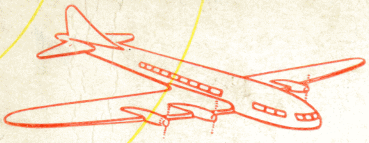

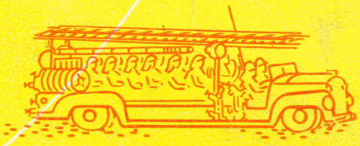

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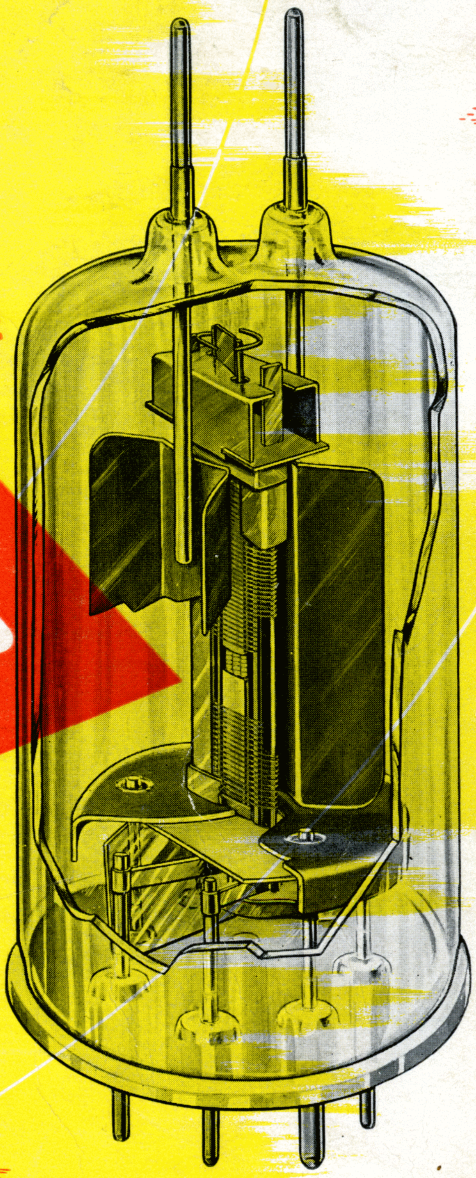
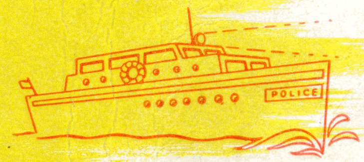


DOUBLE TETRODE QQE 06/40

FOR MOBILE TRANSMITTING EQUIPMENT



PHILIPS ELECTRONIC TUBE DIVISION

DOUBLE TETRODE QQE 06/40

FOR

MOBILE TRANSMITTING EQUIPMENT

CONTENTS

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INTRODUCTION

The ever-increasing use of radio communication over short distances has already occupied to a large extent the frequency ranges up to about 220 Mc/s. Therefore, it will be understood that

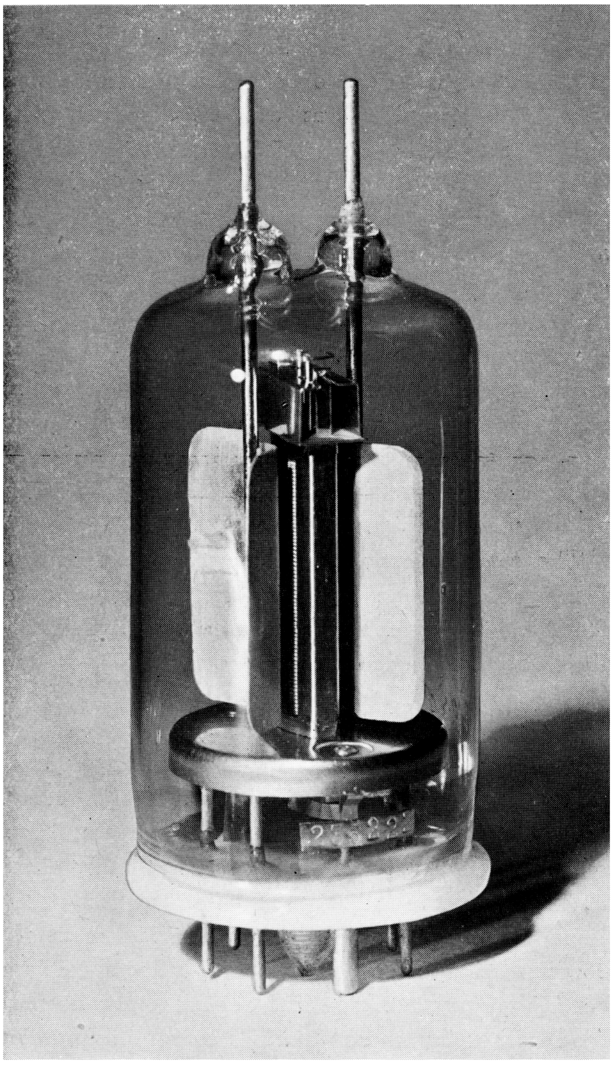


Fig. 1. The QQE 06/40 (actual size).

there is a tendency to use higher frequencies for this electronic field. Operation at higher frequencies, however, makes higher demands on the design of tubes and circuits. Transmitters for this class of service must give a useful output power between 5 and 100 watts and, especially in mobile equipment, they must have a stage gain as high as possible in order to minimize the required number of stages.

From the point of view of stage gain, which is very important in the type of equipment mentioned above, a tetrode is to be preferred to a triode and therefore in transmitting tube engineering the aim has been to improve tetrodes of conventional design so as to make them suitable for operation on frequencies of 250 Mc/s and higher, with relatively high stage gain and with the use of parallel lines or lumped circuits.

It is well known that at high frequencies push-pull circuits have several advantages. In such a circuit a low self-inductance of the connecting leads between the two cathodes and the two screen grids of the two tubes is very important. The undesired phenomena resulting from these self-inductances are explained in detail in the next section. A considerable reduction of lead self-inductance can be obtained by mounting two tetrodes in one envelope.

In the next section the double-tetrode transmitting tube QQE 06/40 is described and the special measures taken in the design of the tube in order to minimize the aforementioned self-inductances to a quite negligible value are discussed. This improvement enables the tube to operate at frequencies up to 500 Mc/s.

Following this description a practical application of the QQE 06/40 in an experimental transmitter is given. In this transmitter two double tetrodes type QQE 06/40 are used, one operating as frequency tripler with an output frequency of 430 Mc/s and the other as final amplifier.

THE DOUBLE TETRODE QQE 06/40

DESCRIPTION

The QQE 06/40 is a double tetrode with which an output of 90 W at 200 Mc/s and of 34 W at 430 Mc/s can be obtained, whilst at 500 Mc/s the available output is still 20 W. It embodies in its design features which have been incorporated to answer the requirements of the frequency range between 200 and 500 Mc/s.

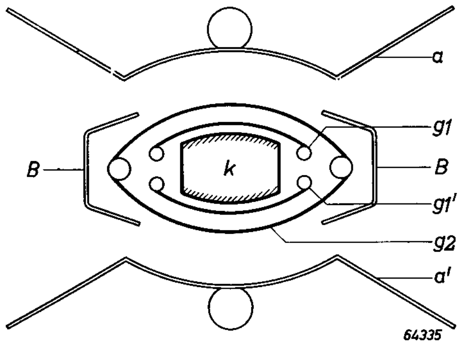


Fig. 2. Horizontal cross section of the electrode system of the QQE 06/40. The indications at the electrodes refer to fig. 3.

