VOL. 12 No. 6, pp. 157-184 DECEMBER 1950

Philips Technical Review

DEALING WITH TECHNICAL PROBLEMS
RELATING TO THE PRODUCTS, PROCESSES AND INVESTIGATIONS OF
THE PHILIPS INDUSTRIES

EDITED BY THE RESEARCH LABORATORY OF N.V. PHILIPS' GLOEILAMPENFABRIEKEN, EINDHOVEN, NETHERLAND

TWO TRANSMITTING VALVES FOR USE IN MOBILE INSTALLATIONS

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When in 1896 Marconi succeeded in developing wireless telegraphy into a technically useful means of communication the main application envisaged was for establishing communication between ships at sea and the shore. In those days there was little difference between a fixed radio station and a mobile one, but this changed when, some time later, wireless came to be applied also to aircraft and equipment began to appear in special forms most suited for their purpose. It was about that time, too, that telegraphy was largely ousted by telephony. It is only in recent years that radiotelephony has come to be used on a large scale in automobiles and trains, for which purpose special frequency bands were allotted by the last radio conference at Atlantic City.

As regards the transmitting valves developed for this new form of mobile installations, they are required to possess great mechanical strength combined with high efficiency, the latter property being demanded on account of the fact that the most efficient use possible has to be made of the power available, since this is supplied by a source of only limited capacity, in a car, for instance, by the battery.

In recent years small, mobile, radio-telephonic transmitting and receiving installations have become very popular as a means of meeting a need felt in many directions. When automobiles, trains or small vessels are equipped with these sets communication can be maintained between them and with one or more fixed stations. As examples may be mentioned: taxi companies, fire brigades, police forces, military columns, harbour works, railways (both for the convenience of passengers and for use in marshalling yards), outposts or remote plantations in inhospitable regions, doctors and business people desiring to keep in touch with their homes, offices or works, etc., etc.

For such purposes as these the transmitter and the receiver are usually built together, sometimes making such a compact whole that it can be carried on the back or even in the hand (we have in mind the "walkie-talkies" and the "handie-talkies" which rendered such good services in the allied armies during the war).

This article deals with two transmitting valves that have been developed specially for such mobile installations. The need for new valves arises mainly from the fact that the supply source — the accumulator battery of a car or the dry batteries of the smaller, portable sets — is of a very much more limited capacity than in the larger mobile installations. It is therefore necessary that the transmitting valves should work with a high efficiency and possess such properties that a small number of stages suffices (for amplification and frequency multiplication). Furthermore, valves destined for use in trains or automobiles have to withstand greater mechanical shocks than occur on board ships.

Before proceeding to describe these new valves it is deemed necessary to consider briefly some points that are of importance for mobile transmitters.

Mobile transmitters

Wavelengths

Mobile radio stations were officially recognised at the international telecommunication conference held at Atlantic City in 1947, when a number of frequency bands were allotted to these stations.

For such of these bands as lie between 54 and 420 Mc/s (5.55 to 0.714 m waves) their distribution is indicated in *fig. 1.*

The other bands outside these limits have not been included in this diagram for the following reasons. At frequencies below a certain limit there is a risk of the waves being reflected by the ionosphere and reaching the earth again in parts far removed from the transmitter ¹); welcome use is made of this for long-distance radio communication, but for transmitters intended only for short-range work, like mobile transmitters, this reflection by the ionosphere is undesirable because it is apt to lead to interference over wide ranges where the same wavelengths are being used. At frequencies of 54 Mc/s and higher there is no need to take account of this effect, although at the highest allotted frequencies under certain atmospheric conditions an inversion of the temperature gradient occurs and the signals may cover a range of some hundreds of kilometres, but then the ionosphere has nothing to do with this; such conditions, however, very seldom occur.

The other limit, 420 Mc/s, is about the highest frequency at which the transmitting valves to be described here still work with a satisfactory efficiency; for still higher frequencies entirely different types of valves would be required.

