# DK 91 Battery-operated frequency changer

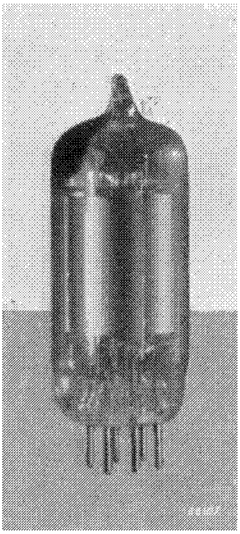

Fig. 1
The DK 91 (approx. actual size).

The heptode DK 91 is a frequency changer for battery receivers designed to operate on low voltages; having regard also to its small size, it is therefore highly suitable for use in portable sets. The filament current of the DK 91 is 50 mA at 1.4 V, but when fed in series with other valves, from an accumulator or mains, it is advisable to limit the voltage to 1.3 V, to ensure that no overloading will occur in the event of fluctuation in the supply voltage.

Good performance is secured at anode and screen grid voltages as low as 45 V, the conversion conductance being then 235 μA/V. At 67.5 V the results are naturally much better ($S_c$=280 μA/V), but if a 90 V H.T. battery is to be used, the screen grid voltage must be reduced to 67.5 V.

As there is no special electrode in this valve to serve as oscillator anode, the functions of the electrodes differ slightly from the conventional arrangement, the sequence here being: filament, oscillator grid, screen grid, control grid, screen grid, suppressor grid and anode. The circuits in which this valve can be used are therefore also rather unconventional; a few such circuits are described in the following pages, distinction being made between those in which the DK 91 itself serves as oscillator, and those in which a separate oscillator is employed. The latter naturally consume more current, but this is offset by the greater simplicity of the circuit and the improved performance of the valve in all wave-bands, particularly on short waves.

### Self-oscillating circuit with reaction coil (Fig. 2)

In the arrangement shown in Fig. 2 the oscillator circuit is connected to the first grid, a reaction coil being included in the circuit of the positive electrodes. Almost all the current emitted by the filament is used for oscillatory purposes, thus combining sufficient oscillation with good conversion conductance.

It is essential, however, that the reaction coil be wound with the correct number of turns to ensure satisfactory oscillation in both the medium and the long wave-bands, for, should this prove to be insufficient, valve noise will become very much more pronounced. It is therefore important that the direct current flowing to the oscillator grid should be maintained above a certain minimum, this being 30 μA for a screen grid voltage of 45 V (with a grid leak of 0.1 MΩ), or 50 μA for 67.5 V.

Furthermore, when deciding upon the strength of the oscillation, it is necessary to take into account the fact that the voltage will drop when the

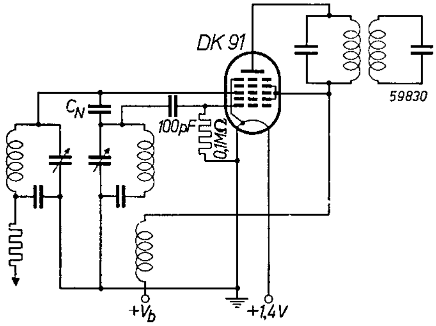

Fig. 2
Mixing circuit using the DK 91, with a reaction coil in the circuit of the positive electrodes.

H.T. battery is approaching the end of its effective life, and sufficient reaction must therefore be provided to maintain oscillation at reduced anode and screen grid voltages. On the other hand, too many turns on the reaction coil will cause a reduction in conversion conductance and may give rise to squegging. The reason for this drop in conversion conductance is as follows.

An increased number of turns results in an increase in the oscillator voltage on the screen grids. Now, cathode current flows only during the positive half-cycle of the oscillator voltage on grid 1, but at this particular moment the oscillator voltage on the screen grids is negative. The effective direct voltage on the screen grids therefore drops when the oscillation amplitude increases, to the detriment of the conversion conductance.

In general, optimum sensitivity is secured in the medium and long wavebands when the reaction coil contains just so many turns that the direct current flowing to the first grid varies between approximately 50 and 150 μA.

To obtain good results in the short-wave band with the circuit shown in Fig. 2, a compensating capacitor $C_N$ must be connected between grid 1 and input (third) grid. Provided that this capacitance is of the correct value, $C_N$ has the effect of reducing the induced voltage on grid 3, and therefore also the adverse effects of this voltage.

