ECH 3 Triode hexode

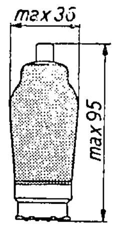

Fig. 1
Dimensions in mm.

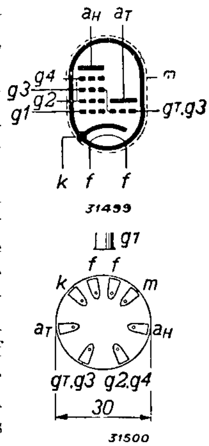

Fig. 2
Arrangement of electrodes and base connections.

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.

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.

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

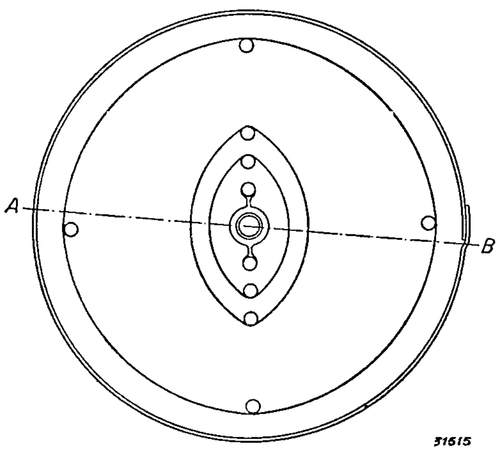

Fig. 3
Cross-section of the system of electrodes in the hexode unit.

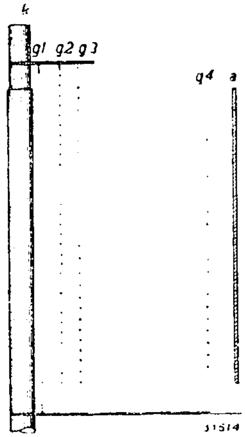

Fig. 4
Vertical cross-section through the system of electrodes of the hexode (see A–B, Fig.3).

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

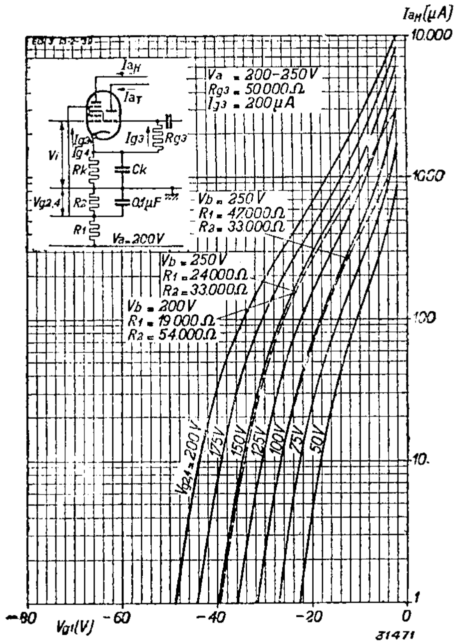

Fig. 5
Anode current of the hexode unit as a function of the grid bias, at different screen potentials with an anode voltage of 200 to 250 V.

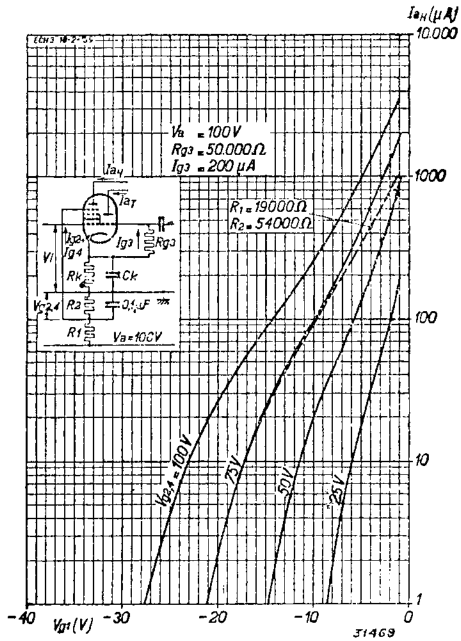

Fig. 6
Anode current of the hexode unit as a function of the grid bias, at different screen potentials, with an anode voltage of 100 V.

