of the output power W_o, for 2 EL 3 valves in a balanced circuit, with $V_a = V_{g_2} = 250$ V.

EL 5 Output Pentode



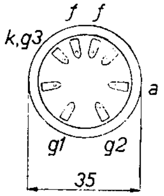


Fig. 2
Arrangement of electrodes and base connections.

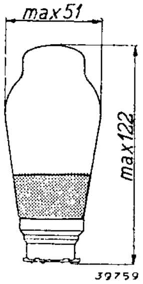


Fig. 1
Dimensions in mm.

The EL 5 is a steep-slope, 18 W output pentode. Using this valve it is possible to obtain greater output power than with two 9 W pentodes in a balanced circuit. Linear and non-linear distortion are considerably reduced by applying A. F. feedback.

Two of these 18 W pentodes in a balanced circuit will deliver an effective output of 20 W, in which case contrast expansion can be successfully employed. The particular form and dimensions of the 3rd grid ensure a very satisfactory upper bend in the dynamic characteristic. At full excitation it is possible for the anode voltage to drop to very low values, with the result that the distortion at 9 W output is extremely low, being 10 % when automatic bias is employed; at lower output powers the amount of 3rd harmonic distortion is very slight indeed. All the advantages of a triode are thus obtained, without its disadvantages, viz. that the output power with a given amount of distortion drops sharply when a loading resistance higher than the normal is used.

As the valve may be used with a screen voltage of 275 V this, in conjunction with an anode voltage of 250 V, will allow for a drop of about 25 V in the output transformer.

HEATER RATINGS

Heating: indirect by A.C., parallel supply.
Heater voltage . . . . . $V_f = 6.3$ V
Heater current . . . . . $I_f = 1.3$ A

CAPACITANCES

Anode-grid $C_{ag1} < 0.8$ μμF

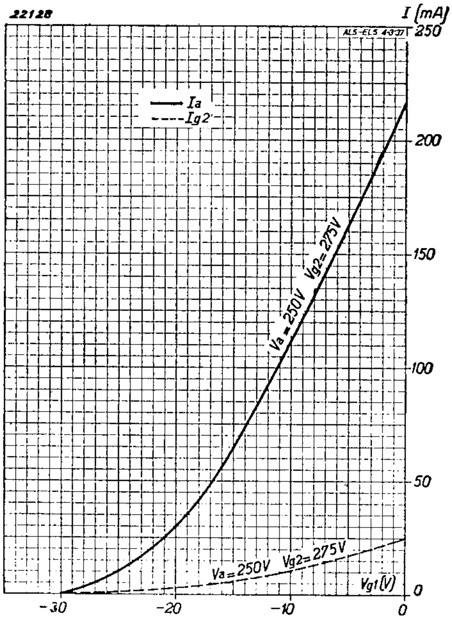


Fig. 3
Anode current and screen current as a function of the grid bias, at $V_a = 250$ V, $V_{g_2} = 275$ V.

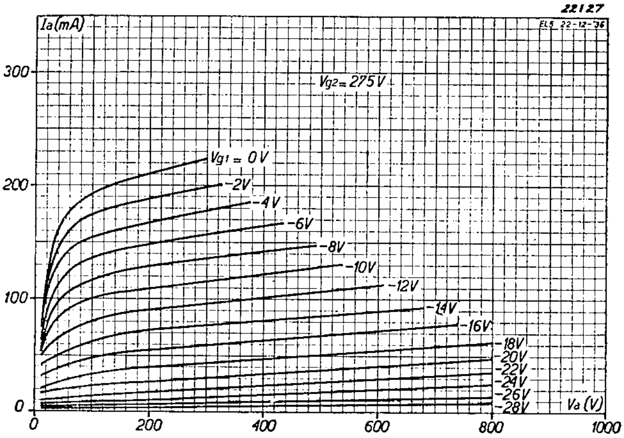


Fig. 4
Anode current as a function of the anode voltage at V_{g_2} = 275 V, for different values of grid bias.

OPERATING DATA: El 5 used as normal output valve (single valve)

Anode voltage	V_a	= 250 V
Screen-grid voltage	V_{g2}	= 275 V
Cathode resistor	R_k	= 175 ohms
Grid bias	V_{g1}	= —14 V
Anode current	I_a	= 72 mA
Screen current	I_{g2}	= 7 mA
Mutual conductance	S	= 8.5 mA/V
Internal resistance	R_i	= 22,000 ohms
Load resistor	R_a	= 3,500 ohms
Output power (d_{tot} = 10 %)	W_o	= 8.8 W
Alternating input voltage with 10 % dist.	V_i	= 9.1 V_{eff}
Sensitivity (W_o = 50 mW)	V_i	= 0.5 V_{eff}

El 5 in a balanced output circuit (two valves), with automatic bias

Anode voltage	V_a	= 250 V
Screen-grid voltage	V_{g2}	= 275 V
Cathode resistor	R_k	= 120 ohms
Anode current (without signal)	I_{ao}	= 2 × 58 mA
Anode current at max. modulation	$I_{a\ max}$	= 2 × 65 mA
Screen current (without signal)	I_{g2o}	= 2 × 6.25 mA
Screen current at max. modulation	$I_{g2\ max}$	= 2 × 10.5 mA
Load resistor between anodes	R_{aa}	= 4,500 ohms
Output power (I_{g1} = + 0.3 μA)	W_o	= 19.5 W
Total distortion (I_{g1} = + 0.3 μA)	d_{tot}	= 5.1 %
Alternating input voltage (I_{g1} = + 0.3 μA)	V_i	= 12.5 V_{eff}

MAXIMUM RATINGS

V_{ao} = max. 550 V
V_a = max. 250 V
W_a = max. 18 W
V_{g2o} = max. 550 V
V_{g2} = max. 275 V
W_{g2} = max. 3 W

I_k = max. 90 mA
V_{g1} (I_{g1} = + 0.3 μA) = max. —1.3 V
R_{g1k} (auto. bias) = max. 0.7 M ohm
R_{fk} = max. 5,000 ohms
V_{fk} = max. 50 V

A. Single output Amplifier

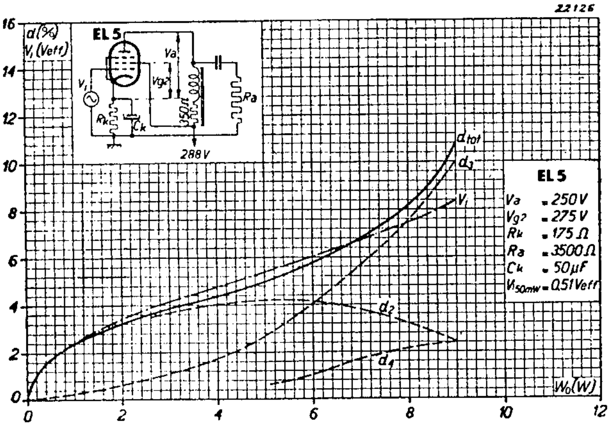


Fig. 5
Alternating grid voltage, total distortion and distortion constituents, as functions of the output power; EL 5 used normal output valve with appropriate anode voltage, 3,500 ohms load resistor and decoupled bias resistor.

Generally speaking, it is not advisable to couple the EL 5 directly to a diode. Figures 5 and 6 indicate the alternating grid input and distortion at V_a = 250 V, V_{g2} = 275 V and R_k = 175 ohms, corresponding to an anode current of 72 mA, as a function of the output power; Fig. 5 relates to a loading resistance of 3,500 ohms and Fig. 6 to 2,500 ohms. From these curves it is evident that when a load of 2,500 ohms is used the 3rd harmonic component is much smaller than in the case of the 3,500 ohms load, so that in all instances where this would be an important factor the smaller load deserves preference.

The suggested pre-amplifier for use with the EL 5 is the EL 6 or EBC 3. When the EL 6 is employed in conjunction with the EL 5 the distortion curve is almost identical to that of the EL 5 alone. With the combination EBC 3 + EL 5 the distortion curve, at a lower output than three-quarters of the maximum, is about 10 % lower, this low distortion figure being due to partial compensation of the 2nd harmonic in the EL 5 by that of the EBC 3. Owing to its high mutual conductance, the EL 5 is eminently suited to the application of negative A.F. feed-back for reduction of distortion. When feed-back is applied, using a factor of about 10, the result is as shown in Fig. 7, in which the EF 6 is represented as pre-amplifier, with the feed-back applied to both valves.

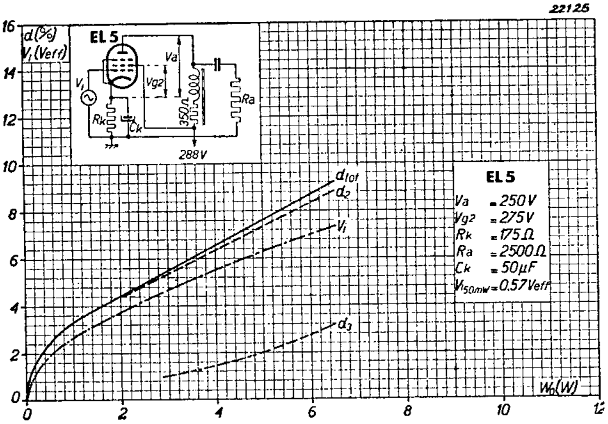


Fig. 6
Relation between alternating grid voltage, total distortion, distortion components and output power of the EL 5, with normal anode voltage, 2,500 ohms load resistor and decoupled bias resistor.

B. Balanced output Stages (2 Valves)

If greater output, or less distortion, is desired, two EL 5 valves can with advantage be coupled in a balanced circuit. With an anode voltage of 250 V and screen voltage of 275 V, the common cathode resistor should be 120 ohms and distortion can be kept down by decoupling this resistor with a high capacitor (25 or 50 μF). The full line in Fig. 8 represents the distortion obtained with this arrangement, with a load resistor of 4,500 ohms (between anodes), as a function of the output power. The distortion is due to 3rd harmonic only.

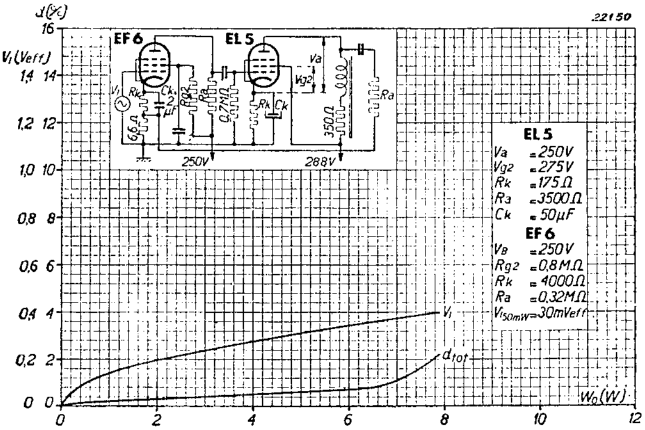


Fig. 7
Relation between alternating grid voltage *Vi*, total distortion *dtot* and output power; EL 5 with pre-amplifier EF 6 and negative feedback applied to the latter.

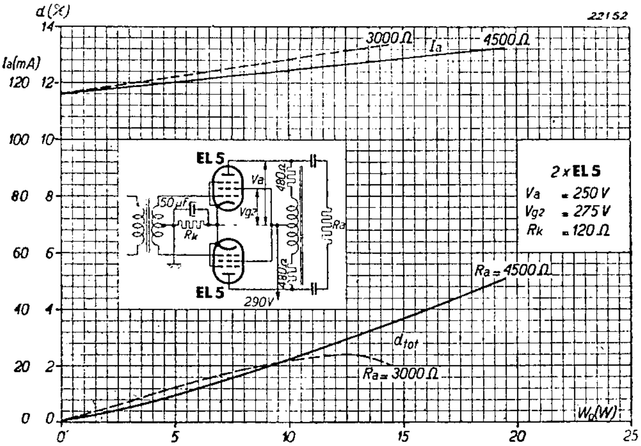


Fig. 8
Anode current and total distortion as a function of the output power; two EL 5 valves in balanced output stage without grid current, employing normal anode voltage and load resistor of 3,000 ohms or 4,500 ohms between anodes.