This compensating capacitance can be obtained very simply by twisting together two lengths of insulated wire, the correct adjustment being obtained in the following manner : The wave-band switch of the receiver is set to the short-wave band and the set is tuned to the low frequency end of the band. The reaction coil should now contain just so many turns that the current flowing to grid 1 is roughly 20 μA (with a grid leak of 0.1 MΩ). The receiver is then tuned to the high frequency end of the waveband and $C_N$ is trimmed for optimum sensitivity. It will be noted that if $C_N$ is too high, the circuit becomes unstable, this being due to excessive coupling between the oscillator and input circuits. A value of $C_N$ slightly below the optimum is therefore recommended, as this greatly reduces the risk of instability without affecting the sensitivity too much.

The effect of $C_N$ on the sensitivity and stability of the receiver is dependent on the oscillator voltage: when this rises, the size of $C_N$ becomes more critical, usually being most decisive at the highest frequencies. Now, the adjustment of $C_N$ can be made less critical by reducing the oscillator voltage, e.g. by connecting a resistor in series with the trimmer in the oscillator circuit. When the wave-band switch of the receiver is set to the medium or long wave-bands, the capacitor $C_N$ may remain between grids 1 and 3 without this having any adverse effects on the characteristics.

## Self-oscillating circuit with reaction coil for operating on 90 V battery

(Figs. 3, 4 and 5)

If the DK 91 is to be used for a receiver operating on a 90 V battery, the circuit described above will be unsuitable, since the maximum permissible screen grid voltage is only 67.5 V. Some modification is therefore necessary.

Fig. 3 shows an alternative arrangement in which the screen grid circuit includes a resistor, the value of which will ensure that the screen grid voltage does not exceed 67.5 V. The conversion conductance in this case is slightly higher than that in the circuit depicted in Fig. 2.

If the receiver also employs the DF 91, another shunted resistor is required to reduce the screen grid voltage of this valve to 67.5 V. Alternatively, a common resistor and capacitor may be used for both the DK 91 and the DF 91, in the manner shown in Figs. 4 and 5. Since the anode voltage of the DK 91 is 90 V in Fig. 4 and only 67.5 V in Fig. 5, the former yields the greater conversion conductance. On the other hand, when the A.G.C. comes into operation in this circuit (Fig. 4), the current flowing through the reaction coil no longer remains constant, the oscillator slope varies, and frequency drift sets in. Such frequency drift is negligible in the medium and long wave-bands, but not on short waves, for which reason it is advisable not to employ A.G.C. in the short wave-band. By way of contrast, in the case of Fig. 5 the current flowing through the reaction coil remains practically constant when control is applied, permitting the use of A.G.C. in the short-wave band as well. Compared with the circuits in Figs. 4 and 5, the arrangement shown in Fig. 3 can be said to combine all the advantages of the other two, although necessitating more components.

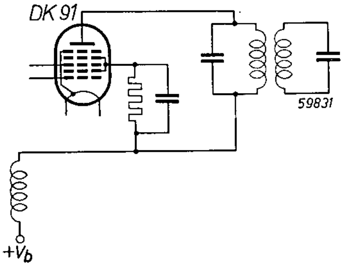

Fig. 3
As Fig. 2, but with a bypassed resistor included in the screen grid feed, to reduce the voltage on these grids.

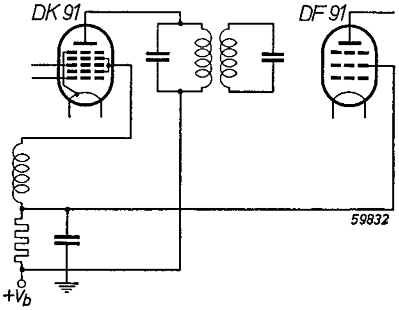

Fig. 4
As Fig. 2, but with the screen grids of the DK 91, together with that of the I.F. amplifier DF 91, fed through a common resistor.

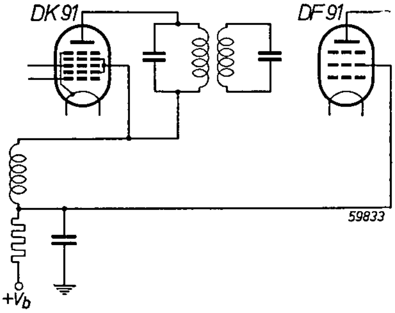

Fig. 5
As Fig. 4, but with the anode of the DK 91 also fed through the common resistor.

## Self-oscillating circuit with tapped oscillator coil (Fig. 6)

Fig. 6 shows a circuit in which the filament of the DK 91 is connected to a tapping on the oscillator coil; in this case, a capacitor for compensating the induced voltage is not usually required. With this circuit, however, it is rather more difficult to make the valve oscillate properly, and, moreover, an extra choke is needed in the filament circuit.