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		

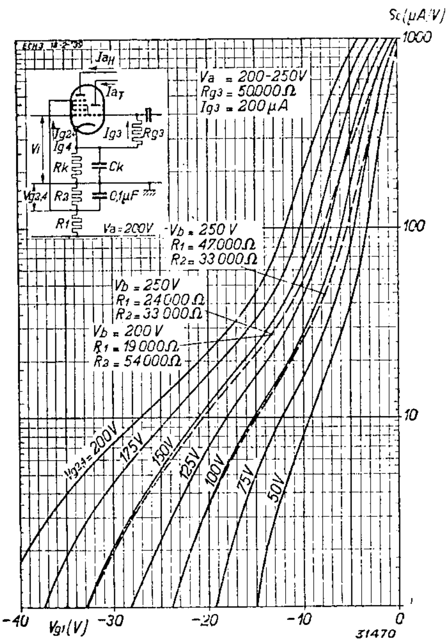

Fig. 7
Conversion conductance Sc as a function of the grid bias Vg_1 at different screen-grid voltages and for an anode voltage of 200–250 V.

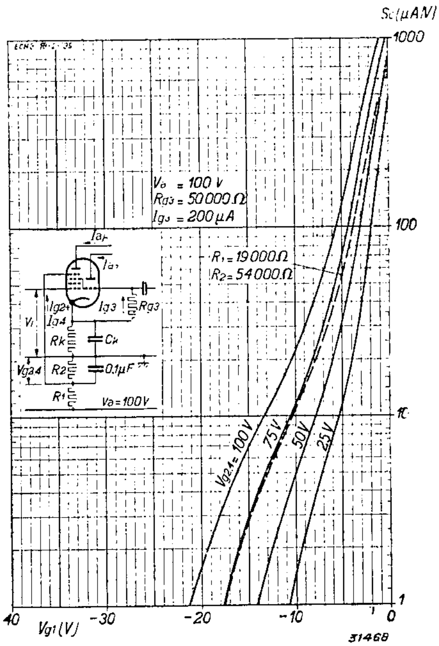

Fig. 8
Conversion conductance Sc as a function of the grid bias Vg_1 at different screen voltages and for an anode voltage of 100 V.

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

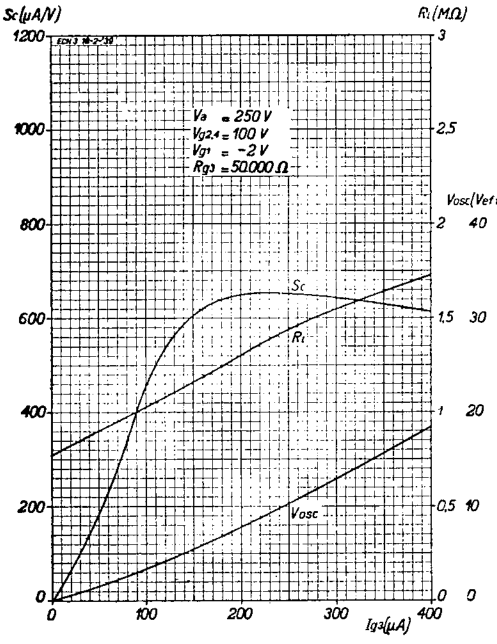

Fig. 9
Conversion conductance *Sc*, internal resistance *Ri* and alternating oscillator voltage *Vosc* as a function of the oscillator grid current I_{g3}, at Va = 250 V, Rg_3 = 50,000 ohms and with fixed screen voltage of 100 V.

