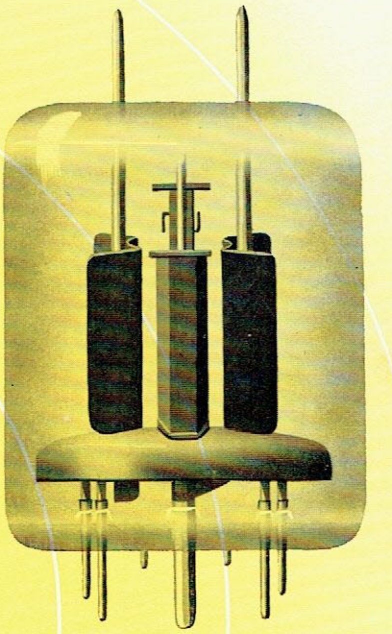
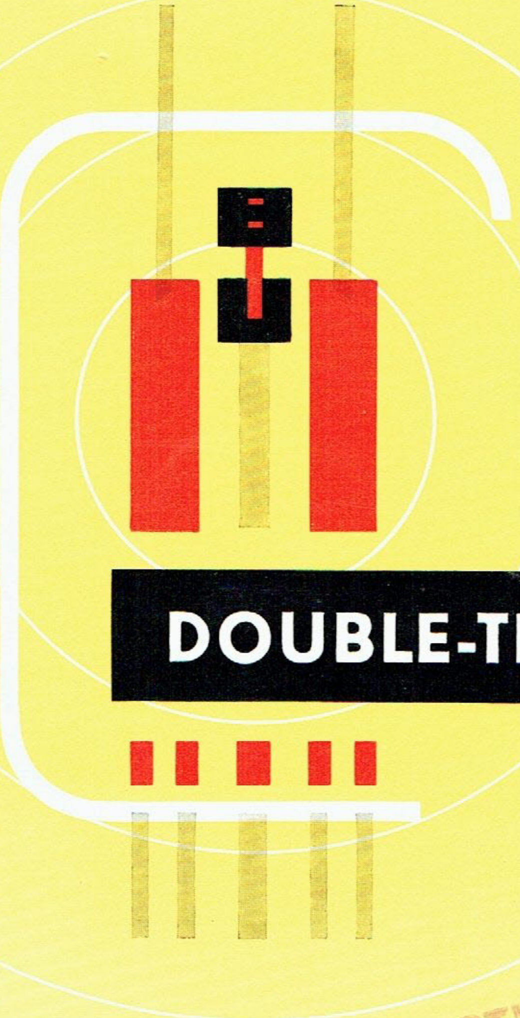
PHILIPS





DOUBLE-TETRODE QQE 03-20

PHILIPS ELECTRON TUBE DIVISION

Preface

R.F. Amplifiers in mobile and small transmitters, operating at frequencies higher than 100 Mc/s, preferably comprise push-pull circuits. These circuits offer the advantages of low input and output capacitances and low radiation. The supply lines are moreover free from R.C. voltages. In order to minimize the power drain from the supply units, and to keep the number of stages and hence the tube complement in the transmitter small, tetrodes with a high stage gain are the most interesting proposition for this purpose.

The two tube systems required for push-pull operation may be mounted in a single envelope, which offers the possibility of keeping the inductances between the cathodes and screen grids low. These inductances can be reduced to an extreme limit when the two tube systems are provided with a common cathode and a common screen grid. This construction moreover makes it possible to use a very simple system for internal neutralization.

The double tetrodes QQE 06/40, QQE 03/20 and QQE 03/12 have been developed accordingly. This Bulletin deals with the type QQE 03/20 which has already been widely and successfully used after its introduction some years ago.

The QQE 03/20 with its hard-glass envelope gives excellent and stable performance as an R.F. amplifier in the frequency range up to 600 Mc/s and can be operated as a frequency multiplier up to 1000 Mc/s. Its high stage gain, internal neutralization and rigid construction render it very suitable in mobile transmitters, while it is also widely used in pre-stages of larger stationary transmitters.

Complete technical data, including operating conditions for use as a push-pull class B modulator and frequency tripler are given in this Bulletin, together with some practical circuits. The RETMA designation 6252 has been alotted to this tube; the service designation is CV 2799.

Contents

QQE 03/20 DOUBLE TETRODE

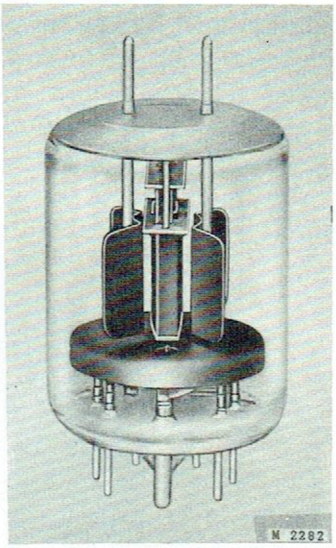


Fig.1. The QQE 03/20

The QQE 03/20 is a transmitting double tetrode especially made for use in mobile equipment, but owing to its attractive properties it is also a useful tube in the pre-stages of larger stationary transmitters. It can be used as an R.F. amplifier and oscillator tube, as a frequency trebler or as an A.F. power output or modulator tube.

Under class C telegraphy conditions one QQE 03/20 can give an output of 48 W at 200 Mc/s at an efficiency of 80%. At 400 Mc/s an output of 24 W may be obtained at an efficiency of 60%, whereas at 600 Mc/s an output of 20 W can be reached at an efficiency of 50%. These favourable results are to be attributed to features given to the QQE 03/20 so as to meet the special requirements imposed by the frequency range between 200 and 600 Mc/s. This, however, does not mean that the tube should not be used at lower or even higher frequencies.

Transmitting tubes with two electrode systems have already been known for some 25 years. In the former designs two complete tube systems were mounted side by side in one envelope and the electrodes not carrying any R.F. voltage (the cathodes and the screen grids) were interconnected in pairs by short connecting strips. Similar to the two control grids and the anodes, the centres (neutral points) of the interconnections were passed through the envelope. A difficulty arising with these tubes is due to the self-inductance formed by the interconnections of the cathodes and the screen grids. At very high frequencies the influence of these self-inductances cannot be ignored. Due to the inductance between the screen grids the resistance is zero only at the resonant frequency of the screen-grid capacitances and the inductance of the interconnection. At lower frequencies the resistance becomes negative and may give rise to instability and even to self-oscillation, whereas at higher frequencies the resistance is positive and causes additional damping. To avoid this phenomenon, some form of neutralization must be applied, which is usually achieved by connecting capacitors between the anode of one tube system and the control grid of the other, when the transmitter is to be used at a lower frequency than the resonant frequency; when the operating frequency exceeds the resonant frequency neutralizing capacitors are connected between the anode and the control grid of the same tube system. An additional effect is that the leads to the neutralizing capacitors have a certain length and consequently a certain inductance, so that neutralization is only accurate for a restricted frequency range and may have to be readjusted when the transmitter is used in another range.

The inductance of the connecting strip between the cathodes has the effect of a negative feedback and constitutes a positive component of input damping. Both effects lead to an increase of the required driving power to obtain a given output.

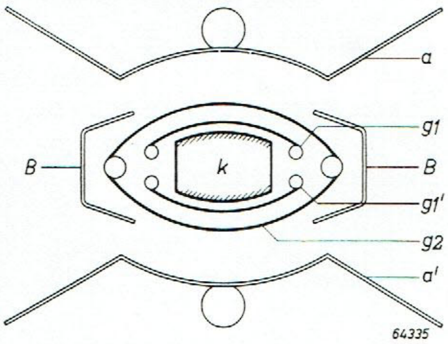


Fig.2. Horizontal cross section of the electrode system of the QQE 03/20. The indications refer to Fig.3.