To avoid loss of filament voltage, the D.C. resistance of this choke should not be too high, usually not more than 1 ohm. Further, the self-inductance should be such as will provide sufficient impedance at the lowest oscillator frequencies. A choke of this kind, suitable for the long-wave band, will be very large and expensive, for which reason the circuit cannot be recommended for sets which are to include a long-wave band; for receivers without long-wave facilities a self-inductance of 30 - 40 μH is ample. The self-capacitance of the choke should be so low that the natural frequency always lies above the highest oscillator frequency.

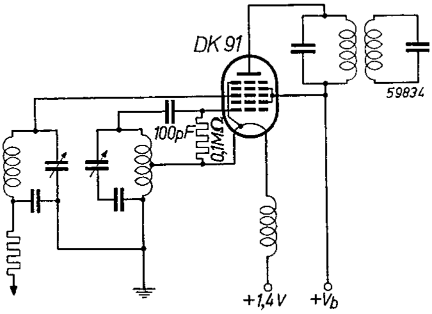

Fig. 6
Mixer circuit employing the DK 91 with the filament connected to a tapping on the oscillator coil.

The tapping on the oscillator coil should be far enough from the earthed end to ensure satisfactory oscillation, but if placed too high it will cause a drop in the conversion conductance. The reason for this is as follows: During the positive half-cycle of the oscillator voltage on grid 1, that is, during the time the filament emits electrons, the oscillator voltage on the filament is also in its positive half-cycle, resulting in an increase in the effective bias on the input (third) grid and a drop in the conversion conductance. The most satisfactory position must therefore be found for the coil tapping; generally speaking, in the medium-wave band the best results are obtained when the current flowing to grid 1 varies between approx. 50 and 150 μA.

In view of the relatively low impedance of the oscillator circuit in the short-wave band, the coils have to be tightly coupled to secure sufficient oscillator voltage at the low-frequency end of the band. The risk of squegging on short waves, brought about by this tight coupling, is eliminated by including a stopper resistor in the oscillator grid lead. This, however, does not dispose of other undesirable effects of tight coupling, such as excessive frequency drift when control is applied to the valve, and an extra circuit, as described in the section on the ECH 41, is therefore recommended.

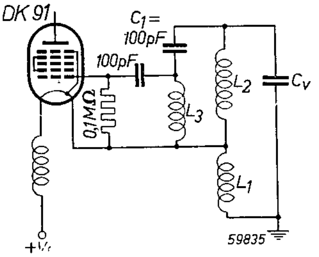

Fig. 7
Short wave oscillator circuit for the DK 91 employing an extra coil $L_3$ to improve oscillator performance.

This extra circuit causes the oscillator voltage to rise at the low frequency end of the wavelength range, permitting the use of looser coupling. The manner in which this extra circuit is arranged is illustrated in Fig. 7, where the coils $L_1$ and $L_2$ with tuning capacitor $C_v$ constitute the oscillator circuit, and coil $L_3$ with capacitor $C_1$ the extra circuit. The tuning frequency of the latter should correspond to roughly 3/4 of the lowest frequency in the waveband.

## TECHNICAL DATA OF THE HEPTODE FREQUENCY CHANGER DK 91

### Filament data

Heating: direct, from battery, rectified A.C., or direct current; series or parallel feed

*In parallel with other valves*

| | | | |
|---|---|---|---|
| Filament voltage . . . | $V_f$ | = | 1.4 V |
| Filament current . . . | $I_f$ | = | 50 mA |

*In series with other valves*

| | | | |
|---|---|---|---|
| Filament voltage . . . . | $V_f$ | = | 1.3 V |

### **Capacitances** (cold valve)

| | | | |
|---|---|---|---|
| Input capacitance . . . . | $C_{g3}$ | = | 7.0 pF |
| Output capacitance . . . . | $C_a$ | = | 7.0 pF |
| Anode - control grid . . . | $C_{ag3}$ | $<$ | 0.4 pF |
| Input capacitance oscillator section . . . . . . . . | $C_{g1}$ | = | 3.8 pF |
| Anode - oscillator grid . . . | $C_{ag1}$ | $<$ | 0.1 pF |
| Control grid - oscillator grid | $C_{g1g3}$ | $<$ | 0.2 pF |

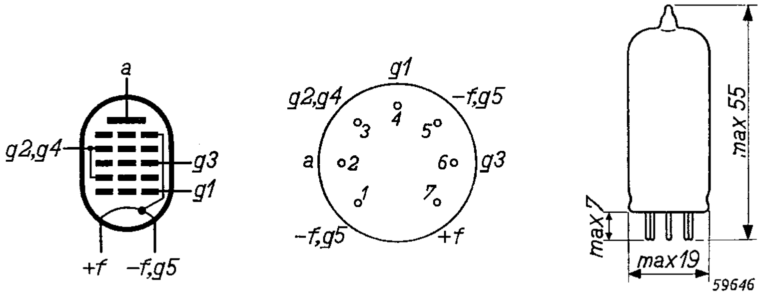

Fig. 8
Electrode arrangement, electrode connections and max. dimensions in mm of the DK 91.