Transmitting tubes with two electrode systems in one envelope have in fact been known for some 15 years already. In the old designs the electrodes not carrying any R.F. voltage (the cathodes and the screen grids) were connected in pairs by short wires or strips, and the centres (neutral points) of the interconnections were led out through the envelope, as were each of the two control grids and the two anodes. A difficulty arising with these tubes was due to the self-inductance formed by the interconnection of the cathodes and of the screen grids. At very high frequencies the influence of these self-inductances cannot be ignored.

The self-inductance between the cathodes causes undesired inverse feedback and constitutes a positive component of input damping, so that in order to obtain a certain output a larger driving power is required.

The influence of the self-inductance between the screen grids is manifested as a negative damping, which is zero only at one given frequency and at other frequencies may reach such a value that in order to avoid self-oscillation some form of neutralization must be applied, especially with tubes having a high mutual conductance. Below the frequency just referred to this neutralization can be brought about by introducing capacitors of a certain value between the anode of the one section and the control grid of the other. Above that frequency these capacitors must be connected between each anode and its corresponding control grid. The measures which have been taken in the design of the QQE 06/40 in order to avoid the above-mentioned complications will be discussed with reference to figs 2 and 3.

The QQE 06/40 contains one indirectly heated cathode the cross section of which is roughly rectangular. Only the long, slightly convex sides are coated with an emitting material, so that in fact the tube has two cathodes interconnected by the shorter sides of the rectangular body. The self-inductance of these short and wide "connecting strips" connected in parallel is so small that even at frequencies of 500 Mc/s the aforementioned effect of self-inductance in the cathode interconnections is quite negligible.

The cathode surface is heated by two filaments inside the cathode body. A short distance away from and facing each of the emitting surfaces are the two control grids.

One single screen grid is placed around the system comprising the cathode and the two control grids. This screen grid is made of windings fixed to two supporting rods. This construction avoids the necessity of separate leads for the two halves of the screen grid and thus also completely eliminates the self-inductance of those leads. At the same time, however, the advantage is lost of the compensating effect of that self-inductance in a certain frequency range with regard to the positive feedback of the anode upon its corresponding control grid. In the absence of such a compensation the tube might tend to oscillate in that range.

This tendency to oscillate is counteracted in the QQE 06/40 by introducing two small neutralizing capacitors. Each of these capacitors is formed by the lead of one anode and a short length of wire

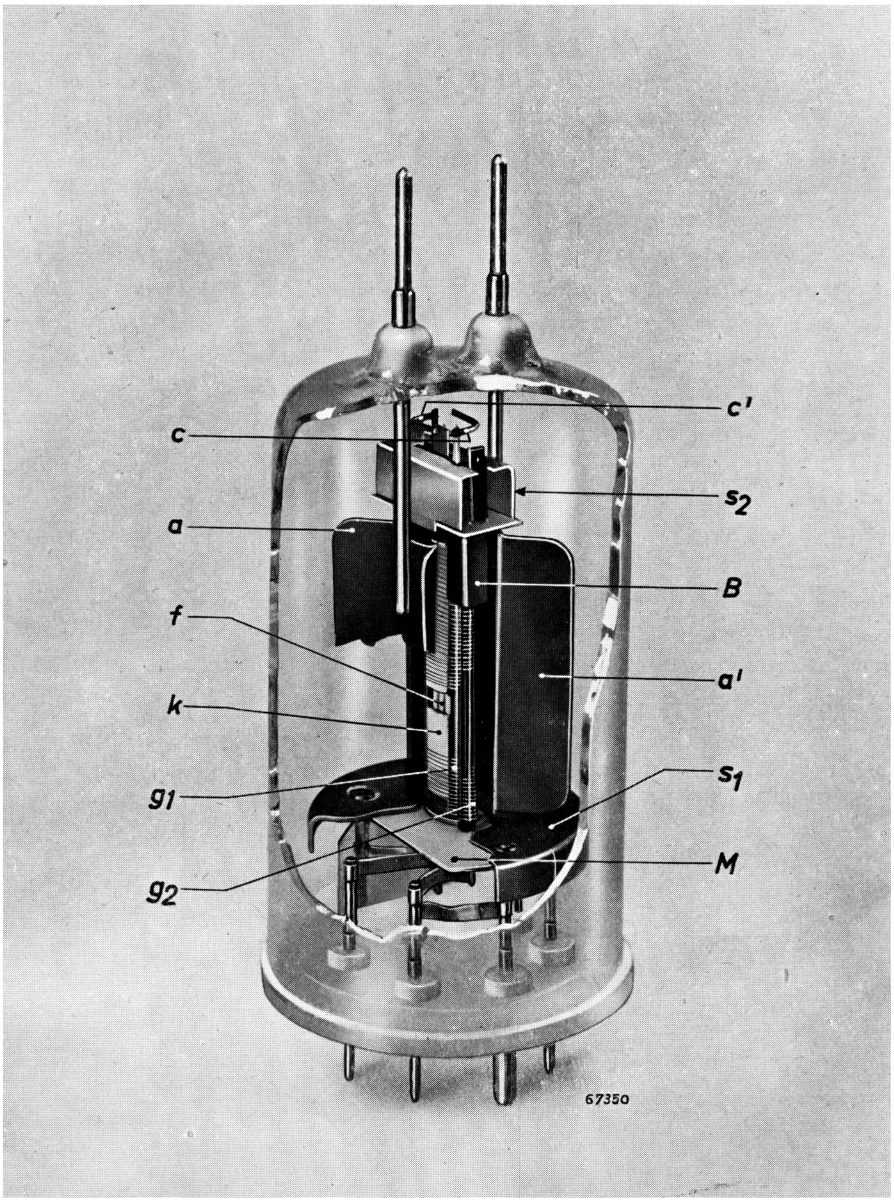


Fig. 3. Photograph showing the construction of the double tetrode QQE 06/40. The heater *f* is surrounded by the cathode *k*, one of the emitting surfaces being visible. Further are shown: one of the control grids, g_1, the screen grid g_2, the anodes *a* and *a'*, one of the beam plates *B*, the screen S_1 screening the mica plate *M* by means of which the electrodes are supported. The rods *c* and *c'* are connected to the supporting rods of the grids g_1 and g_1' respectively and form together with the anode leads neutralizing capacitors. The box S_2 connected to the cathode and the plates B screen the neutralizing capacitors from the electrode systems.

welded onto one of the extended supporting rods of the control grid of the other tetrode section. The capacitance is made practically equal to that between an anode and its corresponding control grid. In this way a neutralization is obtained which is independent of the frequency at which the tube is working.

The anodes are molybdenum plates coated on both sides with zirconium powder to reduce the secondary emission coefficient, to improve radiation of heat and to act as a getter.

A definite advantage of the special construction is the low internal capacitance of grid and anode. The control-grid capacitance is only 3.2 pF and the anode capacitance 10.5 pF, as against 7.0 pF and 14.5 pF respectively of former constructions with separate cathodes.

On either side of the screen grid is a U-shaped plate, called the beam plate, which is connected to the cathode, the object of this being to prevent deflection of the electrons from the shortest trajectory. Thus these plates assist in concentrating such a space charge between the screen grid and the anodes that the secondary electrons cannot reach the screen grid when the anode current is high and the anode voltage is low. Since the beam plates prevent them from following long trajectories, all the electrons have about the same and the shortest possible transit time. Without such a measure there would be differences in transit time and at very high frequencies these differences would adversely affect the efficiency of the tube.