EL 6 Output Pentode

This is another 18 W, indirectly-heated, high conductance output pentode, the need for which arose from a demand for a "larger" output valve which, fully excited, would take about the same grid input as the EL 3. The advantage of this valve is that receivers having a 9 W or 18 W output stage, apart from the rectifier, may be developed along exactly the same lines. At the working point the EL 6 has the unusually high mutual conductance of 14.5 mA/V. With 10 % distortion the maximum obtainable output is 8 W. The peak alternating grid voltage for this output is only 4.8 $V_{(eff)}$ whilst the sensitivity (for 50 mW output) is 0.3 $V_{(eff)}$.

The valve can also figure in balanced output stages, although the output obtainable is then not so high as in the case of two EL 5 type valves. On the other hand, the EL 6 has the advantage of a higher mutual conductance. The optimum output power is 14.5 W with 2.2 % distortion at an alternating grid voltage of 7.3 $V_{(eff)}$ per grid. Taking into account an average voltage drop of 15 V across the output transformer, the output at V_a = 250 V with V_{g2} = 265 V is somewhat higher, viz. 16 W, with 1.4 % distortion with a grid input of 8.5 $V_{(eff)}$. The maximum distortion is roughly 3 %, which occurs at approximately 10 W output.

The very high mutual conductance is due to the special construction of the cathode, with its relatively low heater power: at 6.3 V the current consumed is 1.2 A.

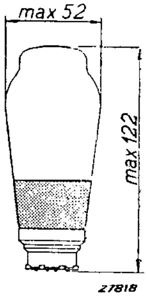


Fig. 1
Dimensions in mm.

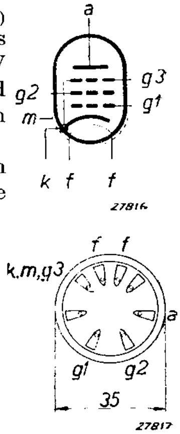


Fig. 2
Arrangement of electrodes and base connections.

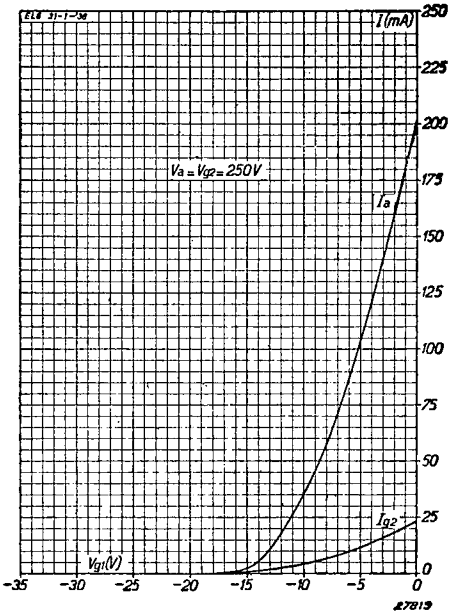


Fig. 3
Anode and screen current as a function of the grid bias. at $Va = Vg_2 = 250$ V.

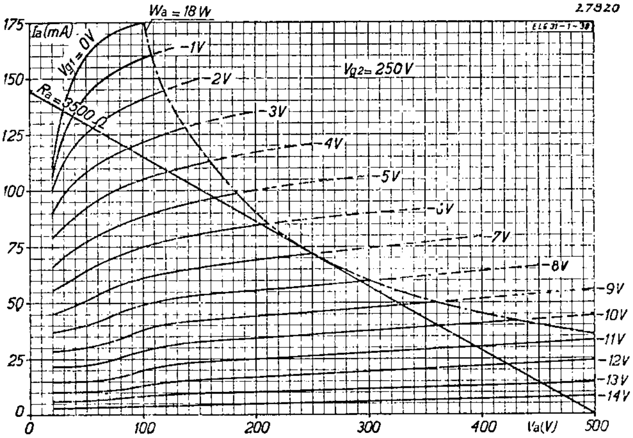


Fig. 4
Anode current as a function of the anode voltage at $V_{g2} = 250$ V with V_{g1} as parameter.

HEATER RATINGS

Heating: indirect by A.C., parallel supply.
Heater voltage . . . . $V_f = 6.3$ V
Heater current . . . . $I_f = 1.2$ A

CAPACITANCES

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

OPERATING DATA: EL 6 used as a normal output valve (single valve)

Anode voltage . . . . V_a = 250 V
Screen-grid voltage . . . . V_{g2} = 250 V
Grid bias. . . . . V_{g1} = —7 V
Cathode resistor . . . . R_k = 90 ohms
Anode current . . . . I_a = 72 mA
Screen-grid current . . . . I_{g2} = 8.0 mA
Mutual conductance . . . . S = 14.5 mA/V
Internal resistance . . . . R_i = 20,000 ohms
Load resistor . . . . R_a = 3,500 ohms
Output power with 10 % distortion . . . . W_o = 8 W
Alternating input voltage for $W_o = 8$ W . . . . V_i = 4.8 V_{eff}
Sensitivity ($W_o = 50$ mW) . . . . V_i = 0.3 V_{eff}
Amplification factor, screen with respect to grid 1 . . . μ_{g2g1} = 20

OPERATING DATA: EL 6 used as an output valve in balanced circuits (two valves) with automatic grid bias.

Anode voltage	V_a	= 250 V	250 V
Screen-grid voltage	V_{g2}	= 250 V	265 V
Cathode resistor	R_k	= 90 ohms	97 ohms
Anode current (without signal)	I_{ao}	= 2 × 45	2 × 45 mA
Anode current at max. modulation	$I_{a\,\max}$	= 2 × 53	2 × 54 mA
Screen current (without signal)	I_{g2o}	= 2 × 5.1	2 × 5.1 mA
Screen current at max. modulation	$I_{g2\,\max}$	= 2 × 8.5	2 × 9.9 mA
Load resistor between anodes	R_{aa}	= 5,000 ohms	5,000 ohms
Output power	W_o	= 14.5 W	16 W
Distortion	d_{tot}	= 2.2 %	1.7 %
Alternating grid voltage per grid	V_i	= 7.3 V_{eff}	8.2 V_{eff}

MAXIMUM RATINGS

Anode voltage in cold condition	V_{ao}	= max. 550 V
Anode voltage	V_a	= max. 250 V
Anode dissipation	W_a	= max. 18 W
Screen voltage in cold condition	V_{g2o}	= max. 550 V
Screen voltage	V_{g2}	= max. 275 V
Screen dissipation (V_i = o)	W_{g2}	= max. 2 W
Screen dissipation (W_o = max.)	W_{g2}	= max. 3 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	R_{g1k}	= max. 0.7 M ohm
External resistance between heater and cathode	R_{fk}	= max. 5,000 ohms
Voltage between heater and cathode (D.C. voltage or effective value of alternating voltage)	V_{fk}	= max. 50 V

Fig. 6 gives a number of useful data plotted against the screen voltage in the range 250—275 V. With an anode voltage of 250 V by means of these characteristics any voltage drop in the output transformer from 0 to 25 V can be taken into account in investigating the operation of the valve. Dynamic characteristics of the EL 6 as a function of the screen voltage, in the case of receivers in which the available anode voltage is less than 250 V and whereby the anode voltage is less than that of the screen by 15 V, are given in Fig. 8. Allowance is made for an average voltage drop of 15 V across the output transformer.

In the case of Class A and A/B amplification the grid bias must be automatic (cathode resistor); semi-automatic bias may be employed so long as the cathode current of the EL 6 is in excess of 50 % of the total current flowing through the biasing resistor. The maximum value of the grid leak, as indicated in the Maximum Ratings should then be reduced in accordance with the following:

$$\frac{\text{Cathode current of the output valve}}{\text{Total current passing through the resistor producing the voltage drop}} \times R_{g1k}$$

It should be noted, further, that the current of those valves to which automatic gain control is applied will affect the bias on the output valve, so that when the control voltage rises the bias quickly becomes too low and the anode current too high.

The high mutual conductance of this valve should be taken into consideration in the design of receiver circuits, in view of the resultant tendency towards R.F. feedback and oscillation. Leads to the valve contacts should therefore be as short as possible, and a resistor of about 1,000 ohms in the grid lead is indispensable.

For the use of the valve in balanced circuits employing automatic bias the necessary data will be found in Figs 8 and 9: the former gives the distortion and alternating grid voltage at $V_a = 250$ V and $V_{g2} = 250$ V, whilst Fig. 9 shows various data, such as the biasing resistor, output power, etc. as functions of the screen voltage when the anode current is 2 × 24 mA with a constant voltage of 250 V on the anode. Using the curves it is possible for the designer to obtain the appropriate operating conditions with respect to almost any voltage drop across the output transformer. In balanced output stages care should be taken, if the anode current (without signal) is more than 45 mA per valve, to see that each valve has its own biasing resistor. This precaution is advisable in all cases where a possibility exists that one of the valves may be removed while the set is in operation, as this will otherwise result inevitably in damage to the other valve.

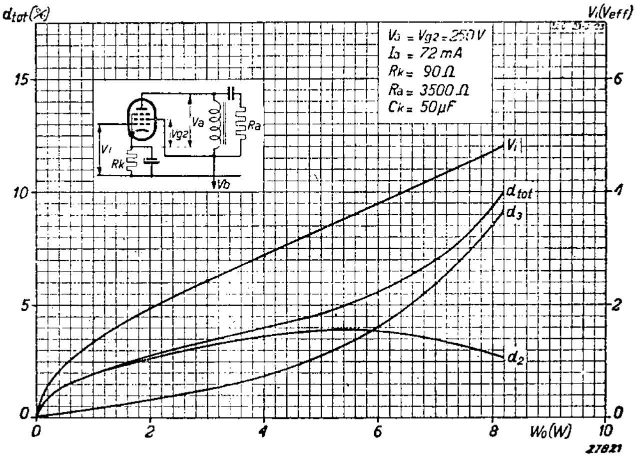


Fig. 5
Total distortion, and 2nd and 3rd harmonic distortion; EL 6 used as normal output pentode with auto. bias and decoupling capacitor in the cathode circuit ($Va = Vg_2 = 250$ V).

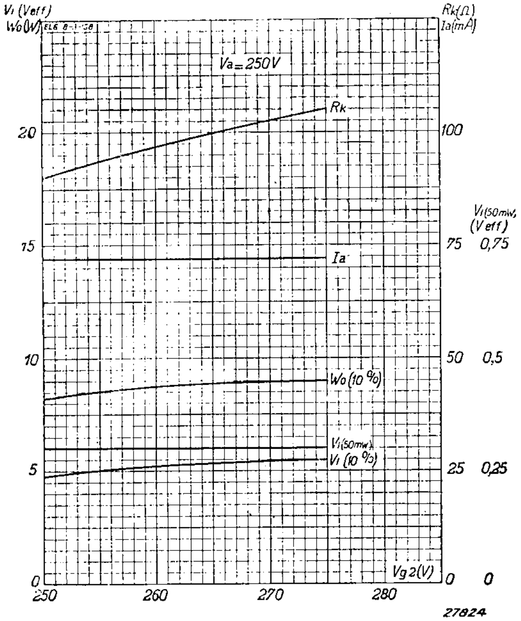


Fig. 6

Output power with 10 % distortion . . .	W_o (10 %)	as functions of the screen voltage (in the range 250–275 V) with a constant anode voltage (V_a = 250 V).
Alternating grid voltage at 10 % distortion	V_i (10 %)	
Sensitivity	V_i (50 mW)	
Cathode resistor	R_k	
Anode current.	I_a	

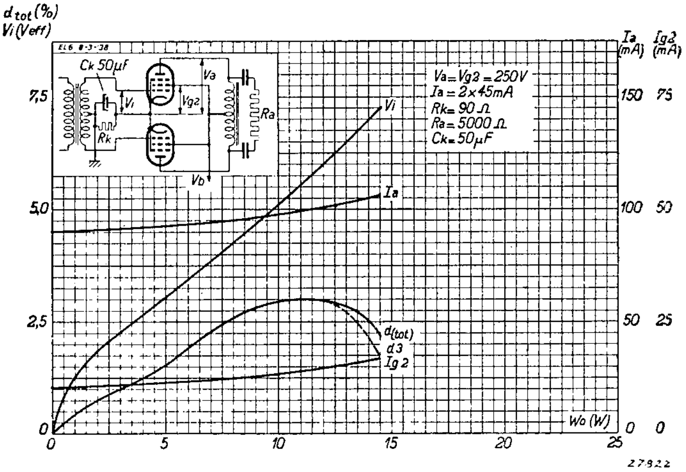


Fig. 7
Total anode current I_a, total screen current I_{g_2}, total distortion d_{tot}, 3rd harmonic distortion and alternating grid voltage per grid V_i, as functions of the output power W_o when using two EL 6 valves in a balanced circuit with $V_a = V_{g_2}$ = 250 V.