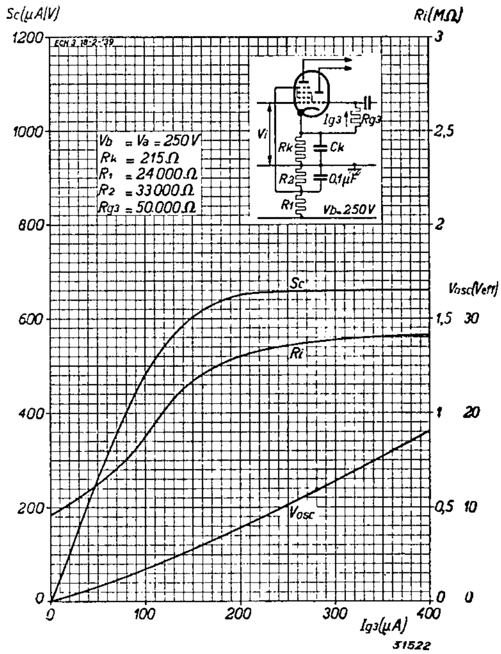

Fig. 10
Conversion conductance *Sc*, internal resistance *Ri* and alternating oscillator voltage *Vosc* as a function of the oscillator-grid current I_{g_3}, at Va = 250 V, Rg_3 = 50,000 ohms and with screen fed from a potential divider of 24,000 + 33,000 ohms (normal operation).

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 n.
[3]) Extreme limit of control

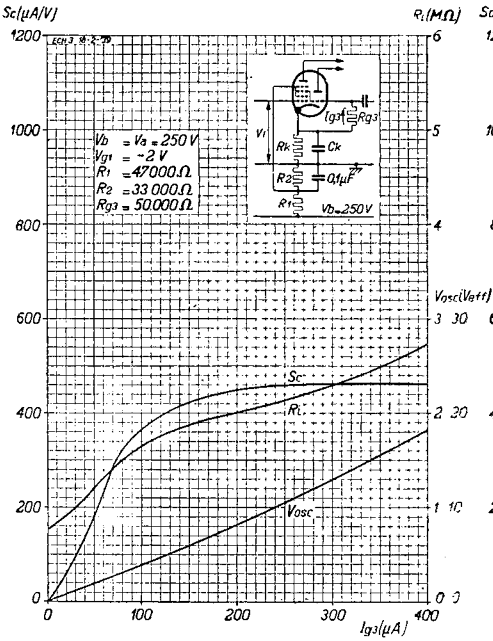

Fig. 11
Conversion conductance Sc, internal resistance Ri and alternating oscillator voltage $Vosc$ as a function of the oscillator-grid current Ig_3 at Va = 250 V, Rg_3 = 50,000 ohms and with screen fed from a potential divider of 47,000 + 33,000 ohms (noise-free operation).

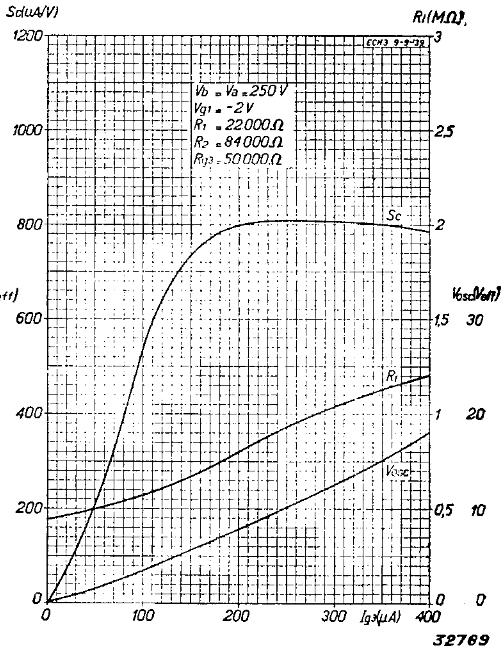

Fig. 12
Conversion conductance Sc, internal resistance Ri and alternating oscillator voltage $Vosc$ as a function of the oscillator-grid current Ig_3, at Va = 250 V, Rg_3 = 50,000 ohms and with screen fed from a potential divider of 22,000 + 84,000 ohms (optimum setting from the point of view of freedom 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}	=	200 μA		
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. [3]) Extreme limit of control