The measures taken in the design of the QQE 03/20 to avoid these complications will be discussed with reference to Figs 2 and 3.

The QQE 03/20 is provided with one single indirectly heated cathode, the cross section of which is roughly rectangular with slightly convex sides. Only the long sides are coated with an emissive layer, so that the tube has in fact two cathode surfaces, interconnected by the shorter sides of the rectangular cathode body. The inductance of these short and wide "connecting strips" is so low that even at frequencies of 600 Mc/s the effect of self-inductance in the cathode interconnections is negligible.

Two control grids are placed at a short distance of the cathode facing its emitting surfaces. The cathode and the two control grids are surrounded by one single screen grid, which is conventionally wound on two supporting rods, so that the construction with two separate screen grids and their interconnection, and hence the effect of the self-inductance of screen-grid leads, is avoided. The screen grid and the control grids are "shadowed", which means that the screen-grid wires are placed behind the control-grid wires in the direction of the electron flow. This measure promotes the formation of a radial beam and the correct space charge conditions between the anodes and the screen grid. Another advantage of shadowed grids is that the number of electrons impinging on the screen grid is reduced, so that the screen-grid current is relatively low.

Due to this construction the resonant frequency of the screen-grid capacitance and the inductance of the interconnections is always higher than the frequency at which the tube can be successfully used, and which is limited by its dimensions. This implies that the tube would have a tendency to instability and oscillation - also due to the anode-to-control-grid capacitance - if no internal neutralization were applied. Neutralization has been obtained by connecting small bent wires to the control-grid rods; these wires form a capacitor with the anode rod of the other tube section. This form of neutralization offers the advantage of avoiding the long connecting wires necessary with external neutralization, so that it is efficient over a very wide frequency range. The stability of the QQE 03/20 is so high that the tube cannot be made to oscillate unless feedback is applied.

The anodes are supported by sturdy rods, which are sealed into the top of the hard-glass bulb, and also constitute the anode connecting pins. The losses are thus reduced to the utmost minimum. The anodes are made of molybdenum coated with zirconium, which serves the following purposes. Firstly it reduces the secondary-emission coefficient of the molybdenum; secondly it improves the heat radiation, and thirdly it acts as a very active getter, keeping the vacuum high, even after a long period of tube life.

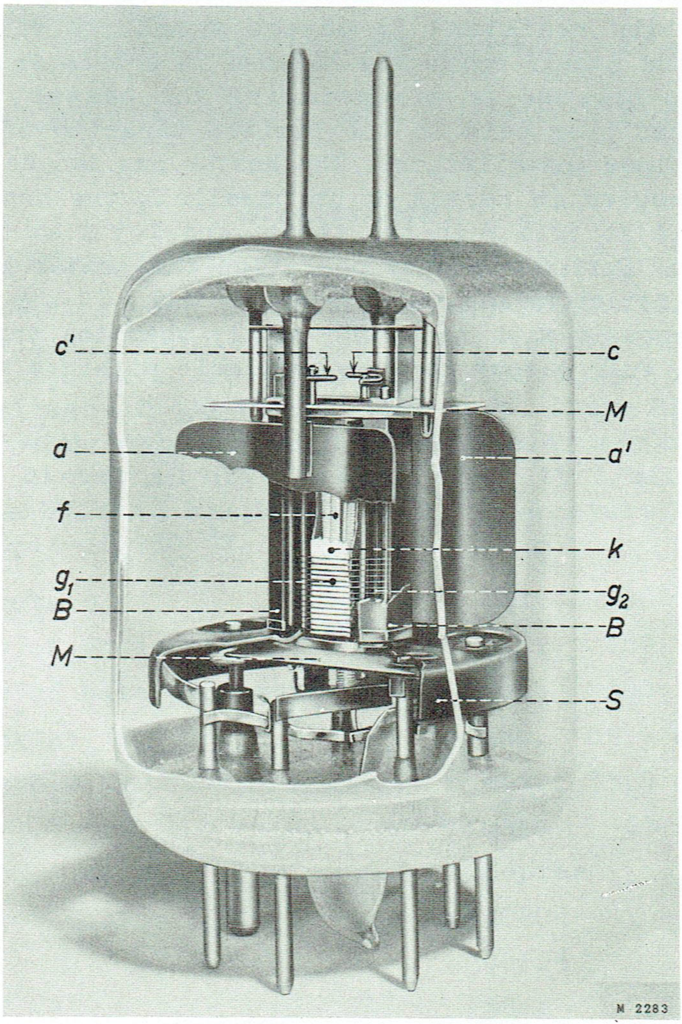


Fig.3. Photograph of a cut-open QQE 03/20. The heater *f* is visible; the cathode *k*, the control grid g_1 and the screen grid g_2 are overlapping, the grid rod of g_1'is also visible. The anodes are indicated with *a* and *a'* respectively. Neutralizing capacitors are formed by the bent wires c and c', which are connected to the grid rods of g_1' and g_1 respectively and placed opposite the anode rods of *a* and *a'*. The beam plates *B* are connected to the large lower screen S, the mica spacers are indicated by *M*.

An advantage of the special construction of the QQE 03/20 is that the internal capacitances are small. The input capacitance of each section is 7.0 pF, and the output capacitance is only 2.6 pF. In push-pull connection the input capacitance is 4.4 pF and the output capacitance 1.6 pF.

On both sides of the screen-grid beam-plates are mounted. These are U-shaped, and placed around the screen-grid supporting rods for constructional reasons. They are connected to the cathode, and serve to prevent deflection of the electrons from the shortest path to the anodes and to reduce losses due to transit time effects. Moreover, they assist in obtaining the correct space charge conditions between the screen grid and the anodes, so that the secondary electrons released from the anode, cannot reach the screen grid even when the instantaneous value of the anode voltage is low.

Owing to the low inductance of the inter-cathode connection and the short internal cathode lead, only little driving power is required.

The exceptionally rigid construction of the electrode system makes the tube resistant to severe shock and vibration, so that it lends itself eminently for use in mobile installations, the more so because in dimensioning the heater, particular attention has been paid to the limited capacity of the supply sources in these installations. The heater has two sections which can be connected in series or in parallel, the heater current being 0.65 A at 12.6 V in the first, and 1.3 A at 6.3 V in the latter case. During stand-by operation the heater power can be reduced by switching off one heater section. It may be switched on simultaneously with the anode supply when the transmitter is to be used. Full output is then available within a few seconds.

TECHNICAL DATA

Electrical

Cathode: Indirectly heated, oxide-coated;
series or parallel supply.

Heater voltage [1]	6.3	12.6 V
Heater current	1.3	0.65 A
pins	5-(1+7)	1-7

Direct interelectrode capacitances

	One system	push-pull
Output capacitance	2.6	1.6 µµF
Input capacitance	7.0	4.4 µµF

Amplification factor (each unit)

grid No. 2 to grid No. 1 (anode current is 20 mA) 8

Mutual conductance (each unit; anode current is 20 mA) 2.5 mA/V

Mechanical

Mounting position: Arbitrary

Cooling: Radiation and convection. Generally natural cooling is sufficient with an anode voltage of 600 V up to 150 Mc/s, of 500 V up to 200 Mc/s, or an anode voltage of 300 V up to 430 Mc/s. Above these limits or with high ambient temperatures it may be necessary to direct an air flow of about 15 l/min on top of the bulb to keep the seal temperature within the limit of 180 °C.