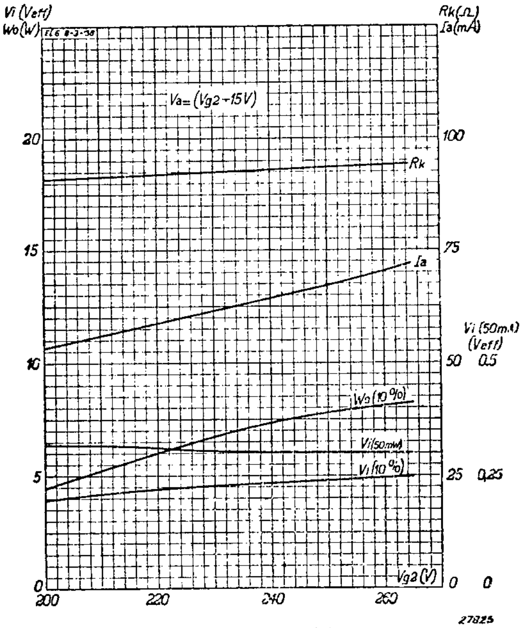


Fig. 8

Output power with 10 % distortion . . . *Wo* (10 %)
Alternating grid voltage with 10 % distortion . . . *Vi* (10 %)
Sensitivity . . . . *Vi* (50 mW)
Cathode resistor . . . . . . *Rk*
Anode current . . . . *Ia*

as functions of the screen-grid voltage (in the range 200–265 V) where the voltage of the anode is 15 V lower than that of the screen.

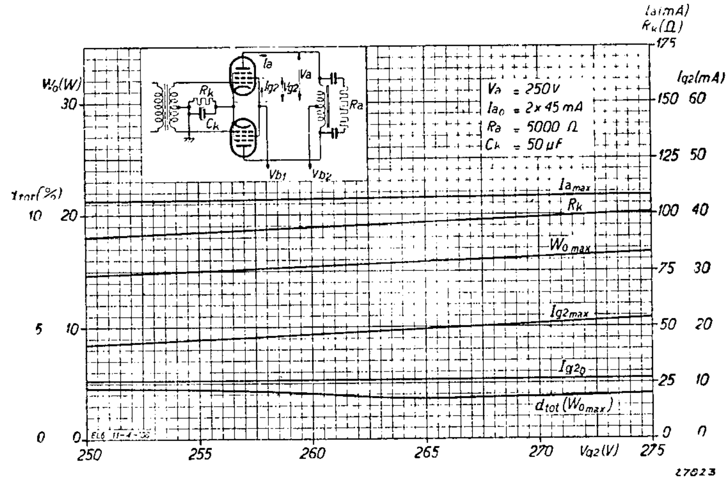


Fig. 9

Output power at max. modulation . . . *Wo*max
Total distortion . . . . *d*tot (*Wo*max)
Anode current at max. modulation . . . *Ia*max
Screen current (without signal) . . . . . $I_{g_2}o$
Screen current at max. modulation . . . I_{g_2}max
Cathode resistor (Iao = 45 mA per valve) *Rk*

as functions of the screen-grid voltage (in the range 250–275 V), at constant anode voltage (Va = 250 V)

ELL 1 Double Output Pentode

This valve was specially designed for car radio receivers and consists of two output pentode units enclosed in a single envelope, each unit having an anode dissipation of 4.5 W. From the point of view of its operation from the car battery, both the heater and the anode current have been kept as low as possible; in consequence, the mutual conductance of each unit invidually is not so very high, viz. 1.7 mA/V. The two valve units have been housed in a common bulb for use in balanced circuits, in order that the power supplied to the anode shall be utilized to the best possible advantage; with 3.5 % distortion, the output power is 4.5 W.

The two cathodes, screen grids and suppressors are inter-connected within the valve.

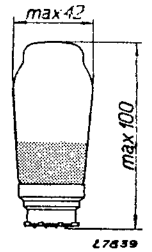


Fig. 1
Dimensions in mm.

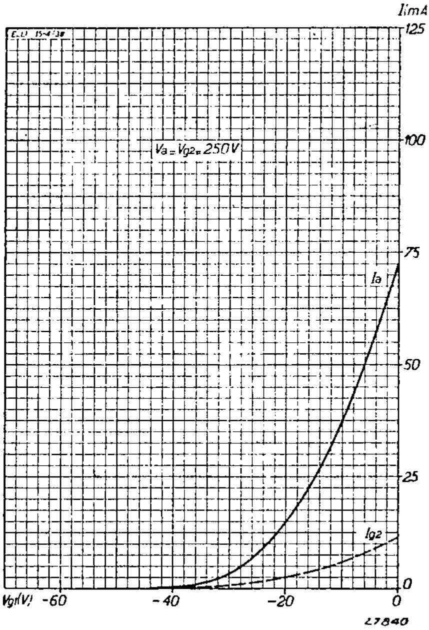


Fig. 3
Anode and screen-grid currents of a single pentode unit of the ELL 1 as a function of the grid bias, at $V_a = V_{g_2} = 250$ V.

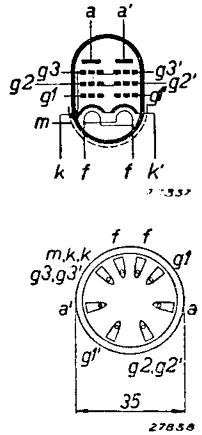


Fig. 2
Arrangement of electrodes and base connections.

HEATER RATINGS

Heating: indirect by battery current, rectified A.C. or D.C.; parallel supply.

Heater voltage . . . . $V_f = 6.3$ V
Heater current . . . . $I_f = 0.45$ A

CAPACITANCES

Anode-grid system 1 . . . . $C_{ag_1} < 1.3$ $\mu\mu$F
Anode-grid system 2 . . . . $C_{a'g_1'} < 1.3$ $\mu\mu$F

STATIC RATINGS (PER SYSTEM)

Anode voltage	V_a	= 250 V
Screen-grid voltage	V_{g2}	= 250 V
Grid bias	V_{g1}	= —19.5 V
Anode current	I_a	= 15 mA
Screen-grid current	I_{g2}	= 2.5 mA
Mutual conductance	S	= 1.7 mA/V
Internal resistance	R_i	= 110,000 ohms

OPERATING DATA FOR BALANCED CIRCUIT

Anode voltage	V_a	= 250 V
Screen-grid voltage	V_{g2}	= 250 V
Common cathode resistor	R_k	= 560 ohms
Grid bias	V_{g1}	= —19.5 V
Anode current (without signal)	I_{ao}	= 2 × 15 mA
Anode current at max. modulation	$I_{a\,\max}$	= 2 × 17 mA
Screen current (without signal)	I_{g2o}	= 2 × 2.5 mA
Screen current at max. modulation	$I_{g2\,\max}$	= 2 × 5 mA
Load resistor between anodes	R_{aa}	= 16,000 ohms
Output power	W_o	= 4.5 W
Total distortion	d_{tot}	= 3.5 %
Alternating input voltage per grid	V_i	= 19 V_{eff}

MAXIMUM RATINGS

Anode voltage in cold condition	V_{ao}	= max. 550 V
Anode voltage	V_a	= max. 250 V
Anode dissipation (per system)	W_a	= max. 4.5 W
Screen-grid voltage in cold condition	V_{g2o}	= max. 550 V
Screen-grid voltage	V_{g2}	= max. 275 V
Screen dissipation per system ($V_i = 0$)	W_{g2}	= max. 0.7 W
Screen-grid dissipation per system (W_o = max.)	W_{g2}	= max. 1.5 W
Cathode current per system	I_k	= max. 30 mA
Grid voltage at grid current start ($I_{g1} = +0.3\,\mu A$)	V_{g1}	= max. —1.3 V
External resistance between heater and cathode	R_{fk}	= max. 5,000 ohms
Voltage between heater and cathode	V_{fk}	= max. 50 V

The data and characteristics given with respect to this valve refer only to a resistance-free source of voltage; in general, car radios are driven by the car battery by means of a vibrator and the latter, together with the transformer and anti-static circuit, have a fairly high resistance which will somewhat reduce the maximum obtainable output power; the internal resistance, therefore, should be as low as possible. In the case of an internal resistance in the supply unit of, say, 1,600 ohms, with the pre-amplifier valves taking 20 mA, the following values will furnish an output of 4.75 W, with 3 % distortion:

Internal resistance of the anode-feed source	R_b	= 1,600 ohms
Current consumption of amplifying valves	I_q	= 20 mA
Anode voltage	V_a	= 250 V
Screen voltage	V_{g2}	= 250 V
Cathode resistor	R_k	= 600 ohms
Anode current (without signal)	I_{ao}	= 2 × 15 mA
Anode current at max. modulation	$I_{a\,\max}$	= 2 × 16.5 mA

Screen current (without signal)	I_{g2o}	= 2 × 2.5 mA
Screen current at max. modulation	$I_{g2\,max}$	= 2 × 4.7 mA
Load resistor between anodes	R_{aa}'	= 16.000 ohms
Output power	W_o	= 4,75 W
Distortion	d_{tot}	= 3 %
Alternating input voltage, per grid	V_i	= 18 V_{eff}

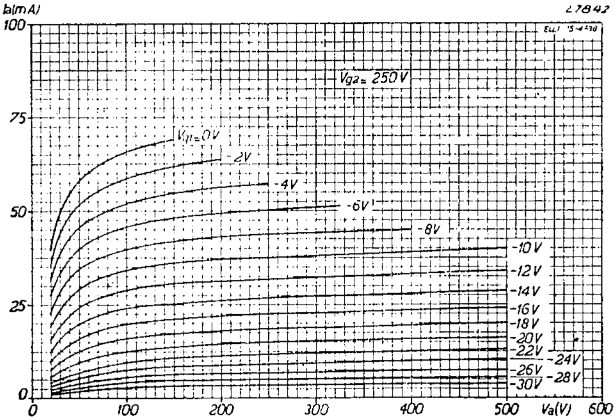


Fig. 4
Anode current of one pentode unit of the ELL 1 as a function of the anode voltage for different values of grid bias, at V_{g2} = 250 V.

The output obtainable in respect of other values may be estimated from the above figures.

The maximum anode voltage is 250 V, which on an average car battery voltage of 6.3 V must definitely not be exceeded; actually the use of car batteries may give rise to considerably greater overloads than are usually met with in the case of mains operation, since, when the battery is charging, voltages of 8 to 9 V may occur, with consequent detriment to the life of the valves. With automatic bias, however, over-voltages on the anode and screen grid of 20 % are permissible. The maximum screen voltage of this valve being 275 V, the voltage drop across the output transformer is allowed for, and there is no necessity for a reduction in anode voltage.

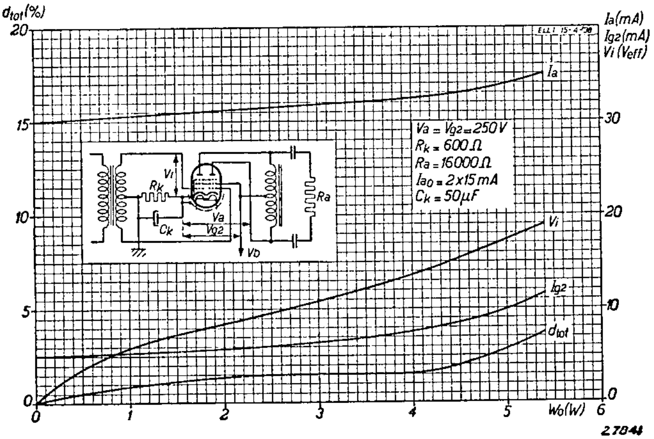


Fig. 5
Total distortion d_{tot}, alternating grid voltage V_i, total anode current I_a and total screen current I_{g2}, as functions of the output power of the ELL 1 when used in a balanced output stage with automatic grid bias.