## Operating characteristics of the DK 91 used as frequency changer

(for circuit see Fig. 2)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Anode and battery voltage | $V_a = V_b$ | = | 45 | | 90 | | V |
| Screen grid voltage | $V_{g2+g4}$ | = | 45 | | 45 | | V |
| Oscillator grid leak | $R_{g1}$ | = | 0.1 | | 0.1 | | MΩ |
| Oscillator grid current | $I_{g1}$ | = | 150 | | 150 | | μA |
| Grid bias | $V_{g3}$ | = | 0 | −9 | 0 | −9 | V |
| Anode current | $I_a$ | = | 0.7 | — | 0.8 | — | mA |
| Screen grid current | $I_{g2+g4}$ | = | 1.9 | — | 1.9 | — | mA |
| Conversion conductance | $S_c$ | = | 235 | 5 | 250 | 5 | μA/V |
| Internal resistance | $R_i$ | = | 0.6 | >10 | 0.8 | >10 | MΩ |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Anode and battery voltage | $V_a = V_b$ | = | 67.5 | | 90 | | V |
| Screen grid voltage | $V_{g2+g4}$ | = | 67.5 | | 67.5 | | V |
| Oscillator grid leak | $R_{g1}$ | = | 0.1 | | 0.1 | | MΩ |
| Oscillator grid current | $I_{g1}$ | = | 250 | | 250 | | μA |
| Grid bias | $V_{g3}$ | = | 0 | −14 | 0 | −14 | V |
| Anode current | $I_a$ | = | 1.4 | — | 1.6 | — | mA |
| Screen grid current | $I_{g2+g4}$ | = | 3.2 | — | 3.2 | — | mA |
| Conversion conductance | $S_c$ | = | 280 | 5 | 300 | 5 | μA/V |
| Internal resistance | $R_i$ | = | 0.5 | >10 | 0.6 | >10 | MΩ |
| Equivalent noise resistance | $R_{eq}$ | = | 185 | — | 195 | — | kΩ |

### Limiting values

| | | | | |
|---|---|---|---|---|
| Anode voltage | $V_a$ | = max. | 90 | V |
| Anode dissipation | $W_a$ | = max. | 0.15 | W |
| Screen grid voltage | $V_{g2+g4}$ | = max. | 67.5 | V |
| Screen grid dissipation | $W_{g2+g4}$ | = max. | 0.25 | W |
| Cathode current | $I_k$ | = max. | 5.5 | mA |
| Grid current starting point | $V_{g3}(I_{g3} = +0.3\mu A)$ | = max. | +0.2 | V |
| External resistance between control grid and cathode | $R_{g3}$ | = max. | 3 | MΩ |