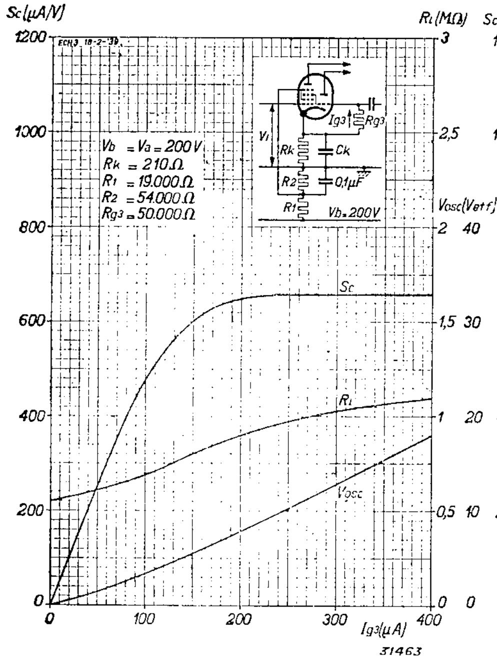

Fig. 13
Conversion conductance *Sc*, internal resistance *Ri* and alternating oscillator voltage *Vosc* as a function of the oscillator grid current Ig_3, at Va = 200 V, Rg_3 = 50,000 ohms and with screen fed from a potential divider of 19,000 + 54,000 ohms (for receivers with switch for A.C. or D.C.).

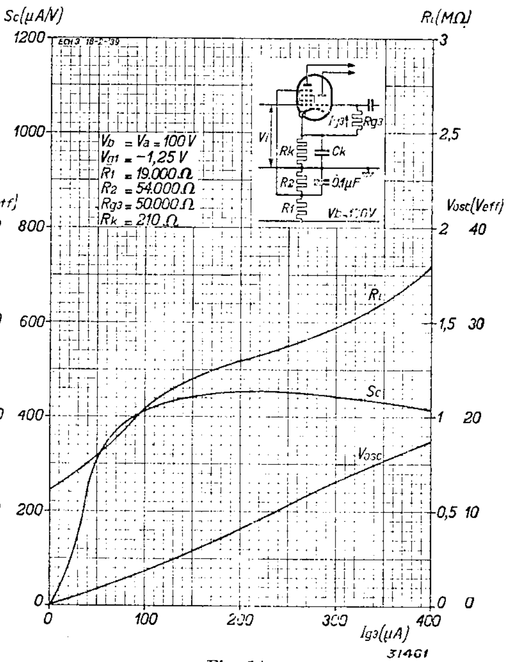

Fig. 14
Conversion conductance *Sc*, internal resistance *Ri* and alternating oscillator voltage *Vosc* as a function of the oscillator-grid current Ig_3, at Va = 100 V, Rg_3 = 50,000 ohms and with screen fed from a potential divider of 19,000 + 54,000 ohms (for receivers with switch for A. C. or D.C.).