EM 1 Electronic indicator

The electronic indicator EM 1 is designed on the lines of a high vacuum tube and is thus able to react without the slightest lag. It consists essentially of the virtual indicator itself, comprising a cathode, anode (screen or target) and four deflection plates. The anode is conical in shape and is coated on the inside with a fluorescent substance, the glow of this fluorescent screen, caused by the electrons striking it, being visible from the end of the valve. Between the cathode and this screen there are four deflection plates, mounted radially, which, as their name implies, exert a deflecting effect upon the electrons passing to the screen. In this way the screen, which is connected directly to the positive high-tension line of the receiver, gives rise to four bands of shadow of variable width.

In a normal receiver circuit the tuning to the desired transmitting station is set to give maximum width of the lighted sectors.

The lower part of the electronic indicator consists of a triode which amplifies the variable control voltage from the automatic gain control circuit, and the anode of this triode is connected internally to the deflection plates and externally, through a resistor of 2 megohms, to the positive side of the H.T. supply.

The variable control voltage on the grid produces variations in potential at the anode and therefore also on the deflector plates, thus varying the width of the sectors of light.

The EM 1 can be used equally well in 6.3 V A.C. receivers, car-radio sets and A.C./D.C. models with their heaters fed in series. Since the direct voltage on the fluorescent screen must not drop below 200 V, however, the use of this tube in A.C./D.C. sets is limited to those working on 220 V D.C. without voltage doubling, A.C. 220 V mains, and 110 V A.C. mains with voltage doubling.

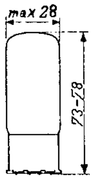


Fig. 1
Dimensions in mm.

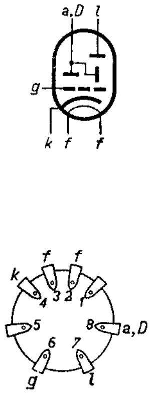


Fig. 2
Arrangement of electrodes and base connections.

HEATER RATINGS

Heating: indirect by A.C. or D.C., series or parallel supply.
Heater voltage . . . . V_f = 6.3 V
Heater current . . . . I_f = 0.200 A

OPERATING DATA

Supply voltage	V_b =	200 V	250 V
Anode series resistor	R_a =	2 M ohms	2 M ohms
Grid bias for smallest angle of light sector	V_g =	0 V	0 V
Grid bias for largest angle of light sector	V_g =	—4 V	—5 V
Anode current at $V_g = 0$ V	I_a =	75 μA	95 μA
Anode current at V_g = —4 V or —5 V	I_a =	20 μA	21 μA
Screen current at $V_g = 0$ V	I_l =	0.13 mA	0.13 mA
Screen current at V_g = —4 V or —5 V	I_l =	0.14 mA	0.14 mA
Angle of light at the edge of the screen, measured at $V_g = 0$ V	β =	20°	16°
Angle of light at the edge of the screen, measured at V_g = —4 and —5 V.	β =	90°	90°

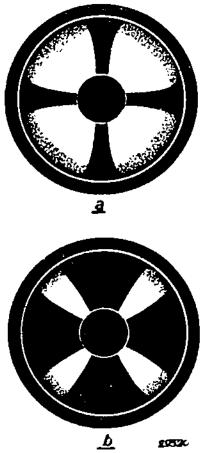


Fig. 4
a. Width of light sectors on the fluorescent screen with a high bias on the grid of the triode section.
b. The same on a low grid bias.

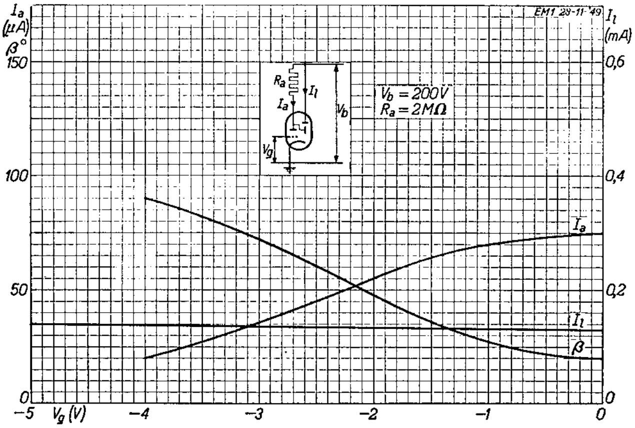


Fig. 3
Anode current of the triode section, *Ia*, current on fluorescent screen *Il*, and light angle β measured at the edge of the screen, as functions of the grid bias, at *Vb* = 200 V.

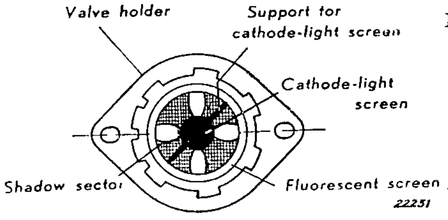


Fig. 5
Top view of the indicator in the holder. The support for the cathode-light screen indicates the position of the cross.

MAXIMUM RATINGS

V_{ao} = max. 550 V
V_a = max. 250 V
V_{lo} = max. 550 V
V_l = max. 250 V ¹)
R_{fk} = max. 5,000 ohms
R_{gk} = max. 2.5 M ohms
V_{fk} = max. 100 V ²)

¹) Allowing for 10 % over-voltage of the mains.
²) Direct voltage or effective value of alternating voltage.

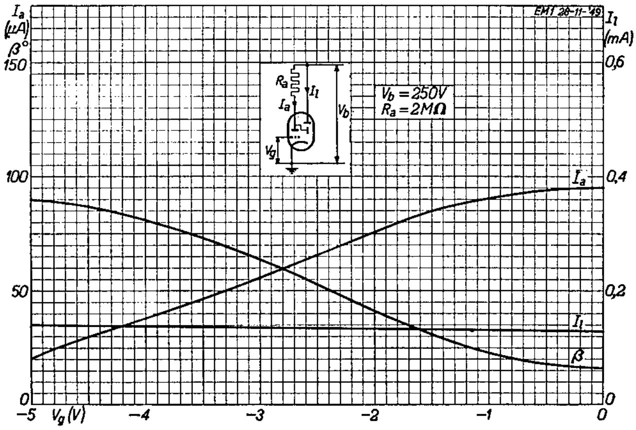


Fig. 6
Anode current of the triode section *Ia*, current on fluorescent screen *Il*, and light angle β measured at the edge of the screen as functions of the grid bias, at *Vb* = 250 V.

C/EM 2 Electronic indicator

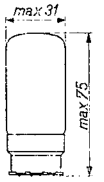


Fig. 1
Dimensions in mm.

The Philips C/EM 2 is an indicator for accurately tuning the receiver to the required station. It works on the same principle as the EM 1, being a high-vacuum valve, with conical screen which is viewed from above. Two fan-shaped fluorescent patterns are formed on the screen and the width of these sectors varies with the tuning.

The difference between this tube and the EM 1 is that instead of four deflector plates only two are provided, whilst there is an extra grid between the anode and the fluorescent screen. As in the EM 1, moreover, the indicator comprises two sections, combined in a single envelope. The lower part of the tube is a triode with a high amplification factor and serves to amplify the direct voltages obtained from the automatic gain control circuit. In the upper portion of the valve a grid is mounted between the conical fluorescent screen and the cathode, by means of two rods. The supporting rods of the triode-anode protrude into the virtual indicator section and lie in the same plane as the grid supports; there are therefore two ways in which electrons from the cathode to the anode (fluorescent screen) can be controlled, viz.

1) by utilizing the deflecting effect of the two triode-anode supports, which serve the same purpose as the four deflector plates in the EM 1 and react upon the width of the light sectors; simultaneously an intensity variation occurs when the voltage on the triode anode falls;

2) the light strength of the fluorescence is controlled by the application of different potentials to the grid of the indicator; in other words, this controls the brilliance, which can ultimately be made to disappear altogether. At the same time, due to the deflecting action of the grid supports, the angles of the sectors can be varied; this means that the indication can be obtained in various ways:

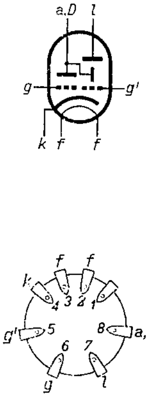


Fig. 2
Arrangement of electrodes and base connections.

a) The tuning can be rendered visible by coupling the grid of the triode section to the A.G.C. circuit; the anode supports, projecting into the indicator, then receive a higher or lower voltage due to the variable voltage drop across a series resistor as in the case of the EM 1; the electrons on their way to the anode are thus deflected to a greater or lesser degree.

b) Alternatively, the voltage on the grid of the indicator itself may be varied, for instance by connecting it to the screen-grid circuit of a controlled R.F. or I.F. valve, leaving the triode section available for other purposes, such as the suppression of interference due to crackle, or the amplification of the A.G.C. voltage.

c) Tuning can be made visible by means of a combination of the two above-mentioned arrangements. It is possible to obtain an effect whereby the light sectors on the fluorescent screen are very small and of low intensity when the receiver is not tuned to a station. As the tuning approaches the carrier-wave frequency the intensity increases until the area of the light sectors, and their intensity, are at a maximum (the screen is then saturated), after which, on a strong carrier wave, a maximum width of about 150° may be reached.

Tuning is thus facilitated by the variations in the intensity as well as by the changes in the width of the light sectors, especially on weak signals.

As in the EM 1, the cathode is provided with a screen cap to avoid unpleasant effects caused by the light emitted by the cathode.

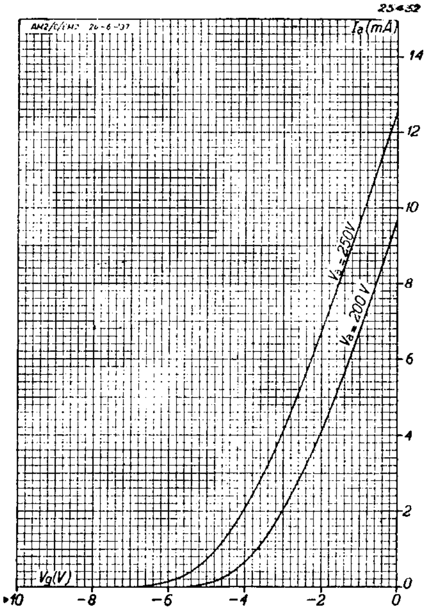


Fig. 3
Triode section of the C/EM 2. Anode current as a function of the grid bias at Va = 200 V and 250 V.

The C/EM 2 can be used in A.C. sets as well as car radio receivers, and A.C./D.C. sets with series heater supply. Since the direct voltage on the fluorescent screen must never be less than 200 V, the use of this tube in the latter type of receiver is restricted to those working on 220 V D.C. without voltage doubling, A.C. 220 V mains, and 110 V A.C. with voltage doubling.

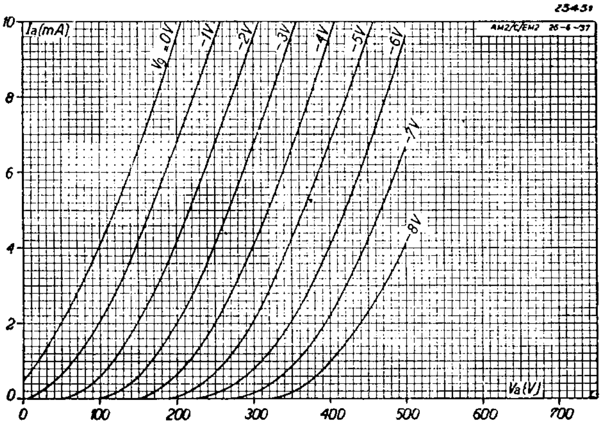


Fig. 4
Triode section of the C/EM 2. Anode current as a function of the anode voltage for various values of grid bias, reproduced on a large anode-current scale.