Bulb temperature:	max. 180 °C
Temperature of anode seals:	max. 180 °C
Temperature of base pin seals:	max. 180 °C
Overall length:	max. 85.5 mm
Seated length:	max. 73.5 mm
Diameter:	max. 46 mm
Base:	Septar
Socket:	40202
Clips:	40623
Net weight:	55 g
Shipping weight:	140 g

---

[1]) The tube may be used with only half the heater energized during stand-by period of a transmitter in order to reduce heater current consumption during this time.

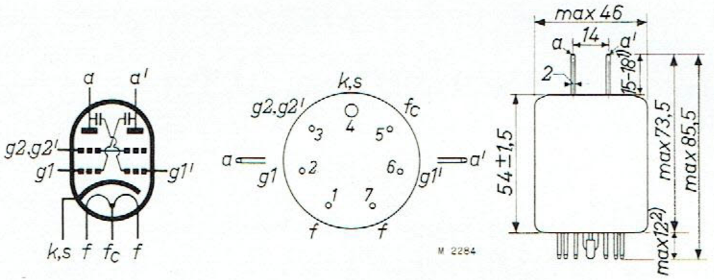


Fig.4. Base connections and dimensions in mm.

TABLE OF OBTAINABLE POWER

Two systems

Frequency	H.F. class C			
	Telegraphy		Anode and screen-grid modulation	
Mc/s	anode voltage (volts)	output power (watts)	anode voltage (volts)	output power (watts)
200	600 400 300 200	48 30 21 13	500 300	31 17
400	400 300 200	24 17 11	300	13
600	400	20		

Frequency	H.F. class C frequency trebler	
Mc/s	anode voltage (volts)	output power (watts)
67/200	300	10
133/400	300	8

A.F. class B amplifier or modulator	
anode voltage (volts)	output power (watts)
500	23.5
300	13.2

Limiting values and Operating conditions

H.F. CLASS C TELEGRAPHY

LIMITING VALUES

Anode voltage	max.	600 V
Anode dissipation	max.	2x10 W
Screen-grid voltage	max.	250 W
Screen-grid dissipation	max.	2x1.5 W
Control-grid voltage	max.	-75 V
Control-grid current	max.	2x2.5 mA
Cathode current	max.	2x55 mA
Resistance between control grid and cathode (fixed bias)	max.	50 kΩ
Resistance between control grid and cathode (automatic bias)	max.	100 kΩ
Voltage between cathode and heater	max.	100 V

OPERATING CONDITIONS

Frequency	200	200	200	200	Mc/s
Anode voltage	600	400	300	200	V
Screen-grid voltage	250	250	250	200	V
Control-grid bias	-60	-50	-40	-30	V
Anode current	2x50	2x50	2x50	2x50	mA
Screen-grid current	2x4	2x4	2x4.5	2x4	mA
Control-grid current	2x0.7	2x0.7	2x0.7	2x1	mA
Anode input power	2x30	2x20	2x15	2x10	W
Anode dissipation	2x6	2x5	2x4.5	2x3.5	W
Screen-grid dissipation	2x1.0	2x1.0	2x1.1	2x0.8	W
Driving power	1.5	1	<1	<1	W
Tube output	48	30	21	13	W
Efficiency	80	75	70	65	%

Frequency	400	400	400	600	Mc/s
Anode voltage	400	300	200	400	V
Screen-grid voltage	250	250	200	250	V
Control-grid bias	-50	-40	-30	-50	V
Anode current	2x50	2x50	2x50	2x50	mA
Screen-grid current	2x2.5	2x2.5	2x3.0	2x2.5	mA
Control-grid current	2x0.7	2x0.6	2x0.5	2x0.7	mA
Anode input power	2x20	2x15	2x10	2x20	W
Anode dissipation	2x8	2x6.5	2x4.5	2x10	W
Screen-grid dissipation	2x0.6	2x0.6	2x0.6	2x0.63	W
Driving power	2	1.5	1		W
Tube output	24	17	11	20	W
Efficiency	60	57	55	50	%

H.F. CLASS C ANODE AND SCREEN-GRID MODULATION

LIMITING VALUES

Anode voltage	max.	500 V
Anode dissipation	max.	2x10 W
Screen-grid voltage	max.	250 V
Screen-grid dissipation	max.	2x1.5 W
Control-grid voltage	max.	-100 V
Cathode current	max.	2x50 mA
Control-grid current	max.	2x2.5 mA
Voltage between cathode and heater	max.	100 V

OPERATING CONDITIONS

Frequency	200	200	400 Mc/s
Anode voltage	500	300	300 V
Screen-grid voltage	250	250	250 V
Control-grid bias	-80	-50	-50 V
Anode current	2x40	2x40	2x40 mA
Screen-grid current	2x4	2x4	2x3 mA
Control-grid current	2x1.0	2x1.0	2x1.0 mA
Anode input power	2x20	2x12	2x12 W
Anode dissipation	2x4.5	2x3.5	2x5.5 W
Screen-grid dissipation	2x1	2x1	2x0.75 W
Driving power	2x5	2x2.5	W
Tube output	31	17	13 W
Efficiency	77.5	71	54 %
Modulation	100	100	100 %
Modulation power	20	12	12 W

H.F. CLASS C FREQUENCY TREBLER

LIMITING VALUES

Anode voltage	max.	600 V
Anode dissipation	max.	2x10 W
Screen-grid voltage	max.	250 V
Screen-grid dissipation	max.	2x1.5 W
Control-grid voltage	max.	-200 V
Cathode current	max.	2x50 mA
Control-grid current	max.	2x2.5 mA
Resistance between control grid and cathode (fixed bias)	max.	50 kΩ
Resistance between control grid and cathode (automatic bias)	max.	100 kΩ
Voltage between cathode and heater	max.	100 V

OPERATING CONDITIONS

Frequency.	66.7/200	133/400	Mc/s
Anode voltage.	300	300	V
Screen-grid voltage.	250	250	V
Control-grid voltage	-175	-175	V
Anode current.	2x45	2x45	mA
Screen-grid current.	2x3.0	2x2.8	mA
Control-grid current	2x1.5	2x1.2	mA
Anode input power.	2x13.5	2x13.5	W
Anode dissipation.	2x8.5	2x9.5	W
Screen-grid dissipation.	2x0.75	2x0.7	W
Driving power.	2x1	2x2	W
Tube output.	10	8.0	W
Efficiency	37	29.5	%

A.F. CLASS B AMPLIFIER AND MODULATOR

LIMITING VALUES

Anode voltage.	max.	600	V
Anode dissipation.	max.	2x10	W
Screen-grid voltage.	max.	250	V
Screen-grid dissipation.	max.	2x1.5	W
Control-grid voltage	max.	-75	V
Cathode current.	max.	2x55	mA
Resistance between control grid and cathode (fixed bias).	max.	50	kΩ
Resistance between control grid and cathode (automatic bias).	max.	100	kΩ
Voltage between cathode and heater	max.	100	V

OPERATING CONDITIONS

Anode voltage	500		300		V
Screen-grid voltage	250		250		V
Control-grid bias	-26		-25		V
Anode-to-anode load resistance. . .	20		11		kΩ
Peak-to-peak driving voltage. .	0	52	0	50	V
Anode current	2x12.5	2x36.5	2x12.5	2x35	mA
Screen-grid current	2x0.35	2x8.1	2x0.6	2x9.5	mA
Screen-grid dissipation	0.18	4.05	0.3	4.75	W
Anode input power	2x6.25	2x18.25	2x3.75	2x10.5	W
Anode dissipation	2x6.25	2x6.5	2x3.75	2x3.9	W
Tube output	0	23.5	0	13.2	W
Total distortion.		3.5		3.5	%
Efficiency.		63.5		63	%