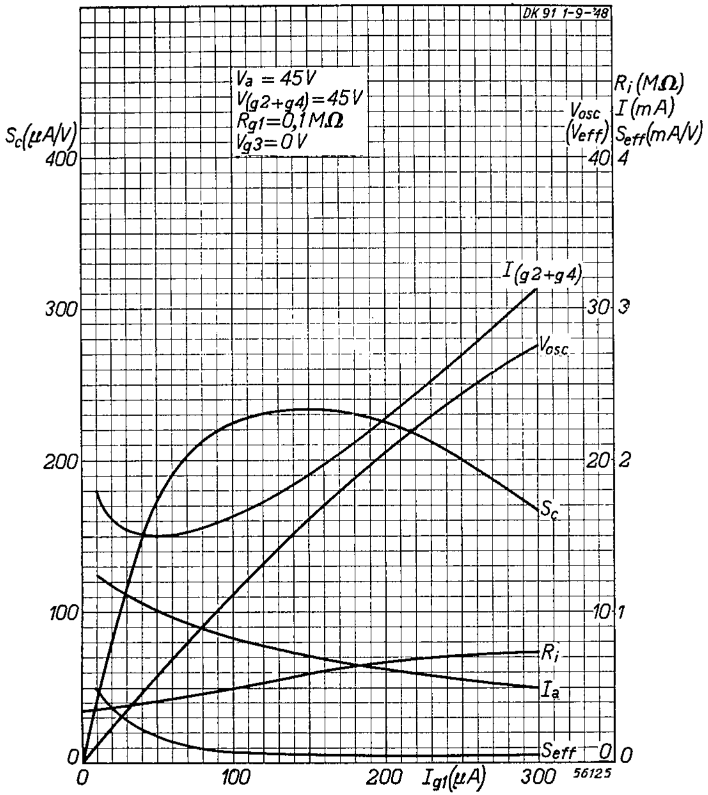

Fig. 9

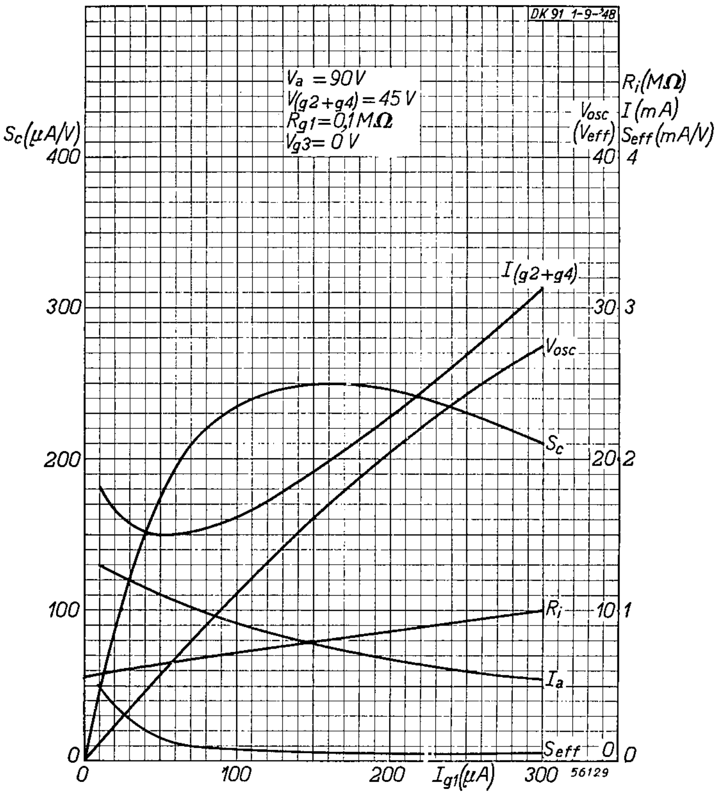

Fig. 10

Anode current ($I_a$), screen grid current ($I_{g_2+g_4}$), conversion conductance ($S_c$), internal resistance ($R_i$), oscillator voltage ($V_{osc}$) and effective slope of the oscillator section ($S_{eff}$) as functions of the oscillator current ($I_{g1}$). Fig. 9: anode voltage ($V_a$) and screen grid voltage ($V_{g_2+g_4}$) = 45 V. Fig. 10: anode voltage ($V_a$) = 90 V and screen grid voltage ($V_{g_2+g_4}$) = 45 V. Measured on oscillating valve in the circuit depicted in Fig. 2.

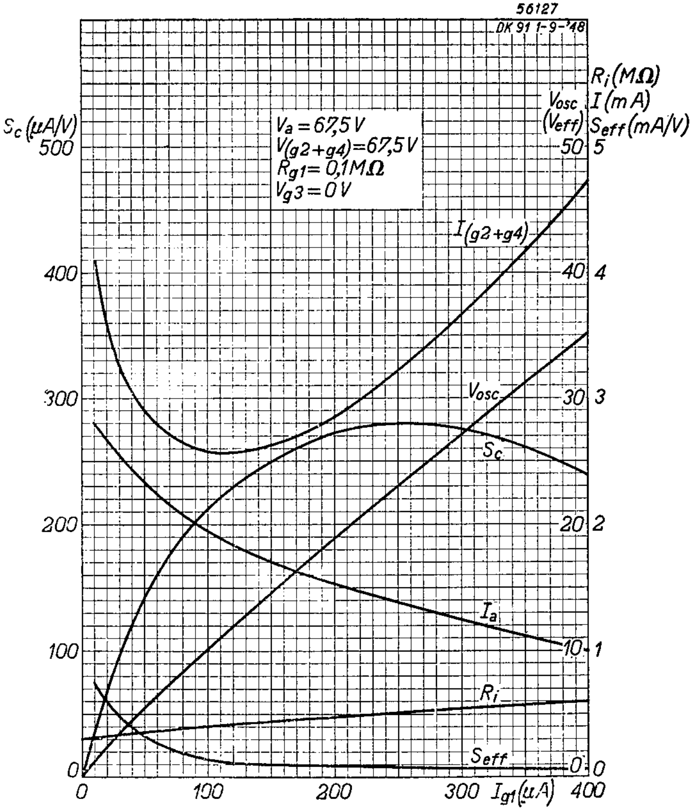

Fig. 11
As Figs. 9 and 10, but at $V_a = V_{g2+g4} = 67.5$ V.