The feedback of each anode upon its corresponding control grid is quite insignificant, thanks to the built in neutralizing capacitors, so that the QQE 06/40 will not oscillate unless feedback is purposely applied externally. In amplifiers the absence of internal feedback ensures a high degree of stability.

Owing to the self-inductance and the resistance of the cathode lead being extremely small, only a small driving power is needed. In fig. 15 the output and the efficiency for the two sections of the QQE 06/40 connected as push-pull amplifier have been plotted as functions of frequency and wavelength. It is seen, for instance, that at frequencies below 200 Mc/s (wavelength > 1.5 m) an output of 90 W can be obtained with an efficiency of 75%, and that at a frequency of 430 Mc/s these figures are still 34 W and 47% respectively.

Owing to the exceptionally rugged construction of the electrode system, which makes the tube resistant to severe shocks, the tube lends itself eminently for use in mobile installations, the more so as in dimensioning the heater attention has been paid to the limited capacity of the supply sources in these installations. The two sections of the heater of the tube can be connected either in parallel or in series as required, the total heater consumption being 6.3 V, 1.8 A or 12.6 V, 0.9 A respectively.

TECHNICAL DATA

HEATER DATA

Heating	indirect by A.C. or D.C.		
Heater voltage	V_f = 6.3	12.6	V
Heater current	I_f = 1.8	0.9	A
	Pins: 5—(1+7)	1—7	

BASE CONNECTIONS AND DIMENSIONS

(*in* mm)

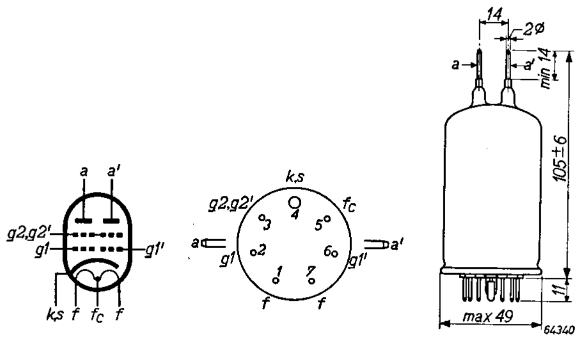


Fig. 4.

Base:	Septar
Socket:	ceramic type 40202
Cooling clips for anode pins:	type 40623
Mounting position:	Vertical; base up or down horizontal; anode pins in one horizontal plane

In order to ensure adequate cooling of the anode pins it is necessary to use the cooling clips type 40623.

CAPACITANCES

One section

Anode	C_a	= 3.2 pF
Control grid	C_{g1}	= 10.5 pF
Anode-to-control grid	C_{ag1}	< 0.08 pF

In push-pull service

Output	C_o	= 2.1 pF
Input	C_i	= 6.7 pF

TYPICAL CHARACTERISTICS

Amplificator factor between screen grid and control grid	μ_{g2g1}	= 8.2
Mutual conductance of one section at 30 mA anode current	S	= 4.5 mA/V

OUTPUT IN CLASS C TELEGRAPHY
(two sections in push-pull)

Wavelength m	Frequency Mc/s	Anode voltage V	Output W
1.5	200	600	90
1.2	250	600	85
0.7	430	400	34

OUTPUT AS FREQUENCY TRIPLER
(two sections in push-pull)

Wavelength m	Frequency Mc/s	Anode voltage V	Output W
6/2	50/150	500	20
6/2	50/150	400	18
4/1.3	75/225	400	12

OUTPUT WITH ANODE AND SCREEN-GRID MODULATION
(two sections in parallel)

Wavelength m	Frequency Mc/s	Anode voltage V	Output W
1.5	200	450	50

OUTPUT AS MODULATOR IN CLASS B
(two sections in push-pull)

Anode voltage V	Output W
600	73
450	54

OPERATING CONDITIONS

R.F. CLASS C AMPLIFIER AND OSCILLATOR (two sections in push-pull)

Wavelength	λ	1.5	1.2	0.7 m
Frequency	f	200	250	430 Mc/s
Anode voltage	V_a	600	600	400 V
Grid bias	V_{g1}	—80	—80	—50 V
Screen-grid voltage	V_{g2}	250	250	200 V
Anode current	I_a	2x100	2x100	2x90 mA
Grid current	I_{g1}	2x2.5	2x2.5	2x2.0 mA
Screen-grid current	I_{g2}	16	16	10 mA
Input voltage peak-to-peak	$V_{g1\,g1'\,p}$	200		V
Screen-grid dissipation	W_{g2}	4	4	2 W
Anode supply power	W_{ia}	2x60	2x60	2x36 W
Anode dissipation	W_a	2x15	2x17.5	2x19 W
Output	W_o	90	85	34 W
Efficiency	η	75	71	47 %

R.F. CLASS C AMPLIFIER WITH ANODE AND SCREEN-GRID MODULATION (two sections in parallel)

Wavelength	λ	1.5 m
Frequency	f	200 Mc/s
Anode voltage	V_a	450 V
Grid bias	V_{g1}	—100 V
Screen-grid voltage	V_{g2}	250 V
Anode current	I_a	2x75 mA
Grid current	I_{g1}	2x2.5 mA
Screen-grid current	I_{g2}	16 mA
Input voltage, peak value	V_{g1p}	120 V
Screen-grid dissipation	W_{g2}	4 W
Anode supply power	W_{ia}	2x34 W
Anode dissipation	W_a	2x9 W
Output	W_o	50 W
Efficiency	η	73 %
At a modulation depth $m = 100\%$		
Modulating voltage, peak value	V_{g2p}	185 V
Modulating power	W_{mod}	34 W

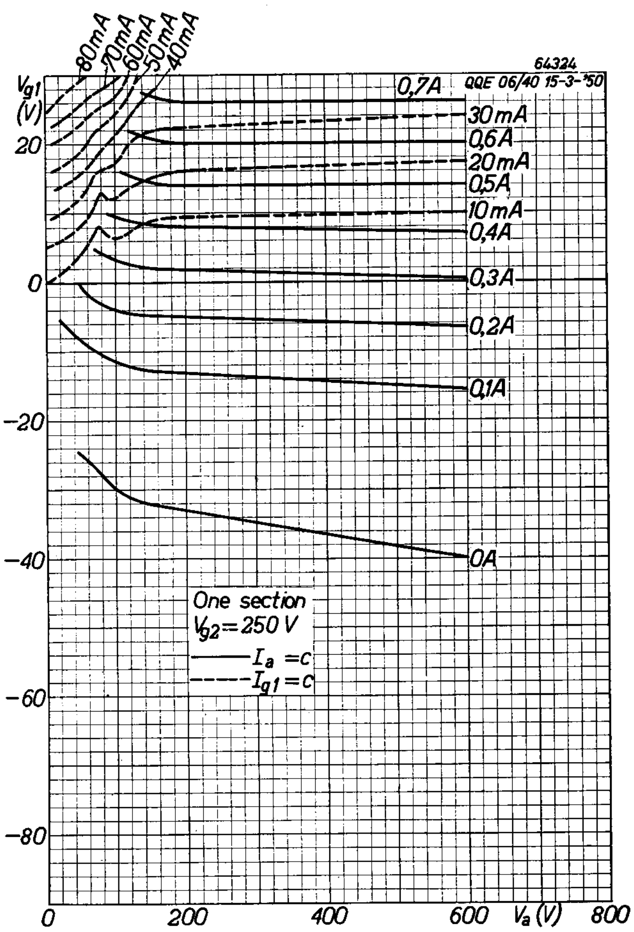


Fig. 5. Control-grid voltage V_{g1} as a function of the anode voltage V_a at constant anode current I_a and constant control-grid current I_{g1} for a screen-grid voltage V_{g2} of 250 V.