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

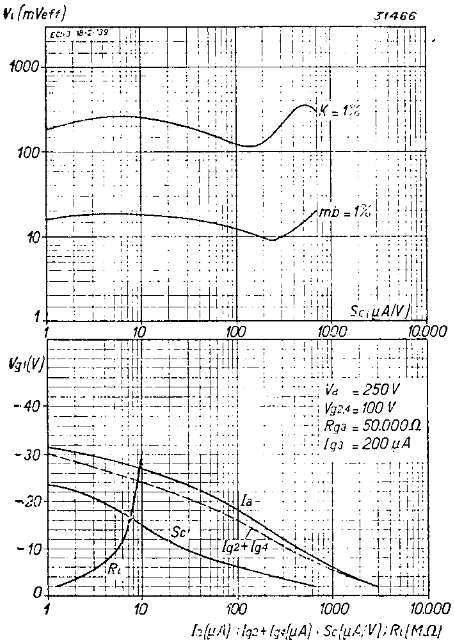

Fig. 15
At V_a = 250 V and with fixed screen-grid voltage of 100 V:
Upper diagram. Permissible R.F. voltage at 1 % cross-modulation (K = 1 %) and permissible alternating voltage of the interfering signal on the grid, with 1 % modulation hum (mb = 1 %), as a function of the conversion conductance.
Lower 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.

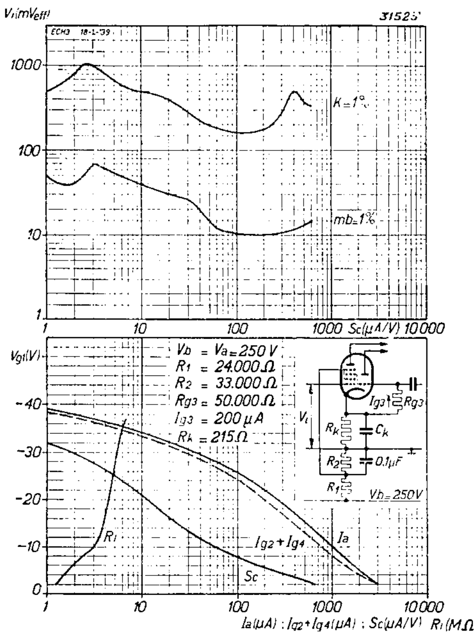

Fig. 16
At V_a = 250 V and with screen fed from a potential divider of 24,000 + 33,000 ohms (normal setting):
Upper diagram. Permissible R.F. voltage at 1 % cross-modulation (K = 1 %) and permissible alternating voltage of the interfering signal on the grid at 1 % modulation hum (mb = 1 %), as a function 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 μA)	V_{g1}	= max. —1.3 V
Grid voltage at grid current start (I_{g3} = + 0.3 μA)	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

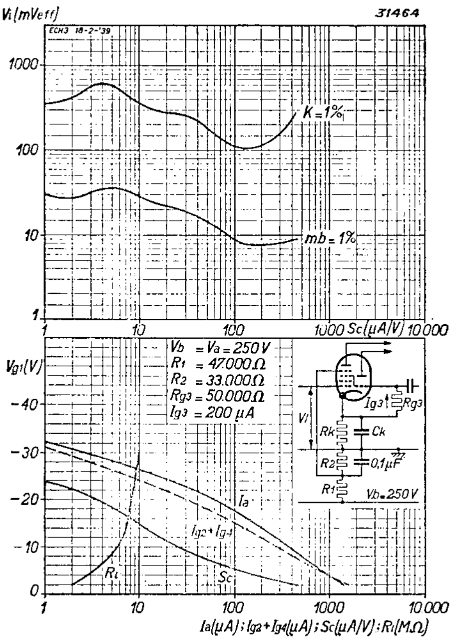

Fig. 17

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.

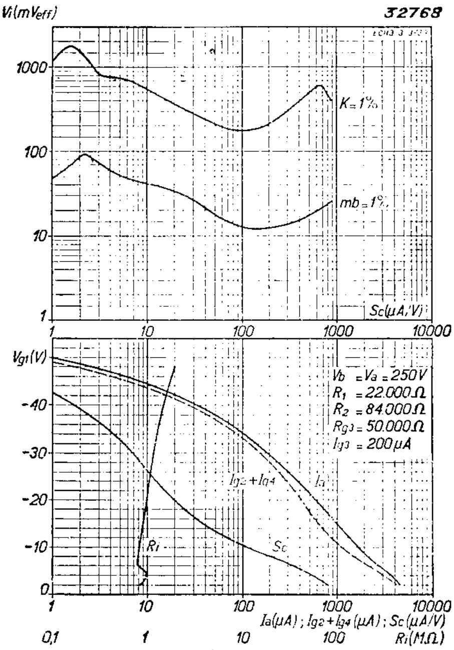

Fig. 18

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 ($I_g = +0.3\ \mu A$)	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}