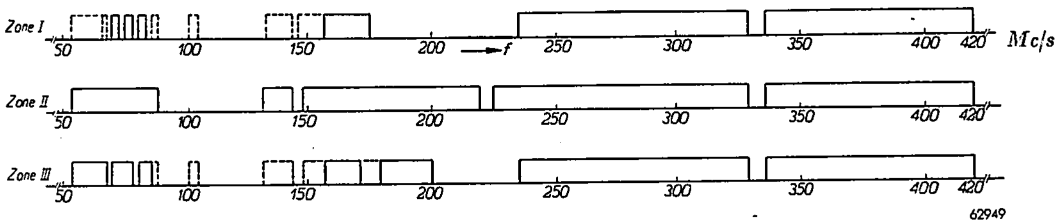

Fig. 1. The frequency bands allotted to mobile transmitters by the International Telecommunications Conference held at Atlantic City in 1947, for so far as these bands lie between 54 and 420 Mc/s. Roughly speaking zone I comprises Europe, Africa and part of Asia, zone II North and South America, and zone III the part of Asia not belonging to zone I, and Australia and New Zealand. The bands denoted by dotted lines can only be used in certain parts of the respective zone. For further details see the text in small type.

For the allocation of frequencies for working mobile transmitters the world has been divided into three zones, where the following arrangements apply for the frequencies between 54 and 420 Mc/s.

In *zone I*, covering Europe, Africa and some parts of Asia, the frequency bands that may be used are: 70-72.8, 75.2-78, 80-83, 85-87.5, 100-108, 156-174, 235-328.6 and 335.4-420 Mc/s. There are some exceptions however: the 85-87.5 Mc/s band does not apply for Great Britain, which has instead the disposal of the 66.5-68 Mc/s band; South Africa and its mandatory territories have been allotted, instead of the 100-108 Mc/s band, the bands 133-144 and 146-174 Mc/s and also, but only for mobile stations used for broadcasting, the 54-68 Mc/s band.

Zone II, comprising mainly North and South America, has been allotted the 54-88, 132-144, 148-220, 225-328.6 and 335.4-420 Mc/s bands.

Zone III, consisting mainly of that part of Asia not included in zone I and of Australia and New Zealand, has the disposal of the bands 54-68, 70-78, 80-87 (in Australia and New Zealand 80-85), 132-144 (not in Australia and New Zealand), 148-200 (in Australia limited to 156-170 and 178-200, in New Zealand limited to 156-200), 235-328.6 and 335.4-420 Mc/s.

In order to avoid interference with or from other radio communications, mobile transmitters are not allowed to work outside the fixed frequency bands, and in order to avoid any mutual interference their frequency has to be highly constant. For this reason crystal control has to be applied.

Power and range

The power of mobile transmitters is closely related on the one hand to the minimum range required and on the other hand to the permissible weight and volume of the apparatus, including the power supply unit.

The range depends not only upon the power radiated by the aerial but also to a large extent upon the construction and height of the aerial, whilst also the surroundings are of great influence. The aerial constructions most favourable for radiation are generally too cumbersome to be of use on an automobile or train. The higher the aerial the greater is the range, but then of course the height is limited for travelling vehicles; on an automobile, for instance, as a rule a simple vertical rod on the roof is used. In open spaces the range is much

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¹) See, e.g.: C. J. Bakker, Radio investigation of the ionosphere, Philips Techn. Rev. 8, 111-120, 1946.

greater than in built-up areas; the adverse influence of buildings is, roughly speaking, felt most at the highest frequencies, though there are exceptions to this rule. In New York, for instance, it has been found that in narrow streets shorter waves are more readily reflected downward by buildings than are longer ones. A second reason for shorter waves being sometimes more satisfactory in a town is that in a street standing waves are apt to be set up; when driving through such a street one therefore passes through maxima and minima, and the quicker these follow each other — the smaller the wavelength — the less does intelligibility suffer.