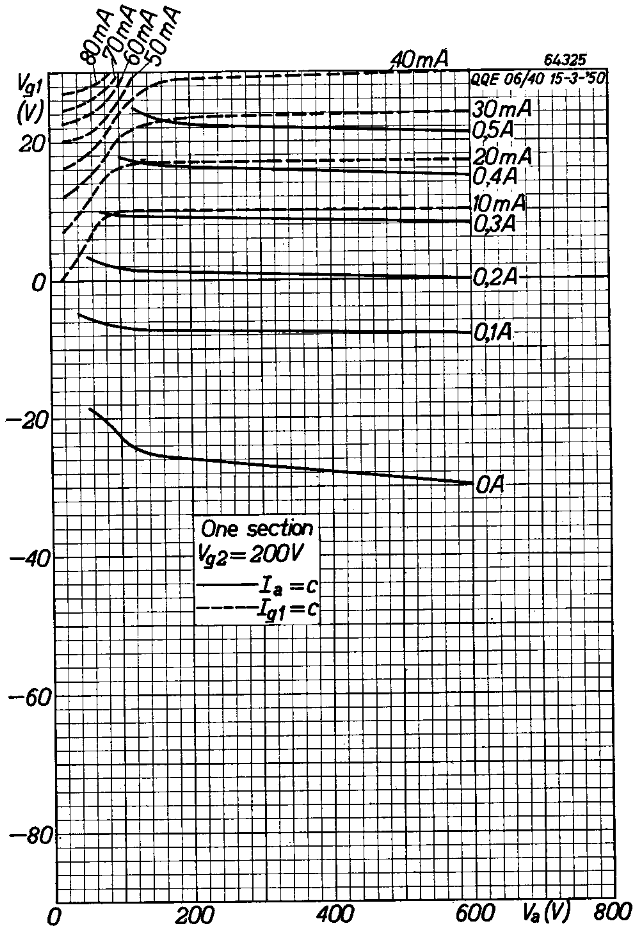


Fig. 6. Control-grid voltage V_{g1} as a function of the anode voltage V_a at constant anode current I_a and constant control-grid current I_{g1} for a screen-grid voltage V_{g2} of 200 V.

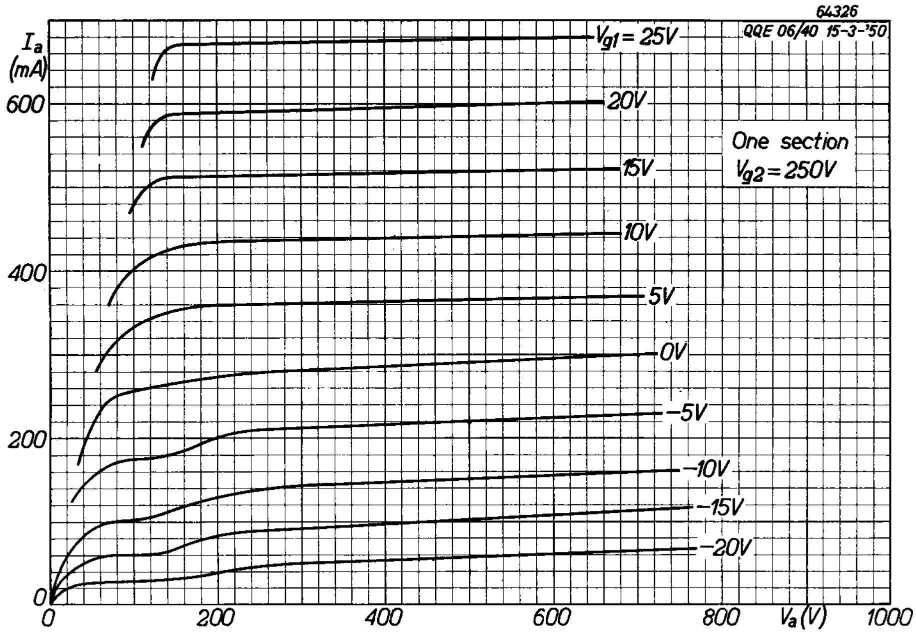


Fig. 7. Anode current I_a as a function of the anode voltage V_a for a screen-grid voltage V_{g2} of 250 V with the control-grid voltage as parameter.

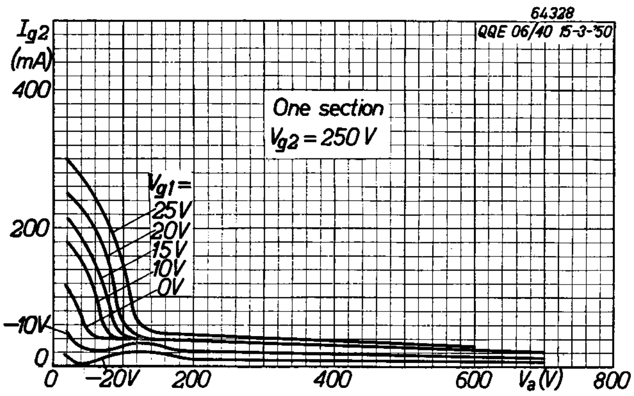


Fig. 8. Screen-grid current I_{g2} as a function of the anode voltage V_a for a screen-grid voltage V_{g2} of 250 V with the control-grid voltage as parameter.

R.F. CLASS C FREQUENCY TRIPLER (two sections in push-pull)

Wavelength	λ	6/2	6/2	4/1.3 m
Frequency	f	50/150	50/150	75/225 Mc/s
Anode voltage	V_a	500	400	400 V
Grid bias	V_{g1}	—150	—150	—150 V
Screen-grid voltage	V_{g2}	250	250	250 V
Anode current	I_a	2x60	2x73	2x65 mA
Grid current	I_{g1}	2x3	2x2.5	2x2.5 mA
Screen-grid current	I_{g2}	10	16	20 mA
Input voltage peak-to-peak	$V_{g1g1'p}$	360	360	360 V
Screen-grid dissipation	W_{g2}	2.5	4	5 W
Anode supply power	W_{ia}	2x30	2x29	2x26 W
Anode dissipation	W_a	2x20	2x20	2x20 W
Output	W_o	20	18	12 W
Efficiency	η	33	31	23 %

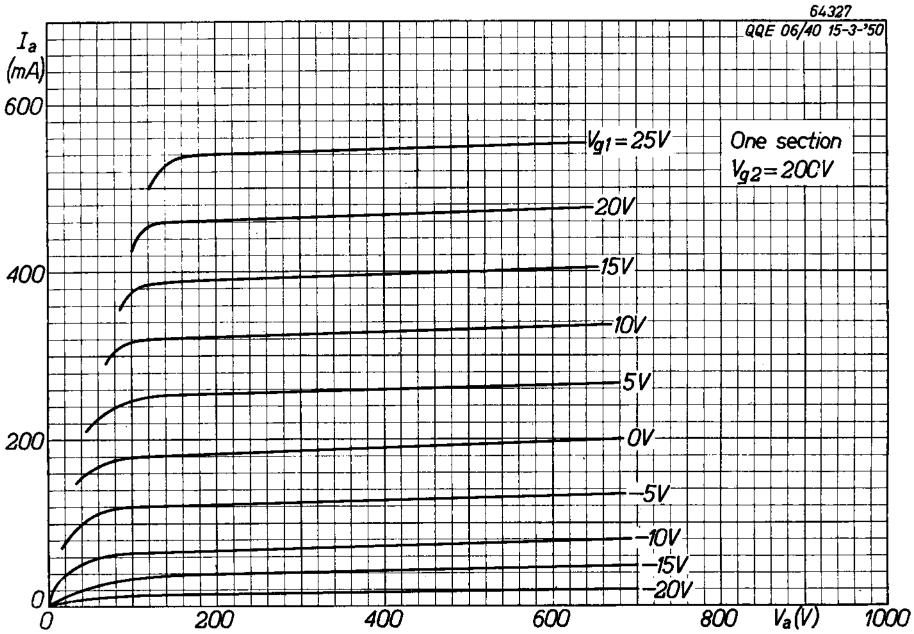


Fig. 9. Anode current I_a as a function of the anode voltage V_a for a screen-grid voltage V_{g2} of 200 V with the control-grid voltage as parameter.