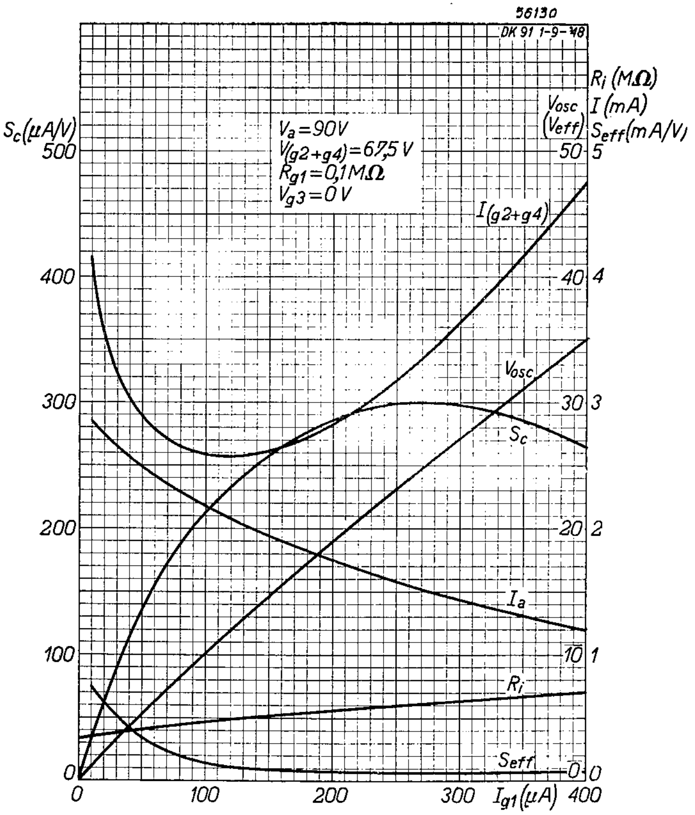

Fig. 12
As Figs. 9 and 10, at $V_a = 90$ V and $V_{g2+g4} = 67.5$ V.