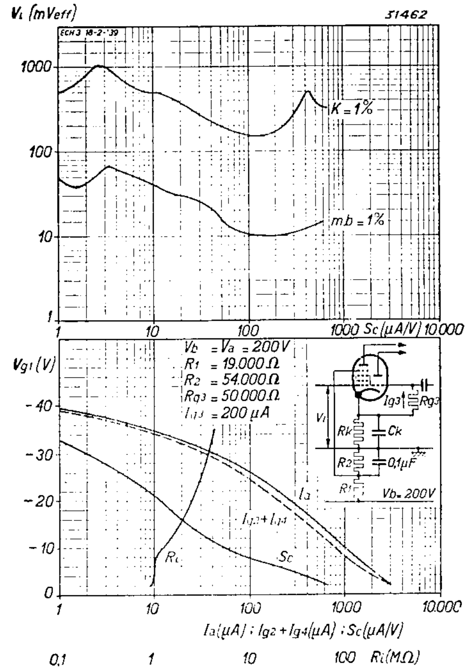

Fig. 19
At Va = 200 V, with screen fed from a potential divider of 19,000 + 54,000 ohms (for receivers with switch for A.C. or D.C.).
Upper diagram Permissible effective R.F. voltage at 1 % cross modulation (K = 1 %) and permissible alternating voltage of the interfering signal on the grid at 1 % modulation 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

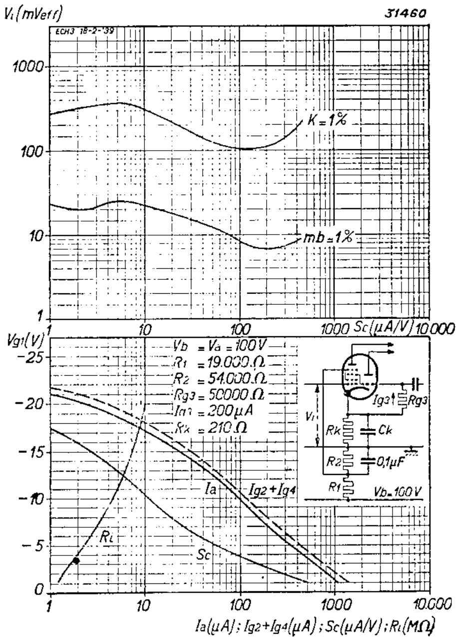

Fig. 20
At Va = 100 V, with screen fed from a potential divider of 19,000 + 54,000 ohms (for receivers with switch for A.C. or D.C.).
Upper diagram. Permissible R.F. voltage at 1 % cross modulation (K = 1 %) and permissible alternating voltage of the interfering signal on the grid at 1 % modulation hum (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.

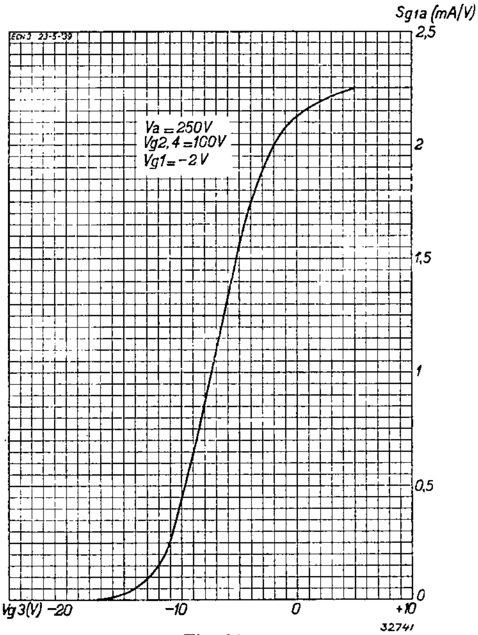

Fig. 21
Grid-current slope Sg_1a as a function of the grid bias.