Intermittent working

If a call is to be heard at once, the receiver in a mobile radio station must be continuously in the stand-by position. After a call has been received, or when another station has to be called up, the installation is changed over to transmission, mostly by means of a switch built into the microphone handle. This changing over is then repeated as the conversation proceeds to and fro. Since as a rule the intervals of rest between talks are much longer than the talks themselves, in practice the transmitter is working only a fraction of the time, while the receiver is working almost continuously. Thanks to these long intervals, for some transmitting valves operating conditions are allowed which permit of a somewhat larger output than would be permissible for continuous working.

Number of stages of the transmitter

Notwithstanding the relatively short working time of the transmitter, it is necessary to aim at the least possible power consumption, i.e. at a high total efficiency of the transmitter. We shall presently deal further with the steps that have been taken in the new transmitting valves in order to limit the losses as far as possible, but another equally important factor upon which the total efficiency depends is the number of stages required between the aerial and the quartz crystal determining the carrier frequency.

This number of stages is closely related to the system of modulation. Two systems, amplitude modulation and frequency modulation, are to be considered, both of which are applied in mobile transmitters; it is not the place here to explain why in one case amplitude modulation is employed and frequency modulation in another.

Where amplitude modulation is employed one has a constant carrier frequency, which of course has to lie in one of the frequency bands allotted. Now the frequencies of these bands are so high that they cannot be generated directly by means of a crystal. Owing to the fragility of the crystal, especially when it is exposed to the shocks occurring in a mobile transmitter, about 0.15 mm is the least thickness it may have, and this corresponds to a natural frequency of about 20 Mc/s [2]). For a carrier frequency of say 320 Mc/s it is therefore necessary to apply at least a 16-fold frequency multiplication. In such cases it is advantageous to use double valves with the two electrode systems, mounted in one envelope, connected in cascade. By frequency doubling in each system no more than two of these double valves are then required to multiply the input (crystal) frequency 16 times.

In addition an output valve and a modulator valve are needed and one or two stages of A.F. amplification between the microphone and the modulator.

With frequency modulation a system can be followed, for instance, as described by **Braak** [3]), where the microphone voltage brings about a phase shift between two currents having the frequency of the quartz crystal, in such a way that the phase φ of the sum of these currents varies according to the equation

$$\varphi = \omega_0 t + a \sin 2\pi\nu t$$

where ω_0 = angular frequency of the crystal, t = time, a = amplitude of the phase shift (phase sweep), ν = frequency of the incident sound at the microphone. Corresponding to the phase modulation of the total current is a frequency modulation, the instantaneous value ω of the varying angular frequency being defined by

$$\omega = \frac{\mathrm{d}\varphi}{\mathrm{d}t} = \omega_0 + a \cdot 2\pi\nu \cos 2\pi\nu t\,,$$

so that the instantaneous value $f = \omega/2\pi$ of the modulated frequency is:

$$f = f_0 + a\,\nu \cos 2\pi\nu t$$

($f_0 = \omega_0/2\pi$). The sweep of this frequency is $a\nu$. For undistorted reproduction the frequency sweep

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[2]) Crystals are also being used, especially in the U.S.A. and in Great Britain, which oscillate with (practically) a multiple of the natural frequency (see, e.g., the article by **W. Parrish** in this number, p. 166), so that frequencies higher than 20 Mc/s can be generated with still crystals.

[3]) **D. J. Braak**, Mobile radio equipment, type SRR 192, Communication News **10**, 120-125, 1949 (No. 4).

has to be proportional to the intensity of the sound and independent of the audio frequency ν, which means to say that the phase sweep a has to be proportional to the sound intensity and inversely proportional to ν [4]).