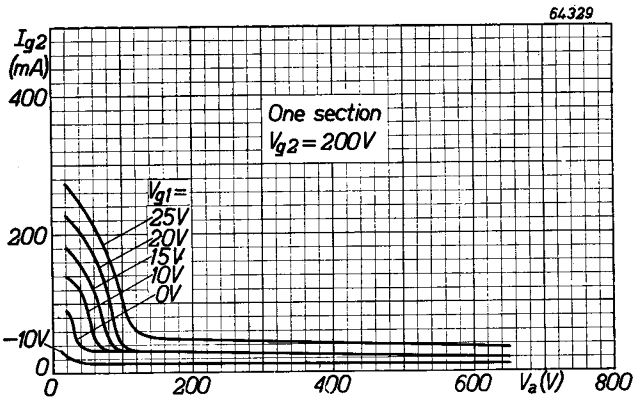


Fig. 10. Screen-grid current I_{g2} as a function of the anode voltage V_a for a screen-grid voltage V_{g2} of 200 V with the control-grid voltage as parameter.

A.F. AMPLIFIER AND MODULATOR IN CLASS B (two sections in push-pull)

Anode voltage	V_a	600		450		V
Grid bias	V_{g1}	—25		—23		V
Screen-grid voltage	V_{g2}	250		250		V
Load between anodes	R_{aa}	8		4.4		kΩ
Input voltage peak-to-peak	$V_{g1g1}{}'_{p}$	0	56	0	53	V
Anode current	I_a	2x17.5	2x84	2x33.5	2x100	mA
Grid current	I_{g1}	0	2x0.6	0	2x1	mA
Screen-grid current	I_{g2}	4	27	8	26	mA
Driving power	W_{ig1}	0	2x15	0	2x24	mW
Screen-grid dissipation	W_{g2}	1	6.8	2	6.5	W
Anode supply power	W_{ia}	2x10.5	2x50.5	2x15	2x45	W
Anode dissipation	W_a	2x10.5	2x14	2x15	2x18	W
Output	W_o	0	73	0	54	W
Total distortion	d_{tot}	—	5	—	2.0	%
Efficiency	η	—	72	—	60	%

LIMITING VALUES

Anode voltage	V_a	max.	600 V
Screen-grid voltage	V_{g2}	max.	250 V
Negative grid voltage	$-V_{g1}$	max.	175 V
Voltage between cathode and heater	V_{kf}	max.	100 V
Anode current	I_a	max.	2x110 mA
Cathode current	I_k	max.	2x120 mA
Peak cathode current	I_{kp}	max.	2x700 mA
Anode dissipation	W_a	max.	2x20 W
Screen-grid dissipation	W_{g2}	max.	7 W
Grid dissipation	W_{g1}	max.	2x1 W
External resistance between grid and cathode			
with fixed bias	R_{g1}	max.	50 kΩ
with automatic bias	R_{g1}	max.	100 kΩ
Temperature of pins and bulb		max.	180 °C

In cases where the maximum permissible temperature is likely to be exceeded, as would normally be the case at frequencies above 150 Mc/s with full ratings, a flow of air has to be directed onto the anode seals and the bulb.

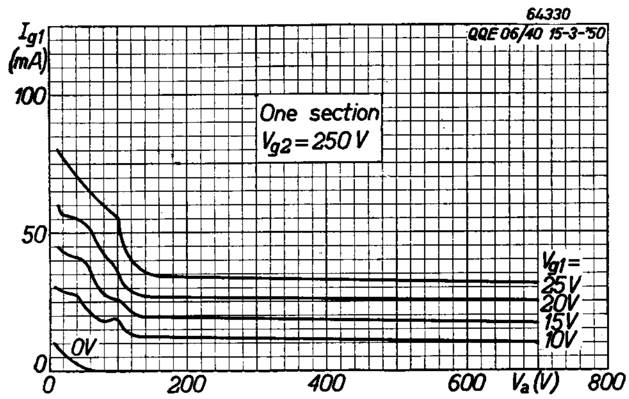


Fig. 11. Control-grid current I_{g1} as a function of the anode voltage V_a for a screen-grid voltage V_{g2} of 250 V with the control-grid voltage as parameter.

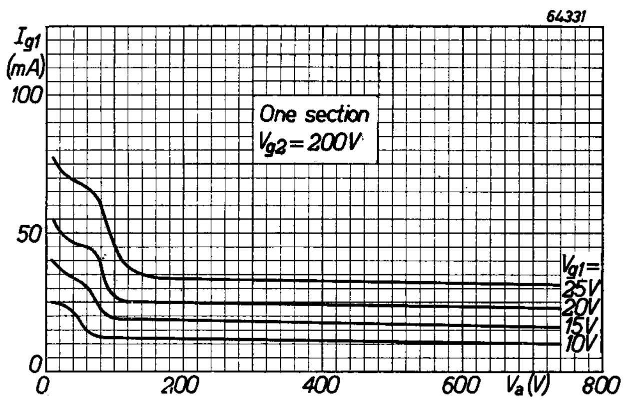


Fig. 12. Control-grid current I_{g1} as a function of the anode voltage V_a for a screen-grid voltage V_{g2} of 200 V with the control-grid voltage as parameter.