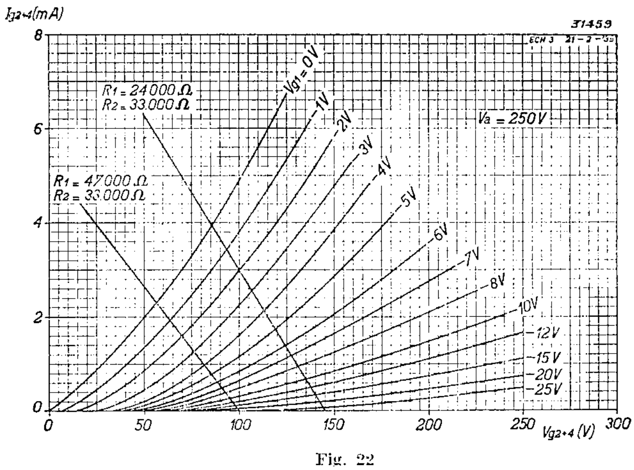

Fig. 22
Screen-grid current $Ig_2 + Ig_4$ as a function of the screen voltage Vg_{2+4} at various values of grid bias Vg_1

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

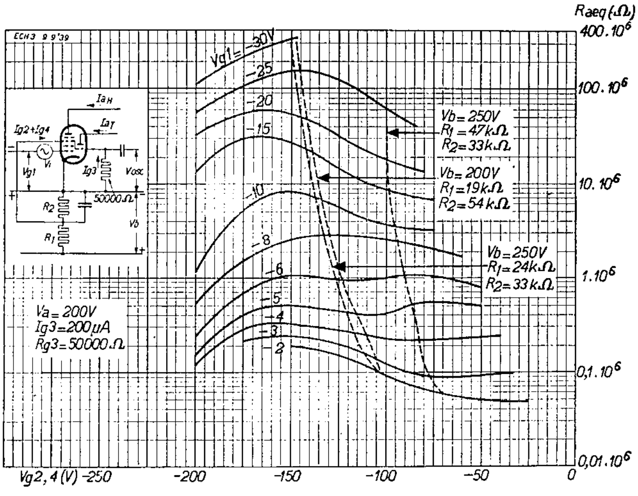

Fig. 23
Equivalent noise resistance *Req* as a function of the screen-grid voltage $Vg_{2,4}$ at different values of grid bias Vg_1.

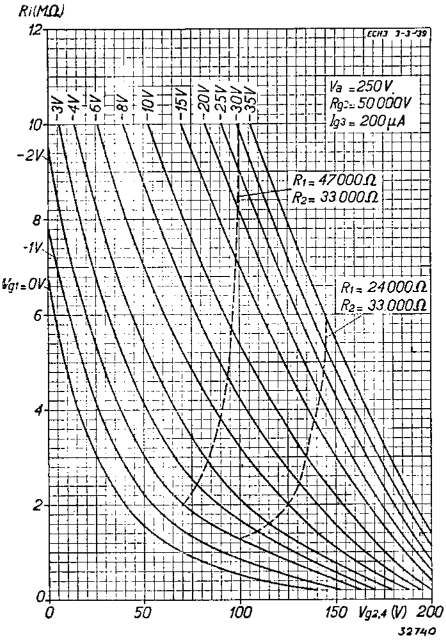

Fig. 24
Internal resistance Ri as a function of the screen-grid voltage $Vg_{2,4}$ at different values of grid bias Vg_1, with Va = 250 V.