If an n-fold frequency multiplication is applied between the modulating stage and the output stage the sweep of the aerial frequency will therefore amount to $na\nu$. For transmitters which are modulated only with speech — as is the case with mobile transmitters — this sweep has been limited by international agreement to 15,000 c/s, and in order to derive the utmost benefit from frequency modulation this sweep has to be used to the full. To prevent prohibitive non-linear distortion the phase sweep a has to be limited to an angle of about 0.5 radian. Hence the frequency multiplication required to get an aerial frequency sweep of 15,000 c/s with the maximum phase sweep, i.e. at the lowest audio frequency ν occurring in telephony (300 c/s), and with full phase modulation ($a \approx 0.5$ radian), is

$$n \approx \frac{15{,}000}{0.5 \times 300} = 100\,.$$

(Since this value of n is greater than that found in the case of amplitude modulation, with frequency modulation the mechanical strength of the crystal is not a determining factor.)

A frequency multiplication of about 100 can be obtained with three double valves, for instance as follows: $(3 \times 2) \times (2 \times 2) \times (2 \times 2) = 96$. For the first of these valves a low-power type suffices, which need not be made for particularly high frequencies, e.g. the double triode ECC 40, but for the third valve (and possibly also for the second one), in which the frequency is much higher than the crystal frequency, it is preferable to use one of the double tetrodes of the type QQC 04/15 or QQE 06/40 [5]) to be described in this article. The same types of valves can also be used as output valves (with either frequency or amplitude modulation), though then the two systems have to be connected in push-pull instead of in cascade; we shall revert to this later.

Choice of the type of valve

A tetrode, rather than a triode or a pentode, has been chosen because of a number of considerations, most of which apply in general to all transmitting valves for the frequency range in question, without being limited to valves for mobile transmitters. These considerations are the following.

At high frequencies a triode is in two respects at a disadvantage compared with a screen-grid valve (tetrode or pentode); in the first place a triode requires a greater driving power [6]) and thus also necessitates a larger number of amplifying stages, whilst in the second place with screen-grid valves, compared with triodes, it is possible to work with fairly high frequencies without (external) neutralization, i.e. compensation of undesired feedback such as arises, for instance, owing to the capacitance between anode and control grid.

That is why a screen-grid valve has been chosen. Of the two kinds to be considered, the tetrode and the pentode, the former is to be preferred at very high frequencies, since the absence of the third grid permits of a smaller anode capacitance, i.e. the capacitance between the anode and the other electrodes together. The absence of the third grid, however, makes it necessary to take certain steps for preventing any secondary electrons emitted by the anode reaching the screen grid; the purpose of the third grid (suppressor grid) in a pentode is to bring about between the anode and the screen grid a potential minimum suppressing the undesired secondary emission. Such a potential minimum, however, can be obtained by other means too, by giving a tetrode system such dimensions that, with the normal working currents and voltages, between the anode and the screen grid a concentration of space charge is brought about which provides the desired potential minimum [7]).

Furthermore, the secondary emission itself can be counteracted by coating the anode with a layer of a material from which the electrons do not easily emerge (see the article quoted in footnote [7])). Both these measures have been applied in the new types of transmitting valves.

The anode capacitance, already small owing to the absence of a third grid, can be still further reduced by dividing the electrode system into two

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[4]) The latter can be reached to a sufficient approximation by means of a correcting network between the microphone and the phase modulator.

[5]) Here the letter Q means tetrode, QQ double tetrode, C directly-heated oxide-coated cathode, E indirectly-heated oxide-coated cathode. The figures 04 and 06 signify that the valve is intended for a supply voltage of 0.4 or 0.6 kV respectively, while the numbers 15 and 40 denote the order of the output in watts (as will presently be seen, in suitably chosen circuits these valves can yield much higher outputs than 15 or 40 W).

[6]) See J. P. Heyboer, Five-electrode transmitting valves (pentodes), Philips Techn. Rev. 2, 257-265, 1937, in particular pp 260 and 261.

[7]) See, e.g.: J. L. H. Jonker, Secondary emission in output valves, Philips Techn. Rev. 10, 346-351, 1948, fig. 3, curve *1*. The difficulty therein mentioned, which makes this method unsuitable for output valves of low-frequency amplifiers, applies in a much less degree for transmitting valves.

parts and connecting the two halves to the external circuits in push-pull. With given total dimensions of the electrodes (thus with a certain permissible heat dissipation in the valve) and certain distances between the electrodes, the input and output capacitances are then four times smaller, since the partial capacitances are in series instead of in parallel.