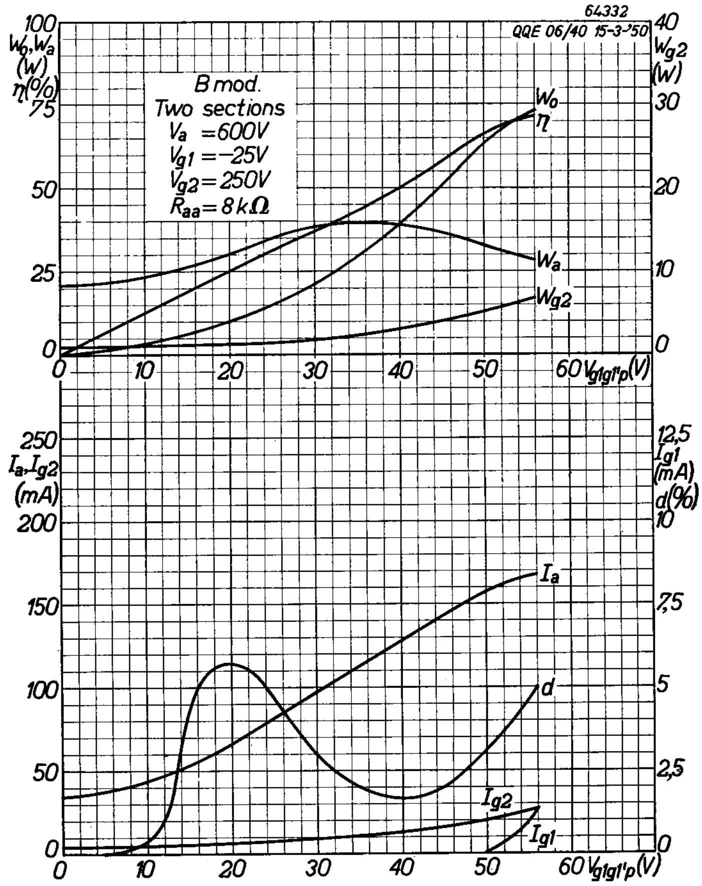


Fig. 13. Curves showing the performance as A.F. amplifier and modulator in push-pull class B. Anode current I_a, screen-grid current I_{g2}, control-grid current I_{g1}, output power W_o, anode dissipation W_a, screen-grid dissipation W_{g2}, distortion d_{tot} and efficiency η are plotted against the peak-to-peak value of the input voltage.

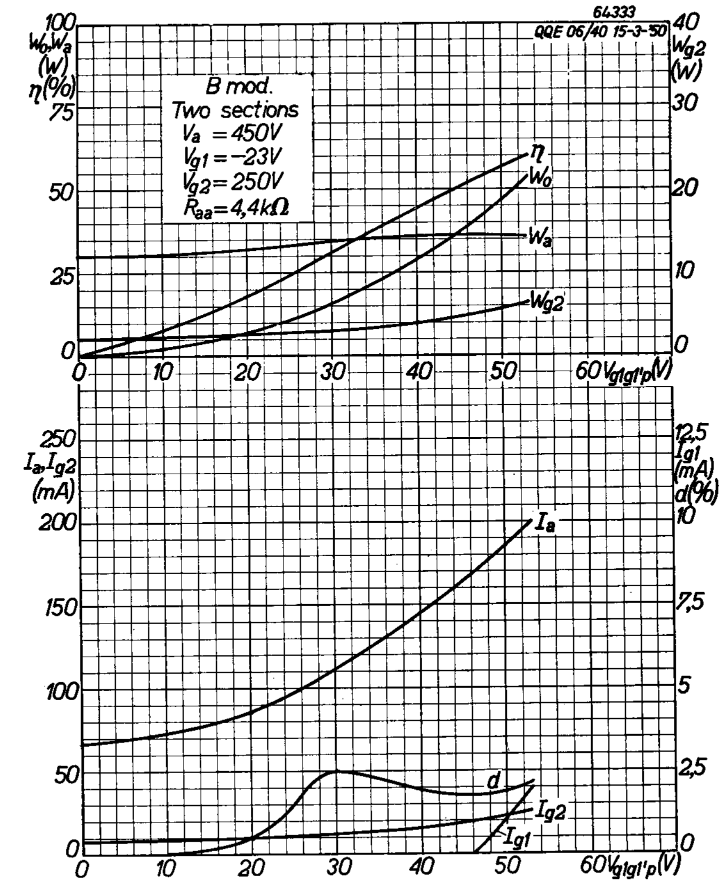
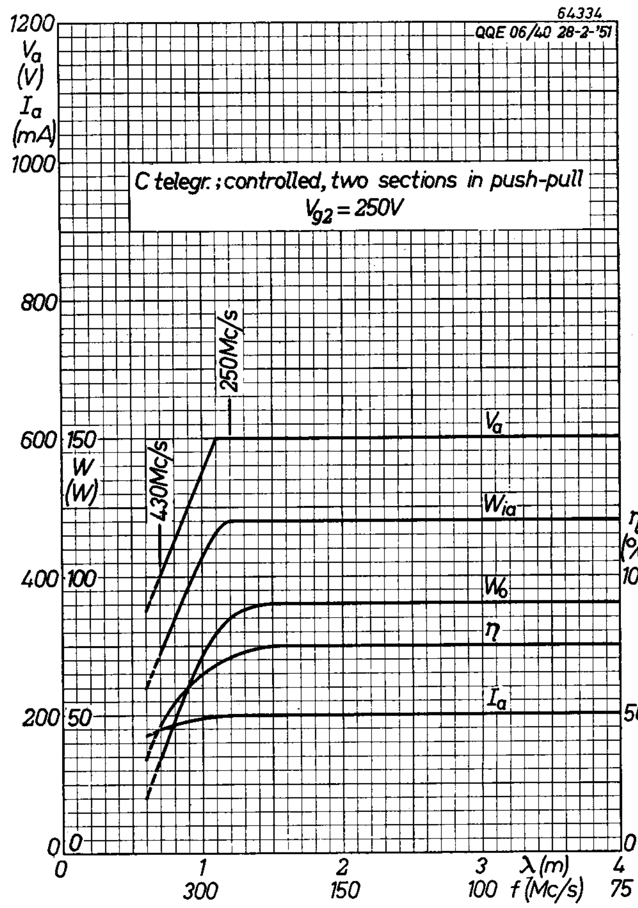


Fig. 14. **The same curves as in fig. 13 but for reduced anode supply voltage.**

Fig. 15. **Anode supply power W_{ia}, output W_o, permissible anode voltage V_a, efficiency η and anode current I_a as functions of frequency and wavelength for the two sections in push-pull under C telegraphy operating conditions.**



A 30 WATT POWER AMPLIFIER AT 430 Mc/s WITH QQE 06/40

The double tetrode QQE 06/40 is highly suitable for designing transmitters with relatively high efficiency for radio communication over short distances at frequencies up to 500 Mc/s and higher. The purpose of this description is not to describe in detail a complete transmitter but to underline the possibilities of the QQE 06/40 in this field on the basis of a simple experimental set-up composed of an oscillator stage, a tripler stage and a final amplifier. This set-up, photographs of which are given in figs 16 and 17, is therefore not to be regarded as a ready-made model but as a guide for the electrical design of this type of equipment.

THE CIRCUIT DIAGRAM

The circuit diagram is given in fig. 21. The sequence of the three above-mentioned stages in the circuit diagram corresponds to the sequence of the three compartments shown in figs 16 and 17.

In the oscillator stage a small double tetrode QQC 04/15 [1]) is used, operating at 143.3 Mc/s. In the photographs only the socket of this tube is visible. The frequency is raised to 430 Mc/s by the tripler stage, using the QQE 06/40 with both sections connected in push-pull. Oscillator and tripler stages are coupled by means of a conventional tuned R.F. transformer.

The output stage operating at 430 Mc/s is likewise equipped with a QQE 06/40, the two sections being also connected in push-pull. The coupling between this stage and the tripler stage consists of two inductively coupled tuned transmission lines, seen in the middle compartment. The load consists in this case of an incandescent lamp, inductively coupled to a tuned transmission line in the anode circuit of the output stage.

The useful output obtained with this transmitter amounts to 30 W. A driving power of about 8 W is required to drive the output stage, this being delivered by the tripler. The tripler in turn requires a driving power of about 5 W, which is provided by the oscillator.

[1]) A full description of this tube is given in the Bulletin "QQC 04/15 Double Tetrode for Mobile Transmitting Equipment".

VOLTAGES AND CURRENTS

The voltages and currents of both sections together of the various tubes are given below. The sequence in the circuit diagram is from left to right.