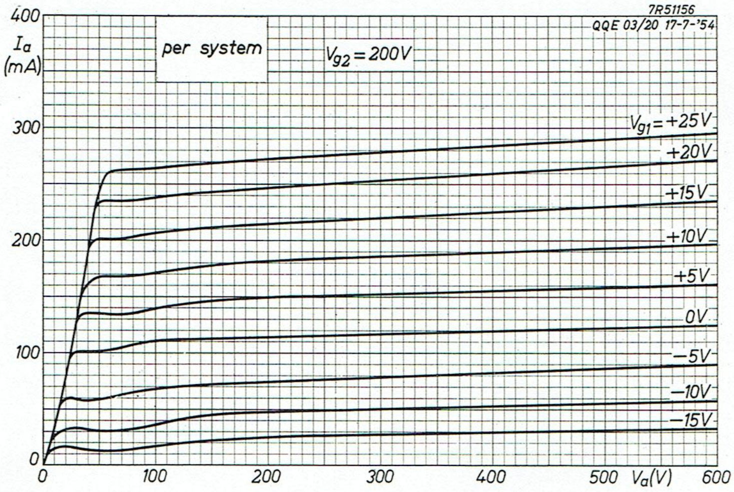


Fig.5. Anode current I_a as function of the anode voltage V_a, with the control-grid voltage V_{g1} as parameter, for each section of the QQE 03/20, at a screen-grid voltage V_{g2} of 200 V.

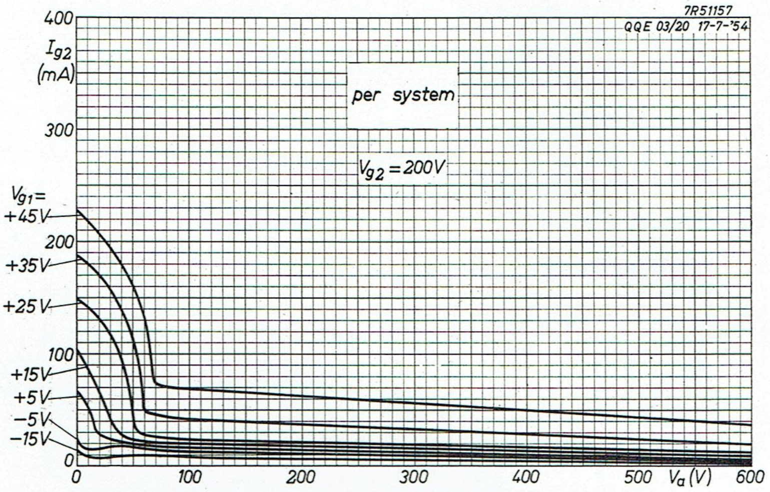


Fig.6. Screen-grid current I_{g2} as function of the anode voltage V_a, with the control-grid voltage V_{g1} as parameter, at a screen-grid voltage V_{g2} of 200 V (each system).

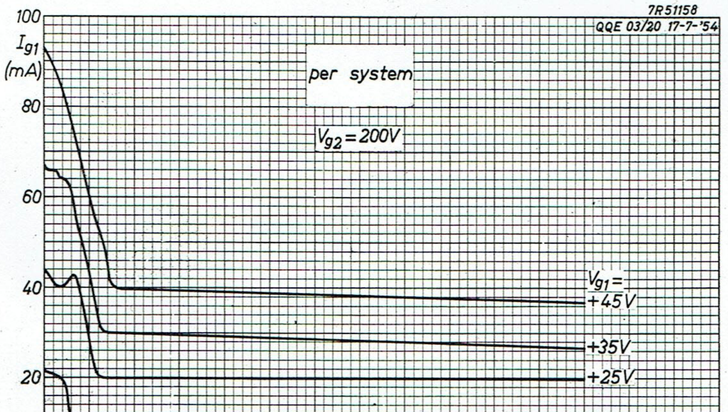


Fig.7. Control-grid current I_{g1} as function of the anode voltage with the control-grid voltage as parameter and at a screen-grid voltage of 200 V (each system).

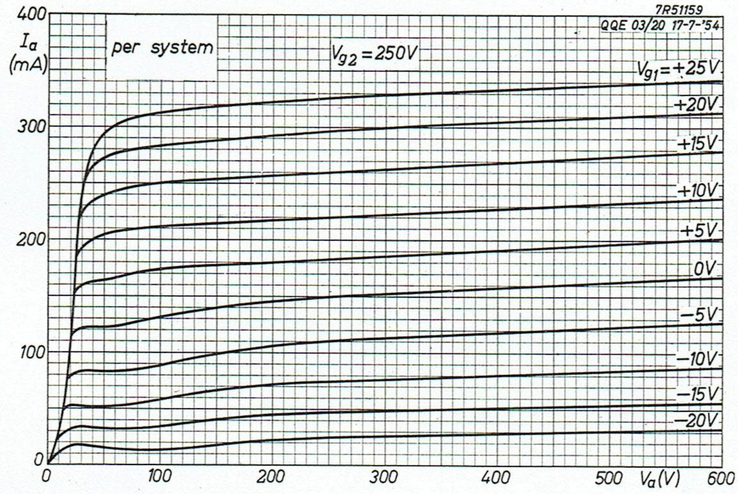


Fig.8. Anode current I_a as function of the anode voltage V_a, with the control-grid voltage V_{g1} as parameter, for each section of the QQE 03/20, at a screen-grid voltage V_{g2} of 250 V.

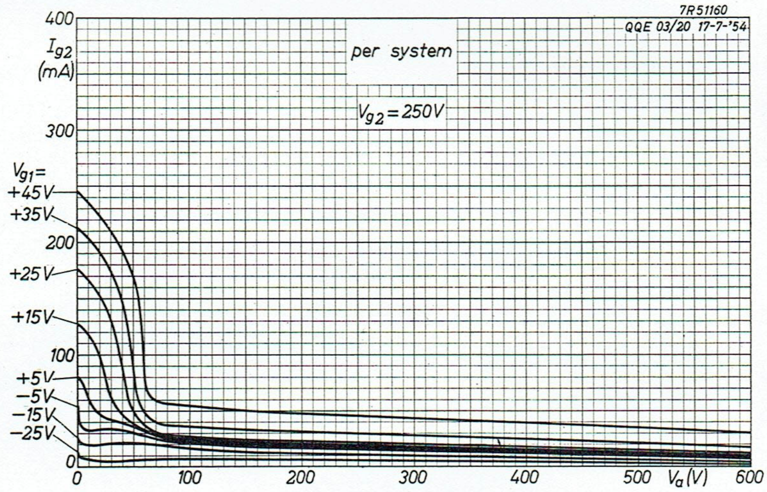


Fig.9. Screen-grid current I_{g2} as function of the anode voltage V_a, with the control-grid voltage V_{g1} as parameter, at a screen-grid voltage V_{g2} of 250 V (each system).

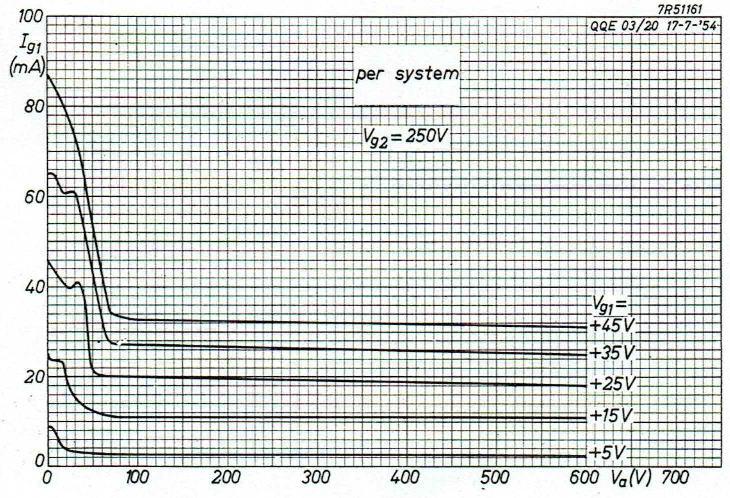


Fig.10. Control-grid current I_{g1} as function of the anode voltage with the control-grid voltage as parameter and at a screen-grid voltage of 250 V (each system).