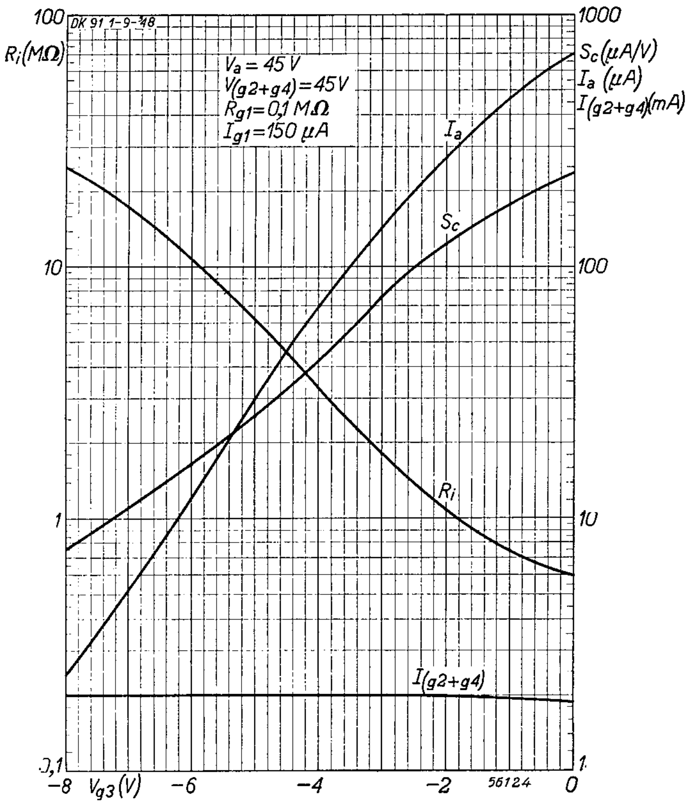

Fig. 13

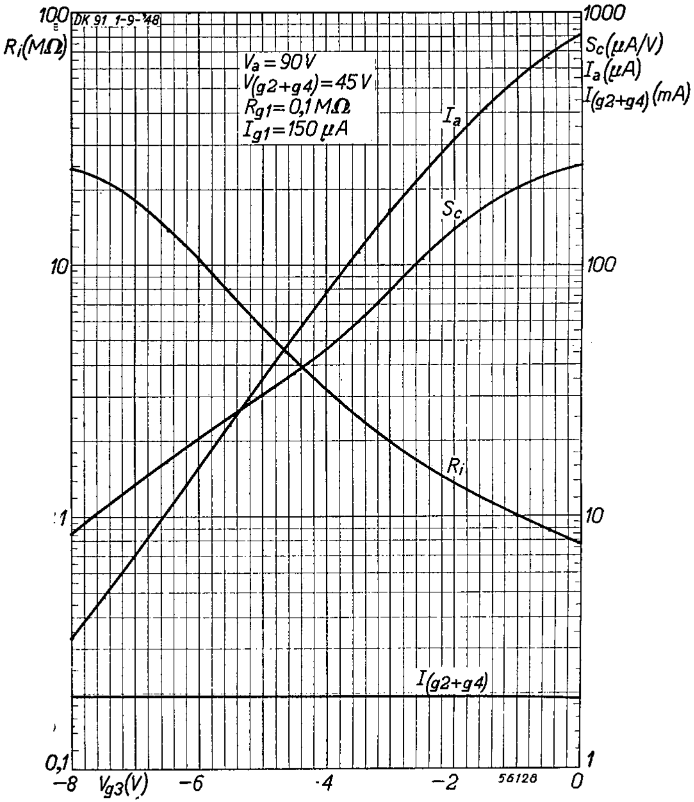

Fig. 14

Anode current ($I_a$), screen grid current ($I_{g2+g4}$), conversion conductance ($S_c$) and internal resistance ($R_i$) as functions of the grid bias ($V_{g3}$). Measured on oscillating valve in circuit shown in Fig. 2.
Fig. 13: $V_a = V_{g2+g4} = 45$ V; Fig. 14: $V_a = 90$ V, $V_{g2+g4} = 45$ V.

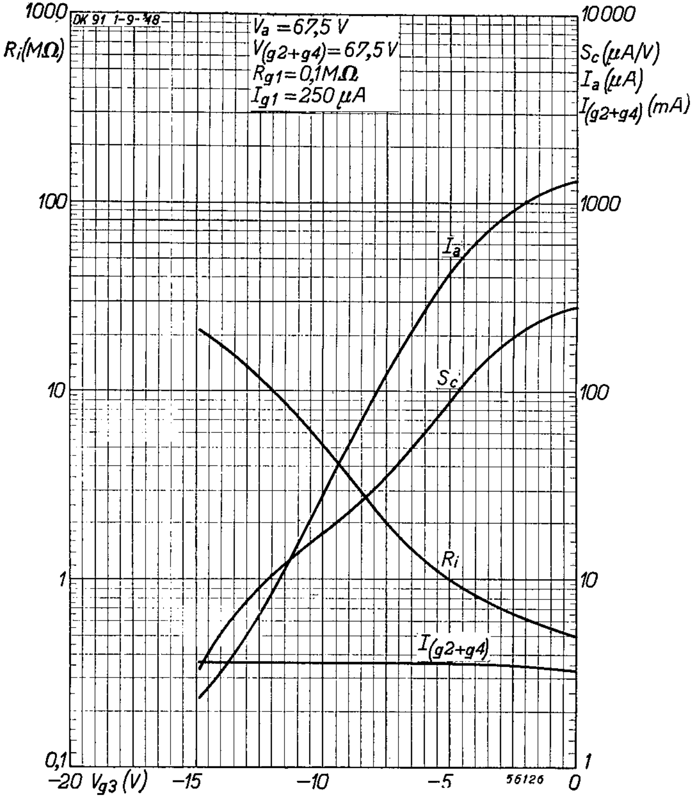

Fig. 15
As Figs. 13 and 14, at $V_a = V_{g2+g4} = 67.5$ V.