QQC 04/15 oscillator	
Anode voltage	180 V
Screen-grid voltage	125 V
Anode current	60 mA
Screen-grid current	2 mA
QQE 06/40 tripler	
Anode voltage	250 V
Screen-grid voltage	150 V
Negative grid voltage	—150 V
Anode current	80 mA
Screen-grid current	3 mA
Grid current	3 mA
QQE 06/40 amplifier	
Anode voltage	400 V
Screen-grid voltage	200 V
Negative grid voltage	— 50 V
Anode current	180 mA
Screen-grid current	10 mA
Grid current	5 mA
Heater voltage of all tubes	6.3 V

QQC 04/15: heater voltage between pins 1 and 5
QQE 06/40: heater voltage between pins 5 and 1-7.

DETAILS OF THE DESIGN

Coupling of stages

The choice of the interstage couplings is governed by the consideration that at 300 Mc/s the input of the QQE 06/40 with the control grids interconnected is in resonance. For higher frequencies the most effective method is to mount series capacitors on the grid connections of the tube socket. When the stages are inductively coupled, as is the case between the tripler and the output stage, this method has the advantage that no D.C. connections to the tuned transmission lines are required. As can be seen from the circuit diagram, the bias of the final stage is applied via a centre-tapped choke.

Output circuits

Connections to the anode pins of the QQE 06/40 can be made by means of two clips, type 40623, fig. 18. Up to 300 Mc/s, where a flexible connection can be successfully applied, it is advisable to use these clips. They increase the surface of the anode connections and thus contribute towards effective cooling of the anode pins. Above 300 Mc/s, where tuned transmission lines with the least possible discontinuities are to be preferred, this clip can

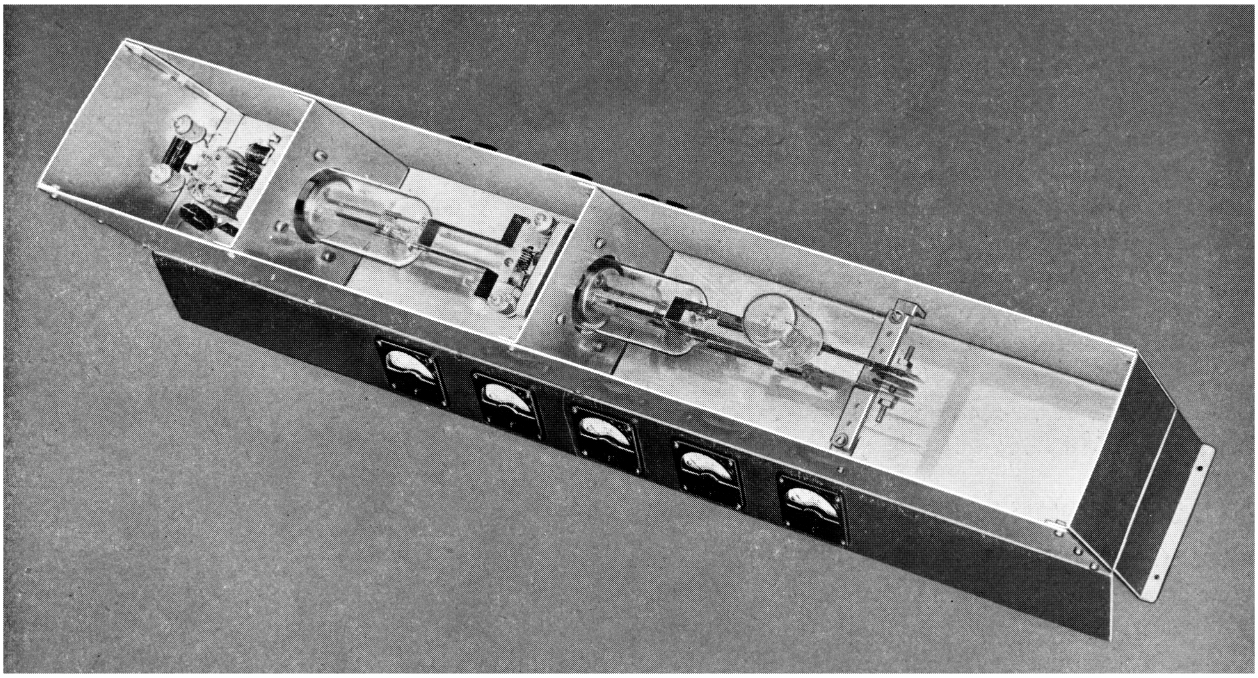


Fig. 16. Photograph of the 30 W power amplifier with QQE 06/40 at 430 Mc/s.
Left compartment: oscillator stage with QQC 04/15.
Middle compartment: tripler stage with QQE 06/40.
Right compartment: final amplifier with QQE 06/40.

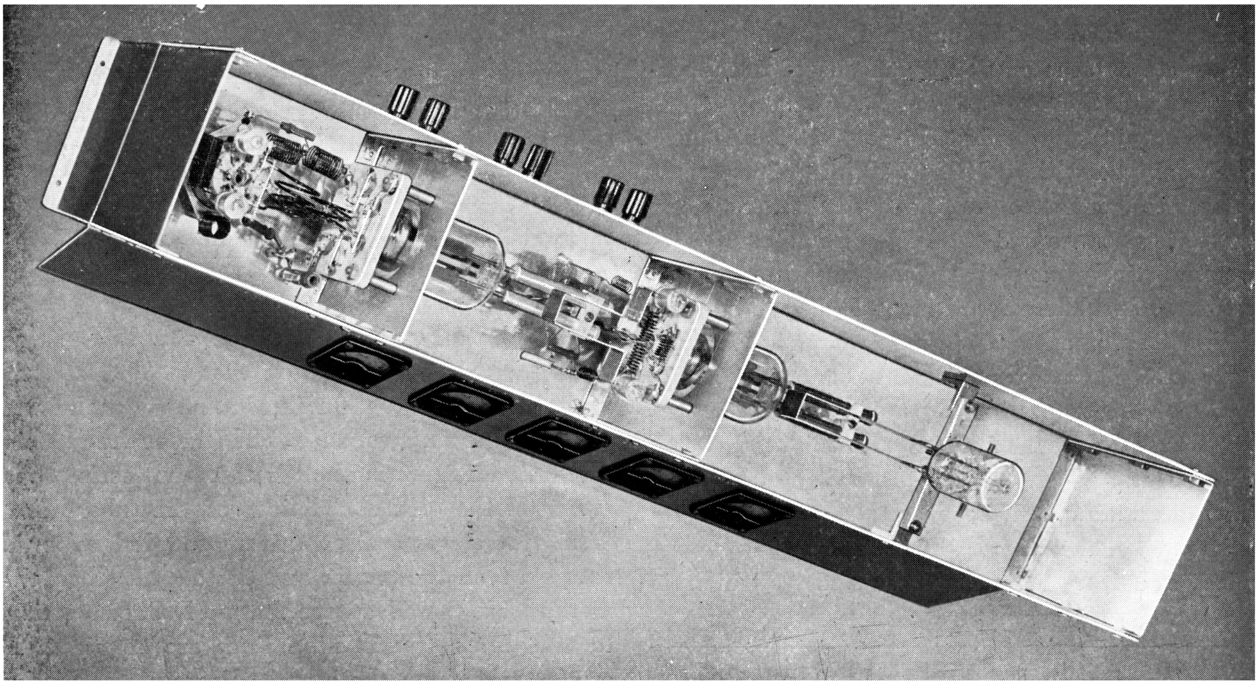


Fig. 17. Another view of the power amplifier with driving stages.

still by used in conjunction with a copper tube (6x8 mm) of a length determined by the desired frequency. A sketch of the elongated clip is given in fig. 19, whilst the application in the output circuits of the tripler and the final amplifeir is illustrated by fig. 17.