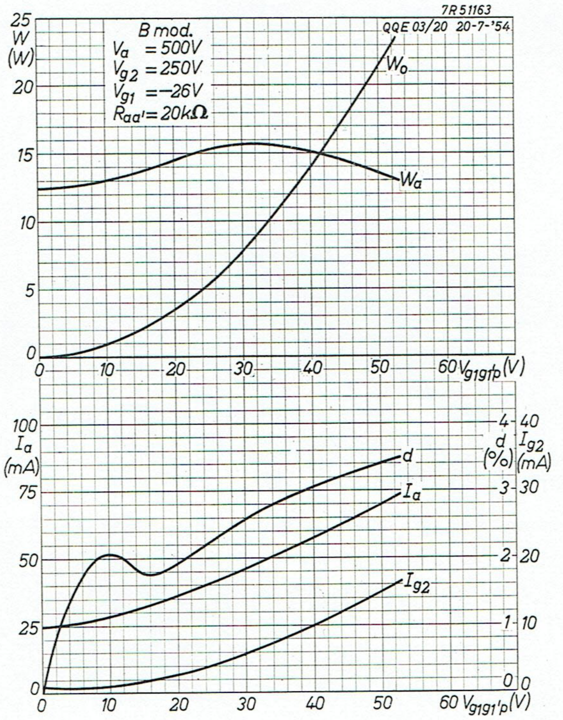


Fig.11. Curves showing the performance as A.F. power amplifier and modulator in push-pull class B. In the upper half the power output W_o and the anode dissipation W_a are given as functions of the peak grid-to-grid driving voltage; in the lower half the anode current I_a, the screen-grid current I_{g2} and the total distortion d are given under the same conditions. The anode voltage is 500 V, the screen-grid voltage 250 V, the negative grid bias is -26 V and the anode-to-anode load resistance is 20 kΩ.

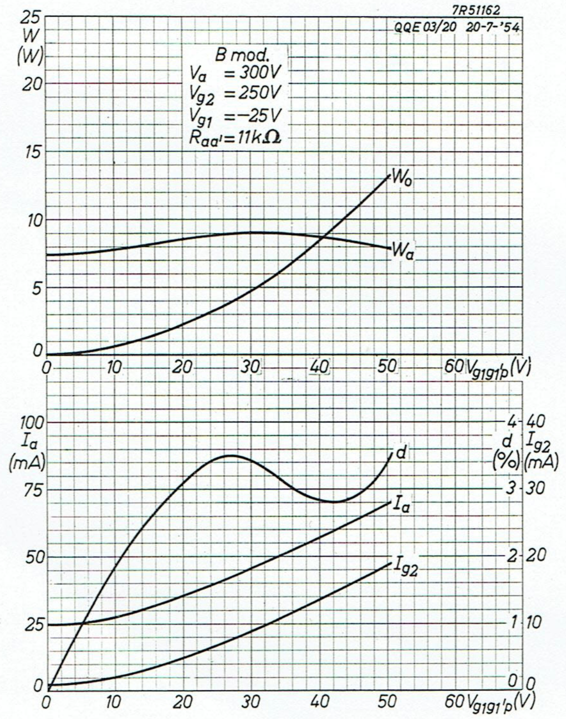


Fig.12. As Fig.11, but at an anode voltage of 300 V, a screen-grid voltage of 250 V, a grid bias of -25 V and an anode-to-anode load resistance of 11 kΩ.

OPERATIONAL NOTES

Limiting values

The limiting values given in the technical data are absolute maxima, which implies that they never may be exceeded, neither by variations in supply voltage or in load, nor by variations caused by the normal tolerances of the components used in the assembly of the transmitter. Therefore, in order not to exceed the absolute limiting values, the equipment designer has the responsibility of determining design centre values, in accordance with his design and the operating conditions, below the absolute limiting values given in the "Technical Data"

Bulb and seal temperatures

The maximum values for the bulb and seal temperatures given are also absolute maxima and should be regarded in the same manner as the other limiting values. Temperature measurements should be carried out with the tube operating in the completely assembled transmitter with all the shields and covers in place, delivering maximum output under the highest ambient temperature conditions and during the longest duty cycle for which the transmitter is designed.

The temperature may be measured with temperature-sensitive paint such as Tempilac, which is made by the Tempil Corporation 11 W, 25th Street, New York 10 N.Y.

When the QQE 03/20 is operated at frequencies higher than 150 Mc/s, it may be necessary to direct a low-velocity air flow of 15 l/sec on the top of the bulb as specified under "Technical Data".

Adjustments

When adjustments are made to a transmitter, or when a new circuit is tried, it is advisable to reduce the anode and/or screen-grid voltages to prevent overload. In many cases a screen-grid dropping resistor, which can be short-circuited, may serve this purpose. A protective device, such as a fuse or an overcurrent relay should be used, not only to protect the anodes, but also the screen grid against overload. It is recommended to use relays or fuses, which remove the anode and screen-grid voltages when the respective currents would reach values dangerous to the tube.

Screening

When the QQE 03/20 is used in H.F. circuits, screening between the output and input circuits is often required for stable operation. Screening can easily be obtained by mounting the tube socket about 18 mm below a hole in the chassis, so that when the tube is inserted in the socket, the internal screening will be in the same plane as the chassis. The grid circuits are then made below, and the anode circuits above the chassis. When the tube is mounted horizontally, a similar system can be used by letting the tube protrude through a hole in the screen between two compartments, the grid circuit being mounted in one, the anode circuit in the other. The arrangements described provide very effective screening between the control-grid and anode circuits.

Mounting

The connections to the anode pins should be sufficiently flexible to allow for mechanical tolerances and also for thermal expansion and other movements of the anode circuit, without subjecting the anode seals to mechanical strain.

The anode pin connectors should be so designed that heat conduction is facilitated and losses caused by poor contact are avoided. They should never be soldered directly to the anode connecting pins. The anode connectors type 40623 are recommended.

Circuitry

The cathode should preferably be connected to one of the heater contacts. When, however, in a design the heater contact cannot be connected directly to the cathode, the rms value of the heater-to-cathode voltage must be kept below the maximum value given in the "Technical Data", which is 100 V. At frequencies higher than 200 Mc/s special care should be given that no R.F. voltage arises between cathode and heater. In some cases it may be necessary to put chokes in all leads. Yet, the use of choke coils should be limited to the utmost minimum. Choke coils in the screen-grid or cathode connections may give rise to parasitic oscillations. Usually the screen grid may be fed in series with an unbypassed stopper resistor of 150 to 250 Ω. The cathode can best be connected directly to earth.

In a push-pull circuit the centre tap of the anode coil should preferably be connected to the H.T. supply source via an unbypassed choke coil. When this choke is bypassed to earth and a slight asymmetry would occur, part of the R.F. power in the anode circuit would flow to earth via the bypass capacitor and be lost.

One of the heater contacts may be connected directly to earth, the other via a capacitor. Much depends, however, on the circuit lay-out, and the above hints should, therefore, be considered as general indications. Sound and reliable equipment can also be designed with the QQE 03/20 along other lines.