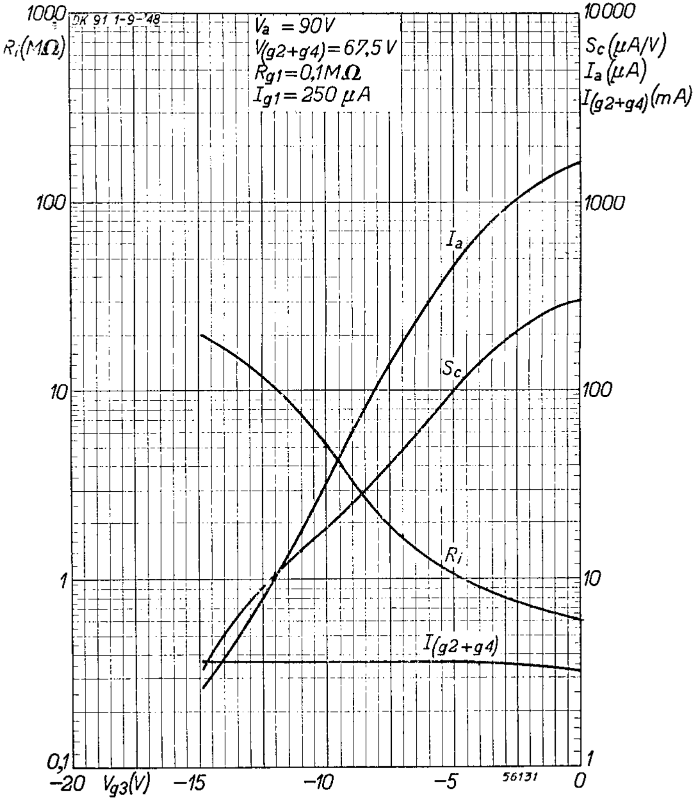

Fig. 16
As Figs. 13 and 14, but at $V_a = 90$ V, $V_{g2+g4} = 67.5$ V.

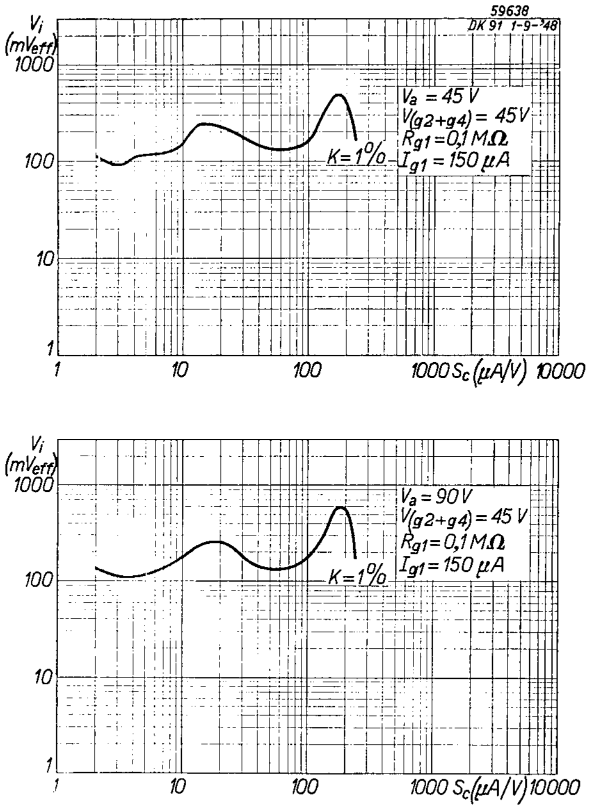

Fig. 17

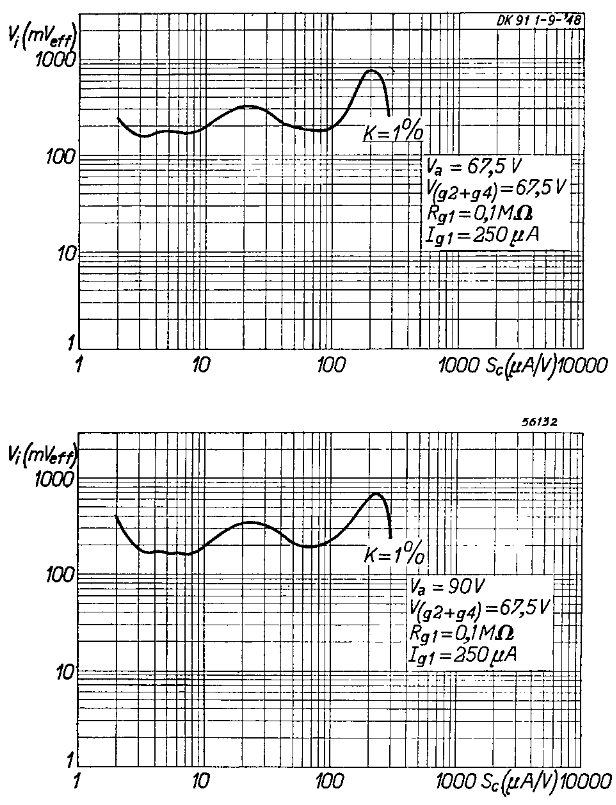

Fig. 18

The voltage ($V_i$) of an interfering signal at the control grid producing 1% cross-modulation is shown as a function of the conversion conductance.

Fig. 17, upper : $V_a = V_{g2+g4} = 45$ V; lower : $V_a = 90$ V, $V_{g2+g4} = 45$ V.

Fig. 18, upper : $V_a = V_{g2+g4} = 67.5$ V; lower : $V_a = 90$ V, $V_{g2+g4} = 67.5$ V.