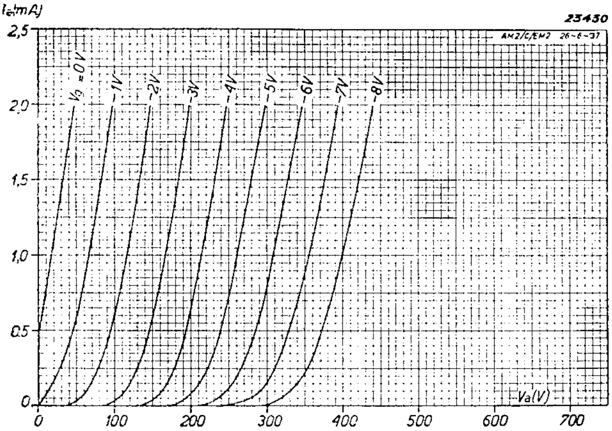


Fig. 5
Triode section of the C/EM 2. Anode current as a function of the anode voltage for various values of grid bias, reproduced on a small anode-current scale.

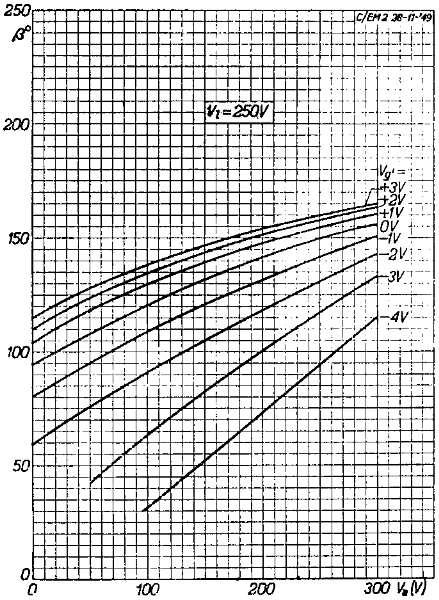


Fig. 6
Light sector angle β of the fluorescent screen as a function of the anode voltage Va of the triode section, with the grid bias Vg of the indicator section as parameter. The broken lines on the curve indicate the range in which the light sectors decrease in size. Voltage Vl on the screen constant at 250 V.

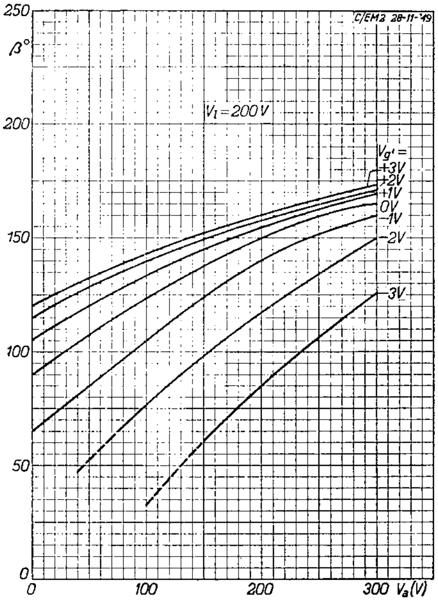


Fig. 7
Light angle β of the fluorescent screen as a function of the voltage *Va* on the triode anode and deflector rods, with the voltage *Vg′* on the grid of the indicator section as parameter. The broken lines in the curves indicate the range in which the intensity of the light decreases. Voltage *Vl* on the screen constant at 200 V.

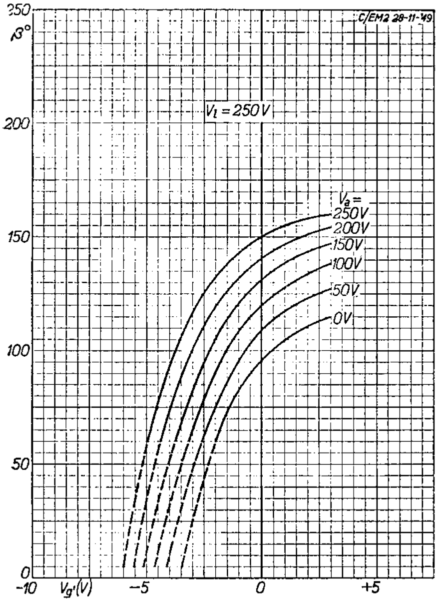


Fig. 8
Light angle β of the fluorescent screen as a function of the voltage *Vg′* on the grid of the indicator section, with the voltage *Va* on the anode of the triode as parameter. Voltage *Vl* on the fluorescent screen constant at 250 V.

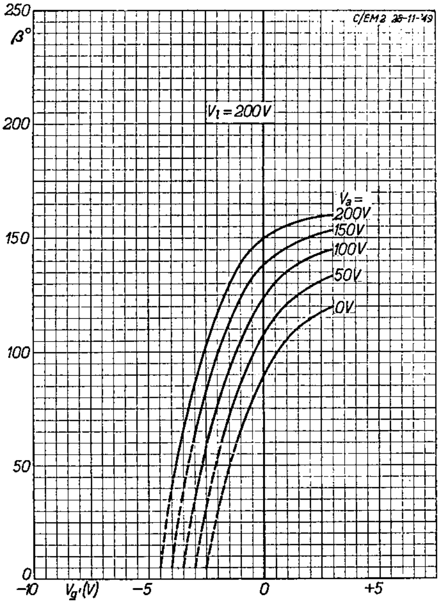


Fig. 9
Light angle β of the fluorescent screen as a function of the voltage *Vg′* on the grid of the indicator section, with the voltage *Va* on the anode of the triode as parameter. Voltage *Vl* on the fluorescent screen constant at 200 V.

HEATER RATINGS

Heating: indirect by A.C. or D.C., series or parallel supply.

Heater voltage	V_f = 6.3 V
Heater current	I_f = 0.200 A

OPERATING DATA: Triode section

Anode voltage	V_a =	200 V	250 V
Grid voltage	V_g =	—2.5	—3.5 V
Anode current	I_a =	3 mA	3 mA
Mutual conductance	S =	2 mA/V	2 mA/V
Amplification factor	μ =	50	50
Internal resistance	R_i =	25,000 ohms	25,000 ohms

OPERATING DATA: Indicator section

Voltage on fluorescent screen . . V_l = 250 V

1. Indicator grid voltage V_g' variable.

Angle of fluorescent sector	β =	5°	150°	160°
Voltage on anode of triode	V_a =	250	250	250 V
Voltage on grid of indicator	V_g' =	—6	0	+ 3 V

2. Voltage on anode of triode V_a variable.

Angle of fluorescent sector	β =	95°	150°
Voltage on indicator grid	V_g' =	0	0 V
Voltage on triode anode	V_a =	0	250 V

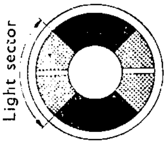
Voltage on fluorescent screen . . V_l = 200 V

1. Indicator grid voltage V_g' variable.

Angle of fluorescent sector	β =	5°	150°	160°
Voltage on anode of triode	V_a =	200	200	200 V
Voltage on grid of indicator	V_g' =	—4.5	0	+ 3 V

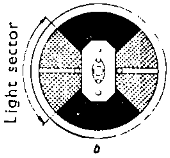
2. Voltage on anode of triode V_a variable

Angle of fluorescent sector	β =	90°	150°
Voltage on indicator grid	V_g' =	0	0 V
Voltage on triode anode	V_a =	0	200 V



a

With screening



b

Without screening

Fig. 10
Definition of the light angle β. Top view of electronic indicator,
a. with cathode light screened.
b. with cathode light not screened.

MAXIMUM RATINGS

V_{ao}	= max. 550 V
V_a	= max. 300 V
W_a	= max. 1.5 W
V_{lo}	= max. 550 V
V_l	= max. 250 V
V_l	= min. 150 V
I_l	= max. 1 mA
I_k	= max. 12 mA
V_g (I_g = + 0.3 μA)	= max. —1.3 V
V_g' (I_g' = + 0.3 μA)	= max. —1 V
R_{gk}	= max. 2.5 M ohms
$R_{g'k}$	= max. 2.5 M ohms
R_{fk}	= max. 20,000 ohms
V_{fk}	= max. 125 V [1]

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[1] Direct voltage or effective value of alternating voltage.

EM 4 Dual-sensitivity electronic indicator

The EM 4 is a dual-sensitivity electronic indicator valve which enables weak and strong signals to be tuned in with equal ease and accuracy. It is hardly possible to distinguish this tube from the EM 1 as regards appearance; it works on the same principle and also has the conical fluorescent screen, upon which shadow sectors are produced by deflection of the electron streams, these sectors being variable in width. Here, too, the screen is observed from the top of the valve. Instead of 4 fluorescent sectors, this tube gives only two and, therefore, also two shadow zones; in the case of the EM 4 tuning is effected by means of the shadow sectors rather than by the light. The shadow sectors do not vary in size to an equal extent when the set is being tuned; one sector is very much more sensitive than the other, that is to say, the angular variation takes place more rapidly.

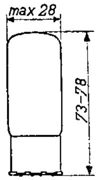


Fig. 1
Dimensions in mm.

The development of this tube was prompted by the following considerations: in circuits employing the EM 1 it was often found difficult to obtain a satisfactory indication on weak signals as well as on strong ones, so that, if a sensitive indication is essential on weak signals as well, there is no alternative but to feed the grid of the EM 1 directly with the direct voltage from the load resistor of the receiving diode or, at any rate, to reduce this voltage only slightly by means of a potential divider. On strong signals, however, such a high voltage occurs on the grid of the indicator that the fluorescent sectors cover the whole of the screen long before the centre of the resonance curve is reached.

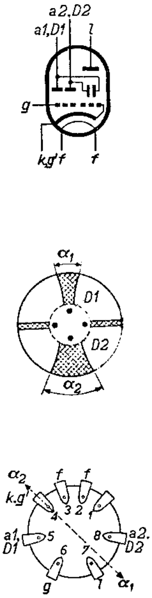


Fig. 2
Arrangement of electrodes and base connections.

On the other hand, if preference is given to a good, clearly visible indication on strong transmitters, a suitable tapping being provided on the potential divider for this purpose, there will be hardly any indication at all on the weaker stations; the direct voltage variations at the grid during tuning are so small that the movement at the edges of the fluorescent zones is barely visible.

In view of the above, a satisfactory indication on both weak and strong signals can virtually be obtained only by using two indicators, one being connected direct and the other across a potential divider, to the load resistor of the receiving diode, but a better solution consists in connecting the two indicators to the load resistor

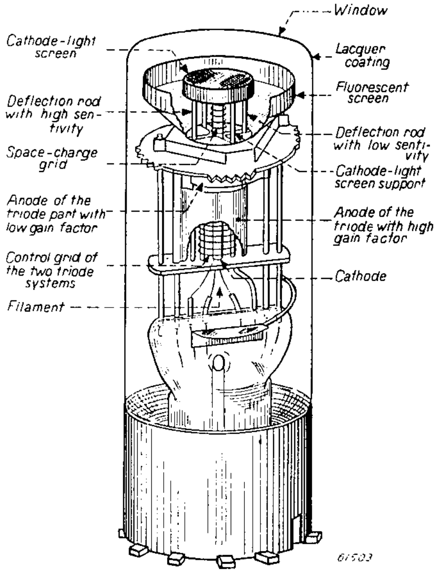


Fig. 3
Construction of Philips Electronic Indicator EM 4.

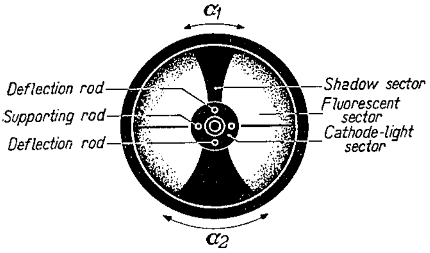


Fig. 4
Arrangement of the components in the indicator section of the EM 4.

in the same manner, e.g. one of the indicators being very sensitive and the other of low sensitivity.

By sensitivity, in the case of an electronic indicator, is meant the angular variation in the fluorescent and shadow sectors for one volt variation in grid voltage. The use of two valves for indicating purposes, due to the high cost and extra space required, would be out of the question, however, even in the highest class types of receiver and the need, therefore, is for a valve that will embrace the qualities of both high and low sensitivity.

Hence the EM 4, which may be regarded as a combination of two electronic indicators of different sensitivity, was developed; the construction, however, is almost as simple as that of the EM 1. The two units have a common fluorescent screen and cathode, one half of the screen serving each of the units.