Particular care should be given to the screen-grid voltage and supply. When the screen grid is fed from a separate source, the anode voltage should be applied before, or simultaneously with the screen-grid voltage. With voltage on the screen grid only, the screen-grid current would be large enough to cause excessive screen-grid dissipation even when some protective control-grid bias is applied. When the screen-grid voltage is obtained from the anode supply via a voltage divider or a series dropping resistor, it is available to provide the voltage divider with an adjustable tapping, or to take care that the series resistor can be adjusted, so that the anode currents of individual tubes can be set to maintain the required input, and variations within the tube tolerances can be compensated.

The screen-grid current is a very sensitive indication of the load in the anode circuit. When the amplifier operates without load, the screen-grid current will rise to a value that may even damage the tube. When the QQE 03/20 is tuned under no-load conditions the screen-grid voltage should therefore be reduced, for example by means of a series resistor that is short-circuited during normal operation, so that the screen-grid input power does not exceed its maximum permissible value.

In class C telegraphy or telephony service, or when the tube is used as a trebler, the driver stage for the QQE 03/20 should give sufficient output power to allow a wide range of adjustments and to provide for the losses in the control-grid circuit. This is particularly important when the tube is operated at high frequencies, where the circuit and radiation losses and those due to transit time effects become quite considerable.

Asymmetry

As with all double tubes, a slight asymmetry between the two sections cannot always be avoided. There are external and internal causes for asymmetry. The former can be avoided by careful and symmetric lay-out of the circuit. Causes of internal asymmetry are: slight differences in tube capacitances, in internal inductances, in the transit times and in the characteristics.

As a rule class C adjustment is not sensitive to asymmetry in characteristics, in constrast to class B operation. In the latter case individual adjustment of the grid bias is recommended if distortion should be minimized.

Asymmetry of the input capacitances may, for instance, affect the symmetry of the grid drive. Experiments revealed that this phenomenon can be practically annihilated by bypassing the centre tap of the grid coil to earth, which can be explained as follows. When the centre tap of the grid coil is earthed, the driving voltages in the coil halves are subtantially equal and independent of the input capacitances, provided the circuit lay-out is symmetric and the coupling to the pre-stage is sufficiently tight. When, on the other hand, the grid leak is not bypassed, asymmetry of the input capacitances will upset the symmetry of the grid drive.

Earth connections

The earth connections appertaining to the circuit of one stage should preferably be made at one point of the chassis, so that no R.F. currents, which may lead to undesired and uncontrollable coupling via the chassis, pass through the chassis from one point to another.

Tube sockets

To keep the circuit losses at high frequencies small, adequate care should be paid to the tube sockets. Parallel losses and series losses should be distinguished. The former depend on the insulating material used, and on its form and dimensions. The input resistance of a tube operating at 500 Mc/s or higher is, however, fairly low, so that the parallel losses caused by the insulating material are less important than might be expected. The series losses at high frequencies are much more serious. In the higher frequency range series capacitors must be employed to reduce the effect of the input capacitance of the tube. A current node will then be situated in the vicinity of the contacts of the tube socket and the base pins of the tube.

Under these conditions a relatively low contact resistance between the tube socket contacts and the base pins will cause considerable loss of power. The contacts of tube sockets designed for high frequencies must therefore be rather heavy and of solid construction, so that the contact resistance is kept very low. The tube socket type 40202 meets all requirements set to high-frequency operation.

Gold-plated contact pins

Contact resistance is kept very low even under the most adverse conditions of humidity and temperature by the use of the gold-plated non-corrosive contact pins which are standard for the QQE 03/20.

APPLICATIONS

Since the operating conditions under "Technical Data" give all the information required for the design of normal transmitters in the frequency range up to 600 Mc/s, no complete transmitter designs will be described in this section. A few experiments carried out on laboratory set-ups of amplifiers of unconventional design or at frequencies up to 1500 Mc/s will be described instead. The circuits given are not engineered for production, but only made for measuring tube outputs with average, and with upper- and lower-limit tubes.

AMPLIFIER WITH A QQE 03/20, TUNABLE FROM 225 TO 400 Mc/s

A test set-up of a miniaturized transmitter output stage was made upon request according to the following specification: Continuous tuning over the band from 225 to 400 Mc/s, minimum output power 10 W; driving power over the same band about 1 W; grid circuit matched to coaxial cable feed; output circuit to suit coaxial cable; overall dimensions 90 x 90 x 114 mm. All the requirements could be met with the QQE 03/20 in the circuit described below, with the exception of the required driving power, which proved to be 1 to 3 W depending on frequency, whereas the output power was 12 W over the entire band.

Circuit description

The circuit is given in Fig. 13. The input coaxial line is terminated by an untuned loop, closely coupled to the grid circuit of the QQE 03/20. To obtain a reasonable size of the grid circuit for coupling purposes (especially at the upper end of the band) it was found necessary to connect series capacitors in the leads from the grid circuit to the control grids of the tube (C_1 and C_3), with the intention to reduce the capacitive loading of the circuit due to the tube capacitances. Initially fixed capacitors were used. However, when tuning over the band with capacitor C_2, from the upper to the lower end, it was found necessary to increase the value of the series capacitors so as to maintain sufficient driving power

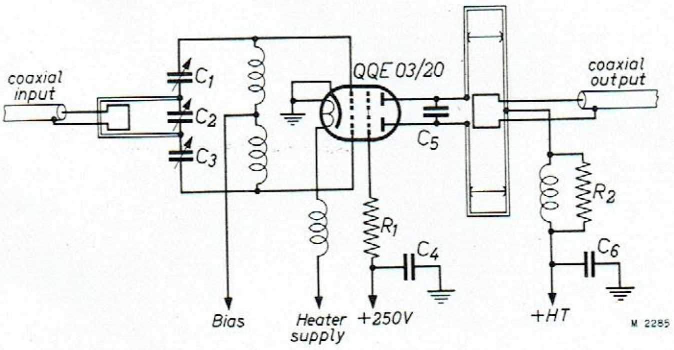


Fig.13. Circuit of the transmitter output stage, tunable from 225 to 400 Mc/s, with the QQE 03/20.

to the tube. This is due to the fact that the reactances of C_1 and C_2 increase as the frequency is reduced, so that a larger proportion of the output voltage of the tuned circuit is lost across the series capacitors, which results in a reduction of the grid drive.

This is compensated by increasing the value of the series capacitors with decreasing frequency, which implies that C_1, C_2 and C_3 have to be ganged. It was found that the tracking requirements are not critical.

For the convenience of making measurements, the cathode was earthed directly, and a fixed bias was applied to the control grids via chokes which are in resonance roughly at the mid-band frequency (310 Mc/s). In a production model, grid-leak bias and/or a cathode resistor would be preferable, or grid-leak bias combined with a clamping tube connected to the screen grid.

The screen grid and the heater were fed by similar chokes, but it was found necessary to shield the screen-grid choke by a small copper plate and to damp this choke with a 1000 Ω resistor so as to avoid oscillations between the screen grid and the control grids of the tube.

Experiments with the double tetrodes QQE 03/12 and QQE 06/40, however, revealed that the screen grid can very well be fed via a stopper resistor of 150 to 300 Ω, and that the use of chokes should be restricted to a minimum.

Several variations of the anode circuit were tested with capacitive methods of tuning, but were unsuccessful for this broad frequency range. It was concluded that only a variable inductance or transmission line method of tuning would be satisfactory. The coupling of the coaxial output to the anode circuit also requires special attention. This must, of course, be satisfactory over the entire frequency band, and if a variable wiper for a transmission line is used, the coupling loop must be moved with the wiper to maintain the coupling. With the space available, this was found to be impossible, so that the circuit given in Fig. 14 was devised.