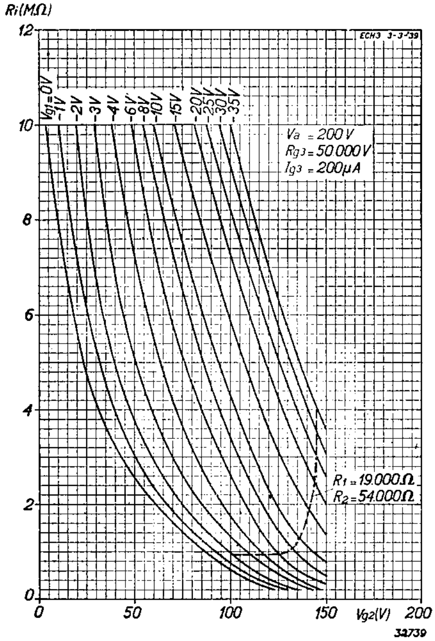

Fig. 25
Internal resistance Ri as a function of the screen-grid voltage $Vg_{2,4}$ at different values of grid bias Vg_1, with Va = 200 V.

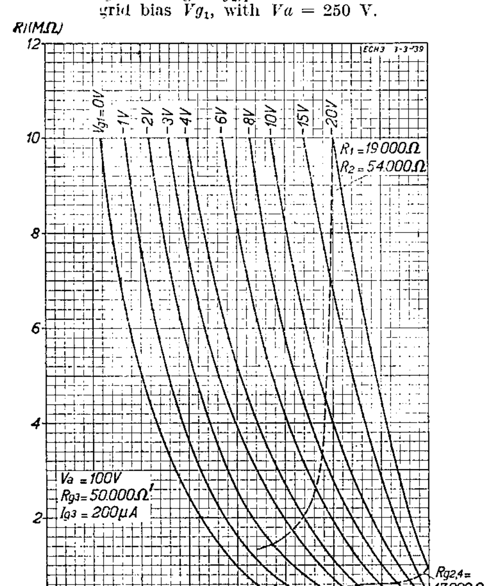

Fig. 26
Internal resistance Ri as a function of the screen-grid voltage $Vg_{2,4}$ at different values of grid bias Vg_1, with Va = 100 V.

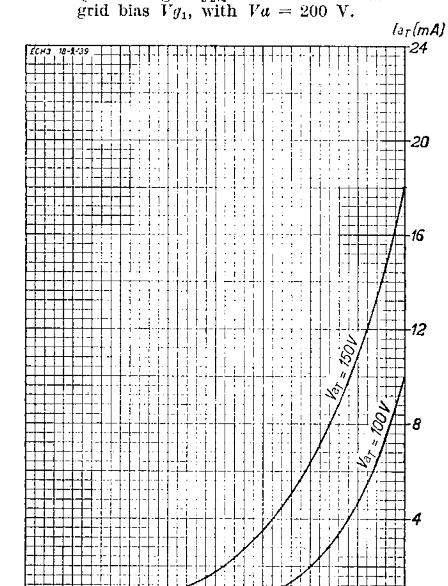

Fig. 27
Anode current of the triode section IaT at VaT = 150 and 100 V.

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.

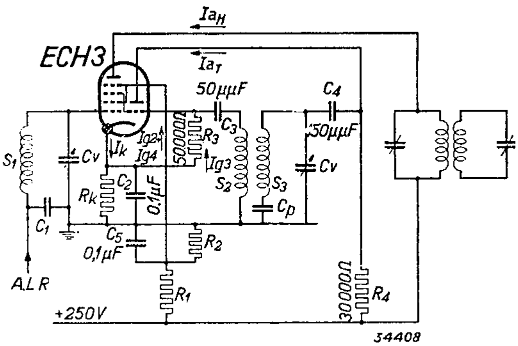

Fig. 28
Theoretical circuit diagram showing the ECH 3 employed as a frequency-changer. A value of 100 pF for capacitor C_4 will usually give a more constant oscillator voltage throughout the whole wave-range.

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.