The construction is as shown in Fig. 3: the conical fluorescent screen is at the top of the tube and the extremity of the cathode projects into it. Between the cathode and the screen, taking the components in order from the centre outwards, there is a space-charge grid, connected to the cathode, and two diametrically opposed deflector rods. The top end of the cathode is screened with a small cap to counteract the unpleasant effect of the light emitted by the cathode. This cap rests on two rods mounted vertically on the fluorescent screen, in contrast with the EM 1, which has an oblique rod. The two rods are fitted on a bar lying at 90° to them (see Fig. 4) and are at the same potential as the screen.

The amplifier section of the tube is at the lower end and consists of two triodes, of different amplification factors, mounted one above the other around the cathode; they are served by a common grid, but the latter is wound at a different pitch for each triode unit. The two anodes are electrically isolated from each other; the upper one, this being the smaller, is that of the high-amplification-factor triode. Each anode is connected to one of the deflector rods of the indicator unit and has its own separate contact on the base of the tube.

In the circuit (see Fig. 9) these anodes are connected across 1 megohm resistors to the positive H.T. line of the receiver; the fluorescent screen is at the same potential.

The two triodes are controlled simultaneously by the bias on the grid (control voltage from the detector diode) and they function as voltage amplifiers; variations in the bias are equivalent to a voltage drop across the anode resistors and therefore produce a variation in the width of the shadow sector behind the deflector rods.

The high-sensitivity triode unit produces a greater variation in the shadow angle behind the relative deflector rod than the other section, for a given grid voltage; in this tube the shadow angle for 0 V

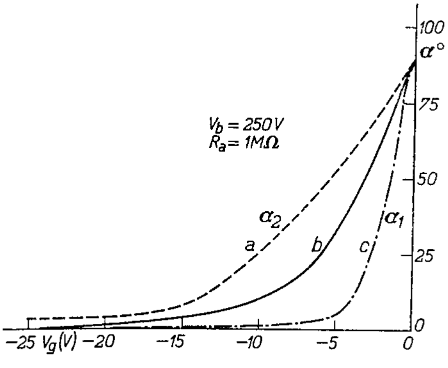


Fig. 5
Various characteristics of the shadow angle plotted against grid voltage:
a. Characteristic of the less sensitive unit of the EM 4.
b. Characteristic of a valve with variable pitch grid.
c. Characteristic of the more sensitive unit of the EM 4.

grid potential (and 250 V supply), is 90°. With —5 V on the grid the shadow angle of the high sensitivity deflector rod is 5° whereas the less sensitive rod does not give this shadow angle until —16 V is reached.

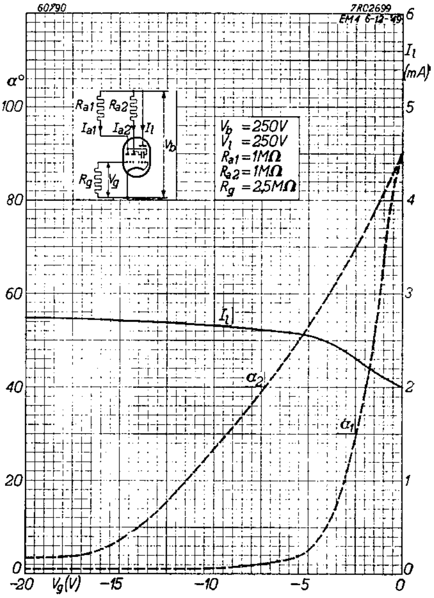


Fig. 6
Shadow angles α_1 and α_2 measured at the edge of the screen, and screen current I_l as functions of the grid voltage on a supply of 250 V.

Fig. 6 shows the characteristics of the sections of the valve, which clearly demonstrate the action of the indicator. The two sensitivities of the EM 4 are thus obtained by the use of two amplifier triodes having different amplification factors. Originally, a solution to the problem of obtaining a clear indication for both weak and strong signals was sought in a special form of characteristic in the amplifier part of the triode, for instance by employing a grid of varying pitch, so that the I_a/V_g characteristic would have a long "tail", but characteristics of this type do not give good results, as will be seen from Fig. 5, in which curve (b) represents the shadow angle as a function of the grid voltage of a tube of this kind. At small grid voltages the mutual conductance is relatively high, giving fairly good sensitivity on weak signals, but not nearly so high as in curve (c) in the figure, which refers to the more sensitive section of the EM 4. At high values of grid potential the tube operates on the tail of the curve and the mutual conductance is low, with correspondingly low sensitivity of the indicator. From Fig. 5 it will be noticed, however, that even on strong signals the indicator is anything but satisfactory; assuming a direct voltage of —10 to —15 V during tuning, curve (a) gives an angular variation of 18° and curve (b) only 6°.

The indication obtained on strong signals is thus not sensitive enough when the indication for weak signals is good; valves made with varying pitch do, in actual fact, yield curves as shown in *b*, which means that such tubes are satisfactory only on weak signals. For a really good indication for both weak and strong signals the only solution is a tube of

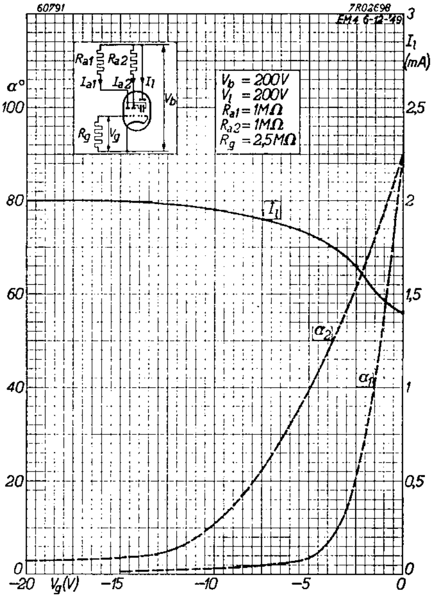


Fig. 7
Shadow angles α_1 and α_2 measured at the edge of the screen, and screen current I_l as functions of the grid potential on a supply of 200 V.

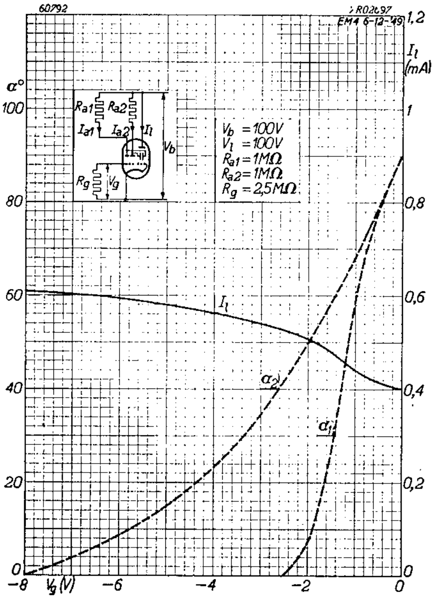


Fig. 8
Shadow angles α_1 and α_2 measured at the edge of the screen, and screen current I_l as functions of the grid potential

the type of the EM 4 with its dual sensitivity ranges.

It should be noted that the EM 4 has only two fluorescent zones instead of the four in the EM 1. In the first place this ensures greater angular variation in each of the individual sectors; secondly, experience has shown that the average listener finds it easier to tune with only two sectors than with four. When there are four fluorescent sectors the layman invariably tries to obtain a symmetrical pattern on the screen, with correspondingly faulty tuning. With only two shadow sectors there is less to occupy the eye and there is not so much tendency towards inaccurate tuning. Due to the presence of the two rods supporting the cathode-light screen, the fluorescent areas are divided by two thin lines of shadow. Fig. 6 shows that at —16 V and —5 V the characteristic commences to flatten out; small lines of shadow remain over, due to the fact that the deflector rods absorb a certain amount of current which in turn produces a voltage drop across the coupling resistor, this preventing the rods from exceeding a certain positive potential. It is on account of this fact that the fluorescent areas cannot overlap each other. Fig. 4 depicts diagrammatically the arrangement of the electrodes and supporting rods in the indicator section of the EM 4.

At the upper end the bulb is moulded to a special shape, being, as it were, depressed to a concave surface, in order that the edge of the glass, which is lacquered, may form a dark background before the actual "window" of the tube. In this way the contrast between the fluorescence and the dark background is accentuated and very slight variations in the light and shadow during tuning are rendered more easily perceptible.

Heater ratings have been chosen for this tube that will render it suitable for parallel feeding on 6.3 V as well as series feeding in 200 mA circuits. Needless to say in A.C./D.C. receivers operating on 110 V the brilliance of the fluorescent sectors is less than when the applied screen voltage is 250 V.

HEATER RATINGS

Heating: indirect by A.C. or D.C., series or parallel supply.
Heater voltage . . . . V_f = 6.3 V
Heater current . . . . I_f = 0.200 A

OPERATING DATA: EM 4 used as tuning indicator

Voltage supply to screen and anode circuits	V_b	= 100 V	200 V	250 V
Anode series resistor for the high-sensitivity section	R_{a1}	= 1 M ohm	1 M ohm	1 M ohm
Anode series resistor for the low-sensitivity section	R_{a2}	= 1 M ohm	1 M ohm	1 M ohm
Screen current at $V_g = 0$ V	I_l	= 0.2 mA	0.55 mA	0.75 mA
Grid voltage for a shadow angle of 90° in the high-sensitivity section	$V_g\ (\alpha_1 = 90°)$	= 0 V	0 V	0 V
Grid voltage for a shadow angle of 90° in the low-sensitivity section	$V_g\ (\alpha_2 = 90°)$	= 0 V	0 V	0 V
Grid voltage for a shadow angle of 0° in the high-sensitivity section	$V_g\ (\alpha_1 = 0°)$	= —2.5 V	—	—
Grid voltage for a shadow angle of 0° in the low-sensitivity section	$V_g\ (\alpha_2 = 0°)$	= —8 V	—	—
Grid voltage for a shadow angle of 5° in the high-sensitivity section	$V_g\ (\alpha_1 = 5°)$	= —	—4.2 V	—5 V
Grid voltage for a shadow angle of 5° in the low-sensitivity section	$V_g\ (\alpha_2 = 5°)$	= —	—12.5 V	—16 V

α_1 = shadow angle with respect to deflector rod D_1, measured at the edge of the screen.
α_2 = the same with respect to deflector rod D_2.

MAXIMUM RATINGS

V_{a10}	= max. 550 V	V_l	= max. 275 V
V_{a1}	= max. 275 V	$V_g\ (I_g = +0.3\ \mu A)$	= max. —1.3 V
V_{a20}	= max. 550 V	R_{gk}	= max. 3 M ohms
V_{a2}	= max. 275 V	R_{fk}	= max. 20,000 ohms
V_{l0}	= max. 550 V	V_{fk}	= max. 100 V ¹)

¹) Direct voltage or effective value of alternating voltage

APPLICATIONS

The EM 4 can be used in all A.C. or A.C./D.C. receivers incorporating diode rectification, so long as the signal strength at the diode detector is sufficiently great (superheterodynes). The electronic indicator should for preference be connected to the diode load resistor; connection to the A.G.C. diode in the case of delayed control has the disadvantage that the indicator will not then function on signals which are below the delay level. Since the more sensitive side of the EM 4 is otherwise designed to permit of exact tuning on weak signals and will do so even when the signal is below the delay level, it is advisable to connect the grid of the EM 4 directly to the detector diode. In this way, moreover, the control voltage rises more quickly during tuning, because the signal voltage at the diode is taken from the second tuned circuit in the I.F. band-pass filter, whilst the signal voltage for the A.G.C. diode is usually derived from the first tuned circuit.

The apparent sensitivity is thus greater at the detector diode than at the A.G.C. diode. Fig. 9 is a typical example of a superhet receiver circuit incorporating the EM 4.