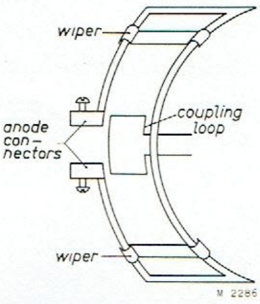


Fig. 14. Anode circuit and coupling loop for the miniaturized transmitter.

If with this circuit the two wipers are arranged to be always symmetrical, the loop will remain at the near-optimum coupling position. This circuit was found to operate satisfactorily over the entire band.

A small fixed capacitor of about 0.5 pF (C_5) was connected across the anode connections to keep the physical dimensions of the circuit sufficiently small, so that it would fit in the space available.

Measured results

With the circuit described and a series-tuned load lamp connected across a coaxial feeder section of 120 cm, the following results were obtained:

Anode voltage	350 V
Screen-grid voltage	250 V
Control-grid voltage	-50 V
Anode current	2x50 mA
Power output (over the whole band)	12 W

The required driving power was about 1 W up to about 300 Mc/s, and gradually increased as the frequency was increased to 400 Mc/s; at this frequency the required driving power was estimated to be about 2 to 3 W.

THE QQE 03/20 AS A TREBLER AT FREQUENCIES FROM 1000 TO 1500 Mc/s

A number of experiments have been carried out to investigate whether the QQE 03/20 could be used in the frequency range above 1000 Mc/s and at what frequency a power output of 1 to 2 W could still be supplied to a load. It proved that at 1000 Mc/s a power output of 2 W could be delivered to the load with lower-limit tubes at an efficiency of about 10%. At 1200 Mc/s the lower-limit tubes deliver 0.98 W with an efficiency of 4.9%, the output power of average tubes being 1.15 W with an efficiency of 5.8%. At 1300 Mc/s the figures for average tubes were an output of 0.58 W with an efficiency of 2.7%, and at 1500 Mc/s an output of 0.3 W with an efficiency of 1.4%. From the measurements it may be concluded that the QQE 03/20 used as a trebler can supply a power of 1 to 2 W to a load in the frequency range of 1000 to 1200 Mc/s. However, since the required driving power exceeds 10 W, the major part of which is lost outside the tube, the driving stage must be equipped with at least one QQE 03/20 as a fully driven amplifier, or with a QQE 06/40 operating as a trebler.

At first sight the circuit seems a proposition having little sense, but it can nevertheless be very useful in those cases where a 400 Mc/s transmitter is already available (radio navigation, mobile equipment and amateur shacks), so that only the output stage is needed. It will, moreover, be useful when only one or two transmitters in the range mentioned are required, because there is no need of using coaxial circuits, which are fairly expensive when made in small quantities.

In all other cases the EC 55 or EC 56 with their appertaining coaxial circuits offer the best solution.

CIRCUIT AND OPERATING CONDITIONS FOR A 333.3/1000 Mc/s TREBLER

Fig. 15 shows the circuit of the trebler. In the original set-up a 111.1 Mc/s oscillator was used to drive a 111.1/333.3 Mc/s trebler with a QQE 03/20. The driving power required, however, proved to be so high that the QQE 03/20 in the first trebler stage was overloaded. Therefore, it is recommended for a definite circuit to use an R.F. amplifier with a QQE 03/20, or to equip the preceding trebler with a QQE 06/40.

The grid circuit of the 333.3/1000 Mc/s trebler consists of half-wave capacitance-loaded lines with series capacitors at the control-grid ends. These lines are inductively coupled to the quarter-wave anode lines of the preceding stage.

The anode circuit of the final trebler is a half-wave capacitance-tuned line, since more than a quarter wavelength is located within the tube envelope at this frequency. The output

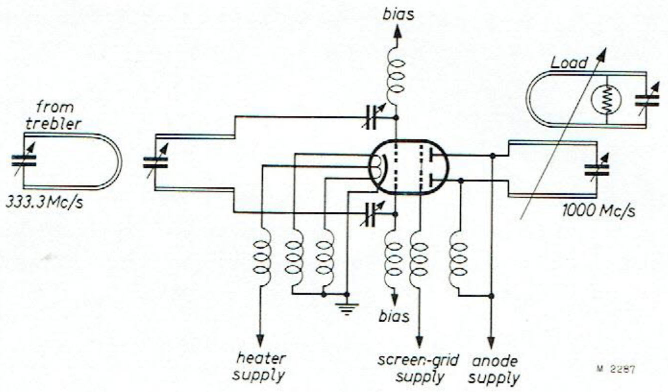


Fig.15. Test circuit for a trebler 333.3/1000 Mc/s.

is dissipated in a 6 V, 6 W incandescent lamp tapped across a quarter-wave capacitance-tuned line coupled to the anode circuit.

In the test set-up the heaters, the control grids and the screen grid were all connected to their various supplies via low-Q resonant chokes. Later experiments on other types of double tetrodes revealed, however, that the use of chokes should be minimized, so that in a definite circuit it is preferable to use resistors in the control grid and screen-grid circuits.

Dimensions of tuned circuits

The anode circuit of the first trebler consists of two 1/4" copper rods 100 mm long and spaced 14 mm.

The control-grid circuit of the final trebler consists of two S.W.G.20 copper strips, 90 mm long, 5 mm wide and spaced 17 mm. The anode circuit of the output circuit consists of two 3/8" square-section brass rods spaced 18 mm. The overall length, including the phosphor bronze anode connectors, is 45 mm. The coupling circuit consists of 20 S.W.G. copper strip, bent into a hair-pin loop, 55 mm long and 15 mm wide. The anode and coupling circuits are tuned by small disc-type capacitors, 15 mm diameter.

Measured results

A number of QQE 03/20 tubes have been measured in the circuit given, the average results being:

Anode voltage	300 V
Anode current	75 mA
Screen-grid voltage	250 V
Screen-grid current	5.2 mA
Control-grid bias	-175 V
Control-grid current	1.5 mA
Power output in load	2.1 W
Efficiency	9.3 %

The driving power, including the circuit losses, averaged 9.25 W.

CIRCUIT AND OPERATING CONDITIONS AS A TREBLER TO 1200, 1300 AND 1500 Mc/s

The experiments described above were continued with the aid of the circuit of Fig. 16. A QQE 06/40 tube is used as an oscillator in the frequency range from 400 to 500 Mc/s. The output of the oscillator is inductively coupled to the series-tuned grid circuit of the QQE 03/20 operating as a frequency trebler, the anode circuit of the previous stage being formed by a quarter-wave transmission line. The anode output system tuned to 1200 and 1300 Mc/s consists of two rods 10 mm diameter

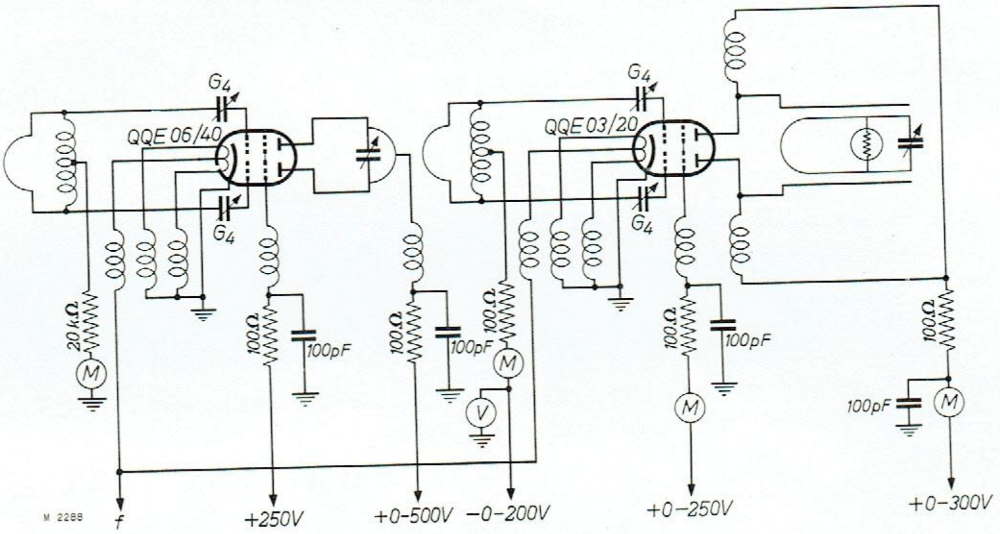


Fig.16. Test circuit for a trebler to frequencies between 1200 and 1500 Mc/s.

and 22 mm long placed on the tube anode pins. The chokes in series with the anode supply are connected to lateral screws as shown in Fig. 17.