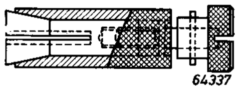


Fig. 18. Anode clip type 40623.

Tuning of the transmission lines is effected by a bridge sliding over the copper tubes of the elongated anode clips. A sketch of this bridge is given in fig. 20. In order to reduce losses it is advisable to plate both the transmission lines and the sliding bridge with silver.

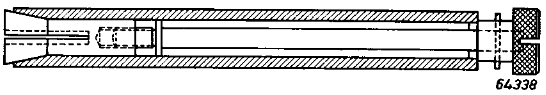


Fig. 19. Example of elongated anode clip for use with tuned transmission lines.

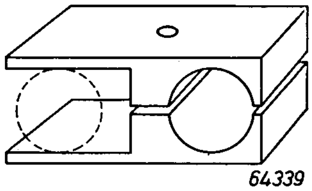


Fig. 20. Sketch of sliding bridge.

Decoupling

a. *Below* 150 Mc/s

At frequencies below 150 Mc/s it suffices to use the shortest possible connections for capacitively earthing all electrodes which should not carry R.F. voltage. In order to avoid parasitic oscillation via the screen grid it is recommended not to earth the screen grid capacitively but to use a series resistor.

b. *Above* 150 Mc/s

At these high frequencies there is a risk of current maxima arising in the internal electrode leads. R.F. voltages will then be induced in the cathode lead, the heater leads or the screen-grid lead. For

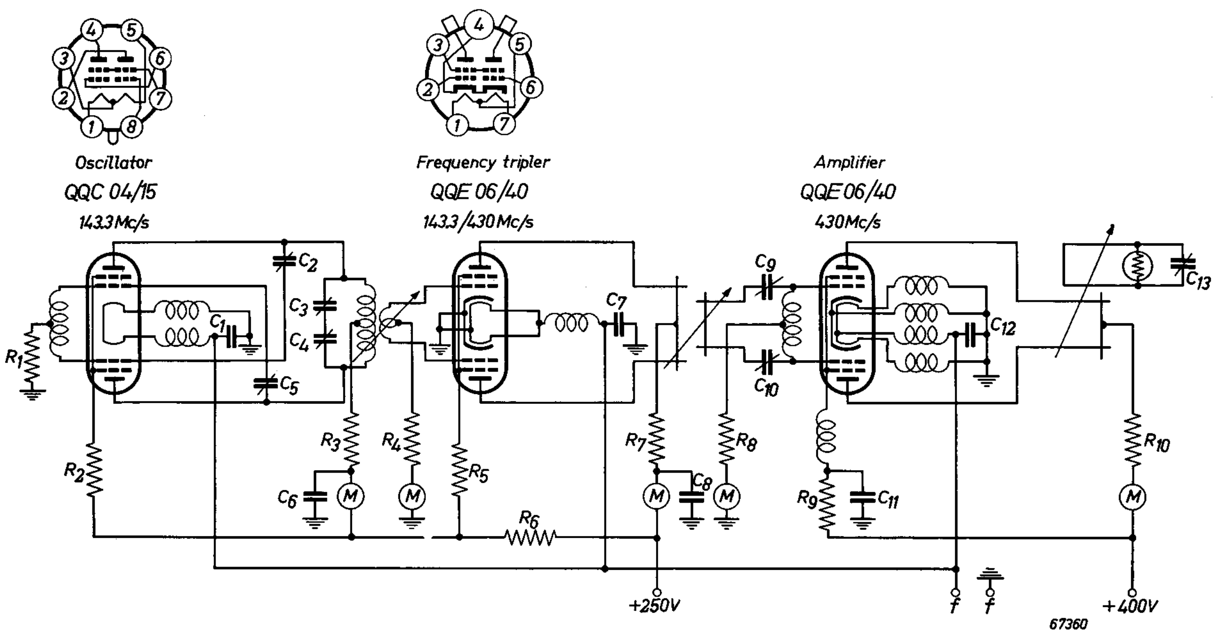


Fig. 21. Circuit diagram of the 30 W power amplifier with QQE 06/40.

The resistors and capacitors used in this circuit have the following values (for inductors and parallel lines see text):

R_1 = 27 kΩ ¼ W	R_7 = 100 Ω 1 W	C_3 = 10 pF var.	C_9 = 5 pF var.
R_2 = 27 kΩ ½ W	R_8 = 10 kΩ ½ W	C_4 = 10 pF var.	C_{10} = 5 pF var.
R_3 = 100 Ω ½ W	R_9 = 20 kΩ 2 W	C_5 = 30 pF var.	C_{11} = 100 pF
R_4 = 50 kΩ ½ W	R_{10} = 100 Ω 5 W	C_6 = 100 pF	C_{12} = 100 pF
R_5 = 10 kΩ ½ W	C_1 = 100 pF	C_7 = 100 pF	C_{13} = 5 pF var.
R_6 = 1 kΩ 5 W	C_2 = 30 pF var.	C_8 = 100 pF	M = mA-meter

that reason it is necessary to insert filters in the supply leads. These decoupling filters consist of a ¼ λ choke with a capacitor of 100 pF to earth.

In fig. 22 the socket type 40202 and the way of decoupling the electrodes is schematically shown. The screen grid g_2 and the centre tap f_c of the heater are decoupled by filters as indicated above.

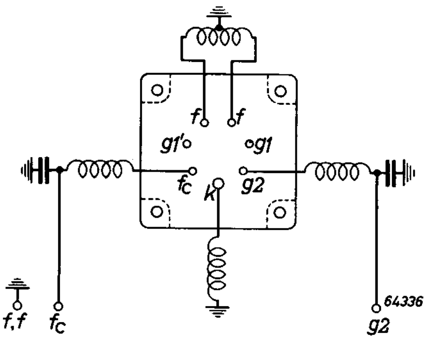


Fig. 22. Method of decoupling the electrodes of socket type 40202.

The two ends of the heater, if connected for 6.3 V supply, are interconnected by a ½ λ choke. The centre tap of this choke is connected to earth. This choke also serves for detuning the heater from the operating frequency, as otherwise, at certain frequencies, part of the driving power might be dissipated in the heater. The absorption of R.F. energy by the heater can be noticed by a rise in temperature of the cathode. It is then necessary to alter the self-inductance of the coil between the ends of the heater.

Inadequate or faulty decoupling of the screen grid may likewise give rise to dissipation of driving power in the screen-grid supply resistance. The series resistor lead must not carry any R.F. voltage with respect to earth.

The decoupling capacitors must be connected directly to the chassis. It is not advisable to use for the earthing of these capacitors the screws by means of which the tube socket is fixed to the chassis. Induction of R.F. voltages from the input circuit on the decoupling lines is thereby avoided.

Screening

The screen inside the tube, indicated by S_1 in fig. 3, and the part of the chassis on which the tube is mounted must be placed in one plane. The tube socket must therefore be mounted about 20 mm below the chassis level. This is illustrated by figs 16 and 17, where the screen inside the tube is clearly seen. Since at high frequencies the radiation losses increase considerably, it is advisable to screen at least both the input and the output circuits, or rather to enclose the whole transmitter in a metal screening box.