Here the grid receives the *full* control voltage across the load resistor of the detector diode. An R.C.-filter circuit is provided to suppress low frequencies existing across the load resistor. Nonetheless, in many cases the signals on the diode will be too strong and it will be found necessary to cut down the direct voltage across the load resistor by means of a potential divider. In this, however, care should be taken to see that the A.C. resistance (R_w) of the diode circuit is not reduced too far, as this will have a bad effect on the ratio of R_g to R_w and the maximum modulation depth for undistorted rectification will be reduced; this can be avoided by using high-ohmic resistors for the potential divider. Actually the same applies to the resistance of the R.C.-filter circuit shown in Fig. 9. In general it will be necessary to ensure that the direct voltage on the grid of the EM 4 corresponding to the strongest anticipated aerial signal is just sufficient to produce the smallest possible shadow sector α_2 of the less sensitive side of the indicator. If this can be done the indications will be excellent. The sensitivity values of the two indicator sections are such that in the majority of cases accurate tuning will be possible on the weakest signals; but, if even greater sensitivity is required on very weak signals, this can be obtained only at the expense of the deflection on the stronger signals. Should the resonance curve of the receiver exhibit two peaks, the indicator may possibly give a maximum deflection on one of the sidebands, and every care must be exercised in ensuring that the bandpass filter produces a single peak only. When the indicator is used in low voltage A.C./D.C. receivers, efforts must be made to see that the screen receives the highest possible potential; otherwise the brightness of the fluorescence will be too low. It may also be found that on a 100 V supply the high-sensitivity section of the indicator gives only a slight indication, and this can be explained in the following manner.

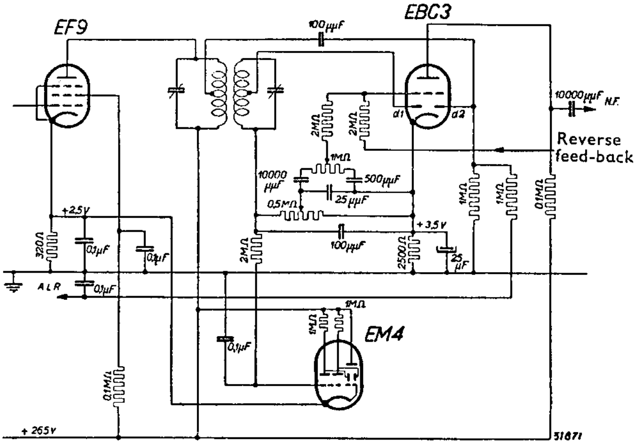


Fig. 9
Theoretical circuit diagram showing the EM 4 in a superheterodyne receiver. The diagram reproduces the I.F. and A.F. sections only.

The grid circuit of the EM 4 must include a resistor of from 1 to 2.5 megohms with a decoupling capacitor to filter out any modulation on the load resistor of the detector diode (see Fig. 9). With no signal, grid current flows, which produces a potential of about 1 V negative, across this resistor. Since the grid swing of the sensitive side of the indicator is only about 2.5 V on a supply of 100 V, this negative potential of 1 V considerably reduces the deflection of the shadow sector; Fig. 10 demonstrates the actual effect of a grid resistor of 1 and 2.5 megohms respectively (chain-dot and dotted lines in fig. 10).

On high supply voltages this effect is not so marked, because the grid swing of the sensitive unit is then much greater, although the effects of grid current are, nevertheless, perceptible.

In view of the above, the sensitive side of the indicator is not generally used in receivers operating on a supply of 100 V and, as the less-sensitive part is then much more sensitive than normally on 250 V, approximating more closely the characteristic of the EM 1 at 250 V, this section of the indicator will give a much more satisfactory range of deflection on average signal strengths.

In A.C./D.C. receivers operating on 100 V it is also possible to short the two anodes of the triode and feed them through a common resistor of 1 megohm, and the characteristics in Fig. 11 show the working conditions under this arrangement, which ensures a marked variation in the shadow angles following upon voltage variations on the grid, even at potentials below the control level. The curve of the shadow angle plotted against the control voltage now lies roughly between that of the more sensitive section of the EM 4 and that of the low sensitivity side on a supply of 250 V. In Fig. 11 the shadow angle refers to a grid resistor of 2.5 megohms; at lower values of the control voltage it is true that the bend in the curve caused by grid current is plainly to be seen, but this bend is nevertheless not nearly so marked as in the characteristic shown in Fig. 10. At a grid potential of 0 V the mutual conductance is higher, from which it follows that the indicator sensitivity is greater. This arrangement will give a maximum shadow angle of about 70°, which is quite sufficient for all tuning purposes; both the shadow angles of the EM 4 are then the same, as is also the angular variation in the two sectors.

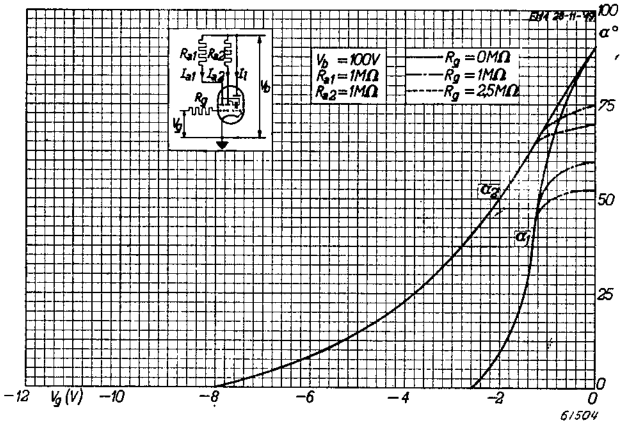


Fig. 10
Full line. Shadow angles α_1 and α_2 measured at the edge of the screen, as a function of the grid potential on 100 V supply, with no resistor connected in series with the grid.
Chain-dot line. The same with a resistor of 1 megohm connected to the grid.
Dotted line. The same with a resistor of 2.5 megohms in series with grid.
As from — 1.2 V, the three curves coincide.

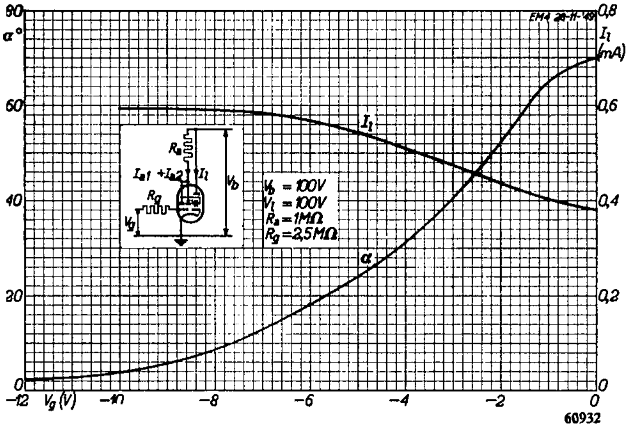
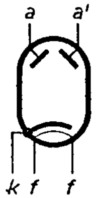


Fig. 11
Shadow angle α of the two sectors, and screen current I_l as functions of the grid voltage on 100 V supply, with the two anodes interconnected and fed through a resistor of 1 megohm. A resistor of 2.5 megohms is connected to the grid.

EZ 2 Rectifying valve



The EZ 2 is an indirectly-heated full-wave rectifying valve, specially designed for car radio receivers. The heater is fed from the car battery at 6.3 V and for this reason the heater-current consumption has been kept as low as possible. The optimum D.C. output is sufficient to operate a normal car radio receiver, not including energizing current for a loudspeaker.

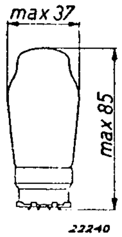


Fig. 1
Dimensions in mm.

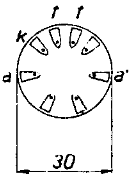


Fig. 2
Arrangement of electrodes and base connections.

HEATER RATINGS

Heating: indirect by A.C. or D.C.

Heater voltage	$V_f = 6.3$ V
Heater current	$I_f = 0.4$ A

MAXIMUM RATINGS

Voltage on no-load, across the secondary winding of the power transformer	V_{tr}	= max. 2 × 350 V_{eff}
D.C. output	I_o	= max. 60 mA
Voltage between heater and cathode (absolute peak value)	V_{fk}	= max. 500 V
Internal resistance of the power transformer (per anode)	R_t	= min. 600 ohms
Capacitance of first smoothing capacitor at $V_{tr} = 2 \times 350$ V_{eff}	C	= max. 16 μF
Capacitance of first smoothing capacitor at $V_{tr} = 2 \times 300$ V_{eff}	C	= max. 32 μF

As rectifying valve in a car radio receiver, the direct voltage with a superimposed ripple voltage between the filament — which is connected to the car chassis through the battery — and the cathode which is taken directly to the positive H.T. side of the first smoothing capacitor must be accepted as such.

At such time as the rectifying valve is not loaded a potential occurs between these components equal to the peak value of the voltage applied to the valve. The maximum permissible voltage between heater and cathode is 500 V, i.e. the maximum peak value of the alternating anode voltage, whilst the optimum value of the direct current delivered is 60 mA, this being an absolute value, applicable also to alternating voltages of 2 × 300 $V_{(eff)}$

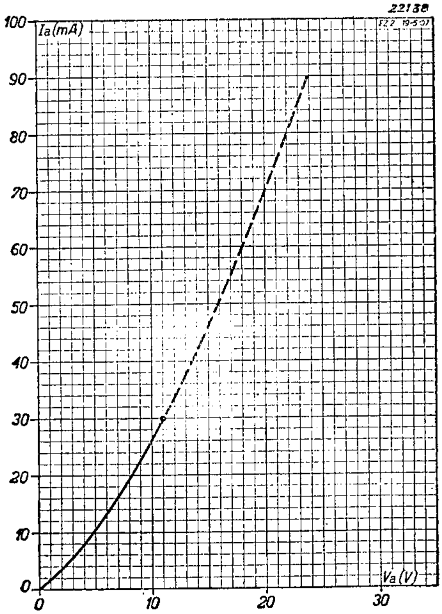


Fig. 3
Current per anode as a function of the applied voltage.

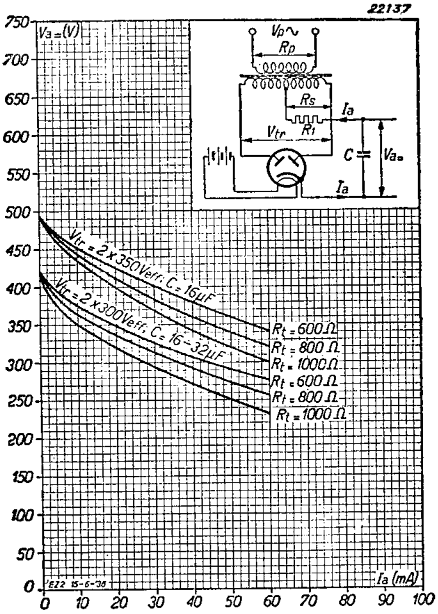


Fig. 4
Loading curves for the rectifying valve EZ 2, for voltages of 2 × 300 and 2 × 350 V on no load, across the secondary winding of the power transformer, and with respect to different values of the internal resistance of the rectifier circuit. The input capacitance is at most 16 μF on 2 × 350 V, or 32 μF on 2 × 300 V. If the internal resistance of the power transformer is less than the minimum of 600 ohms, it must be increased to that value by means of an extra resistor R_1 in series with the half-secondary.

Rt = $Rs + R_1 + n^2 Rp$
Rp = resistance of primary winding.
Rs = resistance of half secondary winding.
n = transformer ratio; prim. winding/sec. half-winding.
R_1 = additional resistance when total resistance is too low.

EZ 4 Rectifying valve

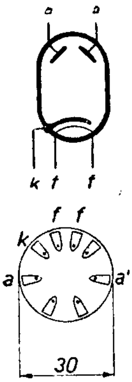


Fig. 2
Arrangement of electrodes and base connections.

The EZ 4 is in indirectly-heated full-wave rectifying valve for use in high-power receivers and small amplifiers. With the two anodes shorted the valve can be used as a half-wave rectifying valve, and two valves connected in this manner provide a full-wave circuit that will give a high voltage with considerable power. The optimum power thus delivered is twice the value that can be obtained from a single EZ 4, the two valves giving 350 mA with 2 × 400 V A.C. across the secondary winding of the power transformer.
The dimensions of this valve are unusually small; notwithstanding the low current consumption, the output is, relatively speaking, exceptionally high.

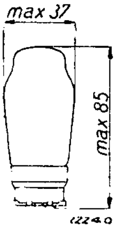


Fig. 1
Dimensions in mm.