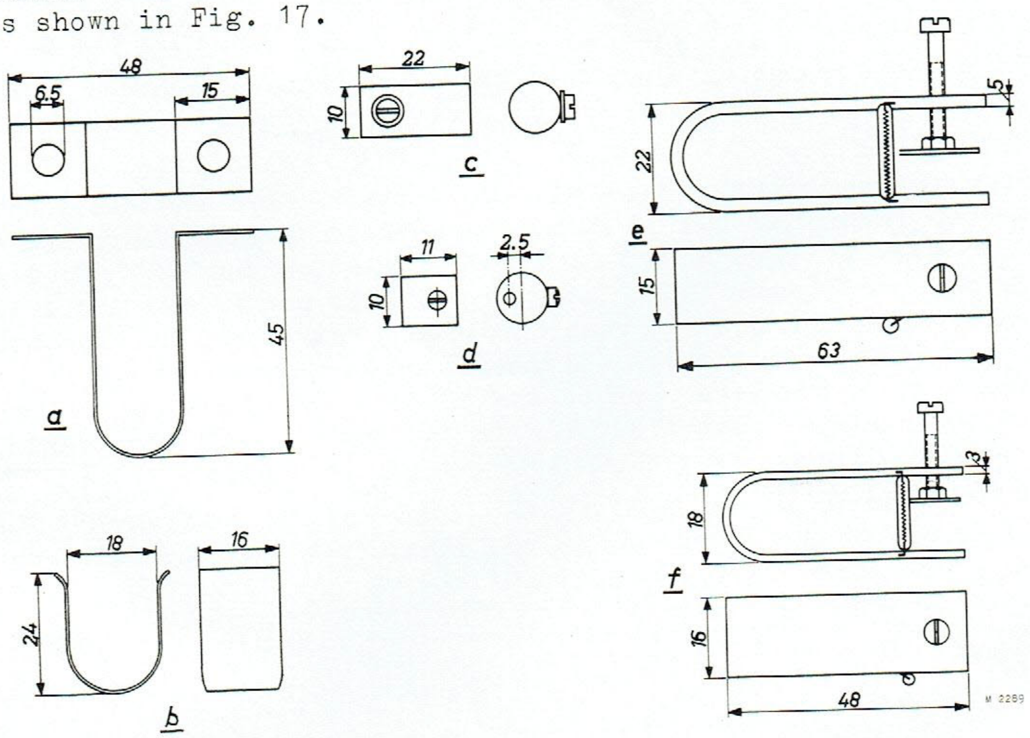


Fig.17. Anode and transmission line output systems for the test circuit of a trebler to 1200 and 1300 Mc/s with a QQE 03/20. (*a*) grid circuit on 1200 and 1300 Mc/s. (*b*) grid circuit on 1500 Mc/s. (*c*) anode circuit on 1200 and 1300 Mc/s. (*d*) anode circuit on 1500 Mc/s. (*e*) 1/4 λ output circuit on 1200 Mc/s. (*f*) 1/4 λ output circuit on 1300 and 1500 Mc/s.

All supply voltages are fed to the tube via low-Q resonant chokes.

Circuit dimensions

In Fig. 17 all dimensions are given of the grid and anode circuits and of the coupling circuits at 1200 and 1300 Mc/s, and also at 1500 Mc/s. Because the major part of the anode circuit is located within the tube envelope, the load is coupled with λ/4 lines placed over the bulb of the horizontally mounted tube (see Fig. 18).

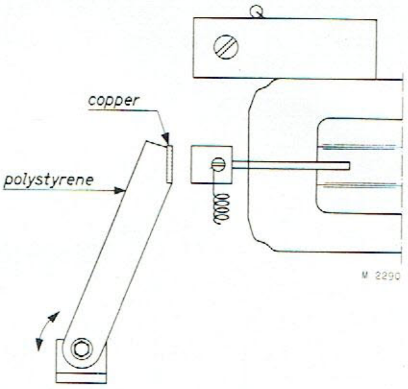


Fig.18. Coupling between output and anode circuits, and the tuning of the anode system at 1500 Mc/s.

Measured results

The following measuring results are the average of a number of tubes tested in the circuit given:

Frequency	1200	1300	1500	Mc/s
Anode voltage	250	250	300	V
Anode current	80	80	75	mA
Screen-grid voltage	250	250	250	V
Screen-grid current	8.4	8.7	7.5	mA
Control-grid bias	-180	-180	-180	V
Control-grid current	2	1.8	1.6	mA
Power output in load	1.15	0.67	0.3	W
Efficiency	5.8	3.4	1.4	%

Under these operating conditions the driving power exceeded 10 W.

Conclusion

From the measurements discussed above, the following conclusions may be drawn. The QQE 03/20 can be used in the frequency range from 1000 to 1200 Mc/s, in which a load output of 1 to 2 W is obtainable under C.C.S. conditions. Life tests under I.C.A.S. conditions have not yet been completed, but it may be expected that for amateur service 1 W useful output power can still be obtained in the lower end of the 1215 to 1300 Mc/s band. When used for radio navigation aids in the 960 to 1215 Mc/s bands, a useful output power of 2.5 to 1 W is available.

Curves giving the output in the load and the efficiency as functions of the frequency in the range from 1000 Mc/s to 1500 Mc/s are given in Fig. 19.

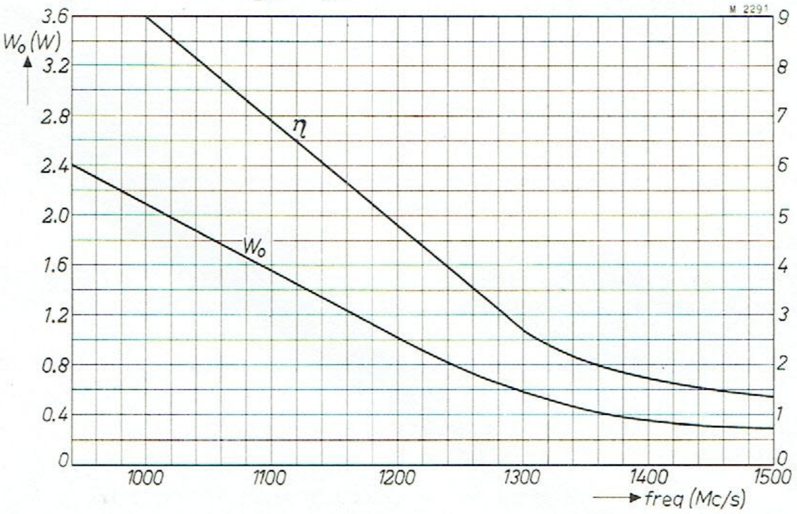


Fig.19. Graphs giving the output power and the efficiency as functions of the frequency (QQE 03/20 as trebler).