HEATER RATINGS

Heating: indirect by A.C.
Heater voltage . . . . V_f = 6.3 V
Heater current . . . . I_f = 0.9 A

MAXIMUM RATINGS

Voltage, on no load, across the secondary winding of the power transformer . . . . V_{tr} = max. 2 × 400 V_{eff}
D.C. output . . . . I_o = max. 175 mA
Voltage between heater and cathode . . . . V_{fk} = 0 V 1)
Internal resistance of the power transformer, at V_{tr} = 2 × 300 V_{eff} (per anode) . . . . R_t = min. 200 ohms
Internal resistance of the power transformer, at V_{tr} = 2 × 350 V_{eff} (per anode) . . . . R_t = min. 250 ohms
Internal resistance of the power transformer, at V_{tr} = 2 × 400 V_{eff} (per anode). . . . . R_t = min. 300 ohms
Capacitance of the first smoothing capacitor at V_{tr} = 2 × 350 V_{eff} and 2 × 400 V_{eff} . . . . . . C = max. 16 μF
Capacitance of the first smoothing capacitor at V_{tr} = 2 × 300 V_{eff} . . . . C = max. 32 μF

---

1) The cathode must in every case be connected to one side of the heater.

The heater of the valve must not be included in the heater circuit of the receiving valves, but a separate winding should be provided in the power transformer; the cathode should be connected directly to one end of the heater. Of the smoothing capacitors, the first may be increased in value from 16 to 32 μF, provided the A.C. voltage is reduced to 2 × 300 V_{eff}. Owing to the very low internal resistance of this rectifying valve, not much heat is developed and it is therefore not necessary to take any special precautions in the design of the receiver or the mounting of the valve to ensure ventilation.

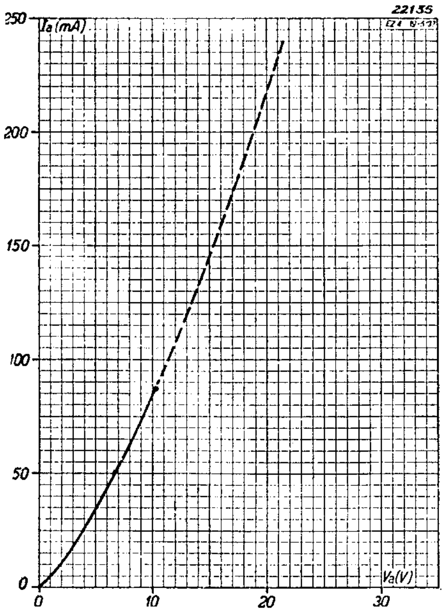


Fig. 3
Current per anode, plotted against the applied direct voltage.

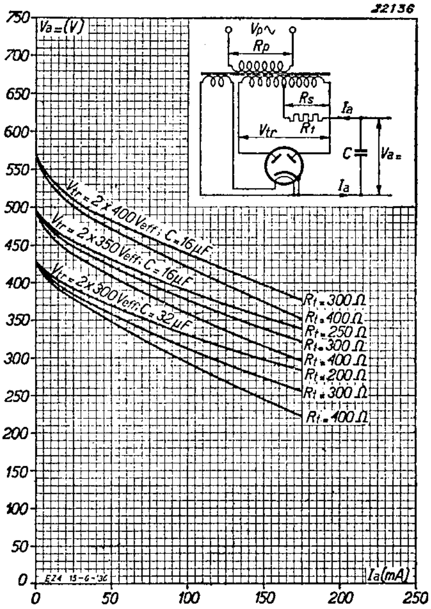


Fig. 4
Loading characteristics of the rectifying valve EZ 4, for voltages of 2 × 300, 2 × 350 and 2 × 400 V(eff) across the secondary winding of the power transformer, for different values of the internal resistance of the transformer.
The input capacitance C of the filter is at most 32 μF on 2 × 300 V(eff), or 16 μF with 2 × 350 and 2 × 400 V(eff). If the internal resistance of the transformer is less than the minimum value it must be raised to this minimum by means of an extra resistor R_1 in series with the half-winding of the secondary.

Rt = $Rs + R_1 + n^2Rp$
Rp = resistance of primary winding
Rs = resistance of the half-secondary winding
n = transformer ratio; primary winding/half-secondary winding.
R_1 = extra resistance when total resistance is too low.

AZ 1 Rectifying valve

This is a directly-heated, full-wave rectifying valve for medium-power receivers operating on normal working voltages.

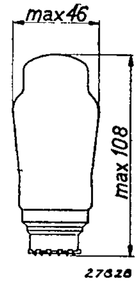


Fig. 1
Dimensions in mm.

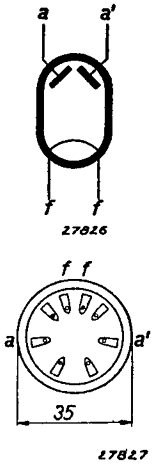


Fig. 2
Arrangement of electrodes and base connections.

FILAMENT RATINGS

Heating: direct by A.C.
Filament voltage . . . . $V_f = 4$ V
Filament current . . . . $I_f = 1.1$ A

MAXIMUM RATINGS

Voltage, on no load, at the secondary winding of the power transformer . . . . V_{tr} = 2 × 500 $V_{(eff)}$
D.C. output on $V_{tr} = 2 \times 500\ V_{eff}$ . . . . I_o = max. 60 mA
D.C. output on $V_{tr} = 2 \times 400\ V_{eff}$ . . . . I_o = max. 75 mA
D.C. output on $V_{tr} = 2 \times 300\ V_{eff}$ . . . . I_o = max. 100 mA
Capacitance of the first smoothing capacitor . . . . C = max. 60 μF

If the valve is to be mounted horizontally, it should be located so that the filament lies in the vertical plane.

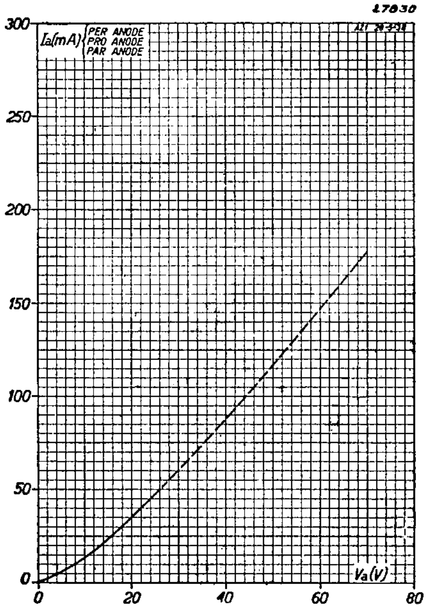


Fig. 3
Current per anode, as a function of the applied direct voltage.

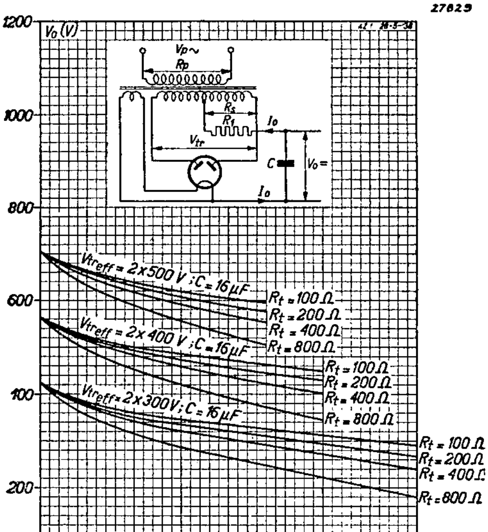


Fig. 4
Loading characteristics relating to different transformer voltages, on no load, for different values of the internal resistance of the transformer ($Rt = Rs + n^2 Rp + R_1$)

AZ 4 Rectifying valve

The AZ 4 is a directly-heated full-wave rectifying valve for receivers consuming a heavy current.

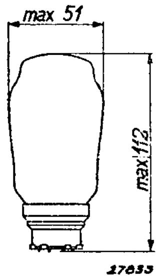


Fig. 1
Dimensions in mm.

FILAMENT RATINGS

Heating: direct, A.C.
Filament voltage. . . . . V_f = 4.0 V
Filament current. . . . . I_f = 2.3 A

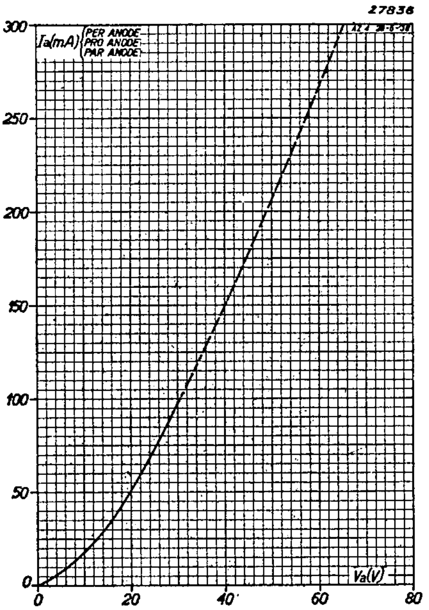


Fig. 3
Current per anode, as a function of the applied direct voltage.

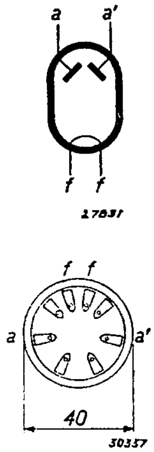


Fig. 2
Arrangement of base connections and electrodes.

MAXIMUM RATINGS

Voltage, on no load, across the secondary winding of the power transformer . . . . V_{tr} = max. 2 × 500 V_{eff}
D.C. output with V_{tr} = 2 × 500 V_{eff} . . . . I_o = max. 120 mA
D.C. output with V_{tr} = 2 × 400 V_{eff} . . . . I_o = max. 150 mA
D.C. output with V_{tr} = 2 × 300 V_{eff} . . . . I_o = max. 200 mA
Capacitance of the first smoothing capacitor. . . . C = max. 60 μF

For medium-power amplifier equipment two AZ 4 valves each working as a half-wave rectifying valve (anodes connected in parallel) may be used in a full-wave rectifier circuit.

If the valve is to be mounted horizontally it should be located so that the filament lies in the vertical plane.

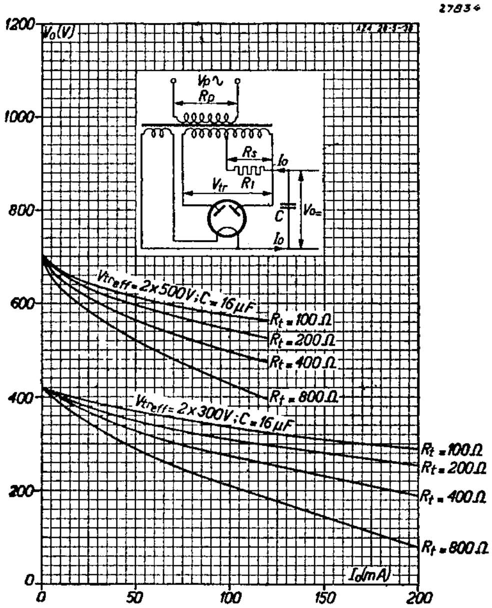


Fig. 4
Loading characteristics for transformer voltages, on no load, of Vtr = 2 × 300 V and 2 × 500 V and with respect to different values of the internal resistance of the transformer
(Rt = Rs + n^2 Rp + R_1).

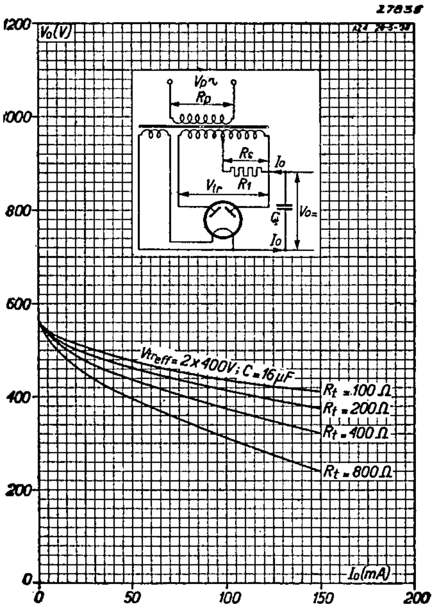


Fig. 5
Loading characteristics relating to Vtr = 2 × 400 V, for different values of the internal resistance of the transformer
(Rt = Rs + n^2 Rp + R_1).