When the two electrode systems of the double valve obtained by this division are connected in cascade instead of in push-pull the same type of valve can advantageously be used also for frequency multiplying, as we have seen above.

Transmitting valves with two electrode systems in one envelope have in fact been known some fifteen years already. In the old designs the electrodes not carrying any high-frequency 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. This is illustrated in *fig. 2a.* A difficulty arising with these valves was the self-inductance of the interconnection of the cathodes and of the screen grids (fig. 2*b*). At very high frequencies the influence of these self-inductances is not to be ignored. The self-inductance between the cathodes causes an undesired inverse feedback and constitutes a positive contribution towards the input damping 8), so that in order to yield a certain output the valve needs a larger driving power. The influence of the self-inductance between the screen grids is manifested as a negative damping 9), which is zero only at one certain frequency and at other frequencies may assume such a value that in order to avoid self-oscillation some form of neutralization or other has to be applied, especially for valves with a high mutual conductance. Below the frequency just referred to this neutralization can be brought about by introducing a capacitor of a certain value between each anode and the control grid belonging to the other anode. Above that frequency these capacitors have to be connected between each anode and its corresponding control grid.

How these complications have been avoided in the new designs of double tetrodes will be shown in the next section.

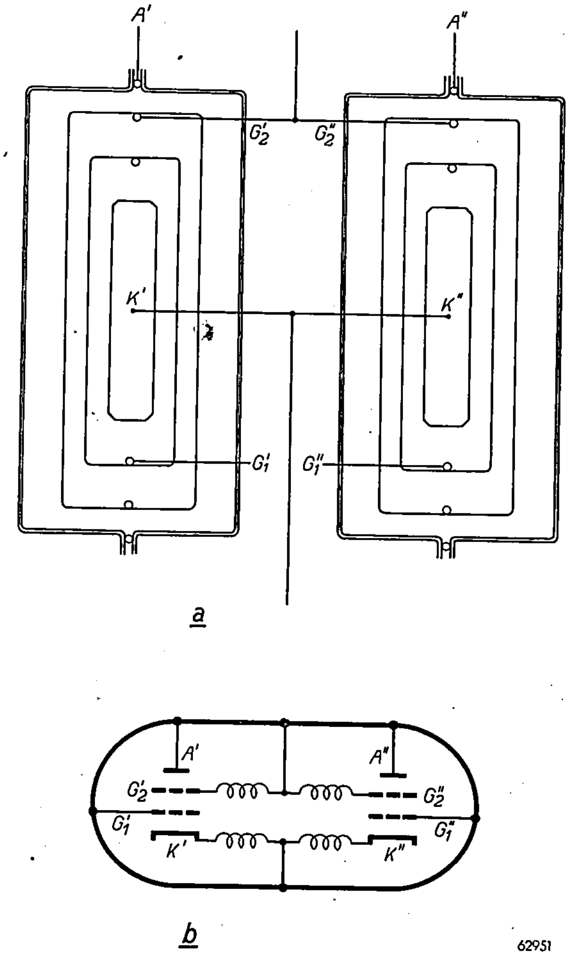

Fig. 2. (*a*) Cross section of a double tetrode of the old design. K', K'' cathodes; G_1', G_1'' control grids; G_2', G_2'' screen grids; A', A'' anodes. In the equivalent diagram (*b*) the stray self-inductances in the leads of the cathodes and screen grids are indicated. (The stray capacitances that are also present are not indicated.)

The double tetrode QQE 06/40

Construction

A double tetrode of the type QQE 06/40, illustrated in *fig. 3*, contains one indirectly heated, nickel cathode in the form of a roughly rectangular tube (*fig. 4*). Only the long, slightly convex sides of this tube are coated with an emitting material, so that really 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 400 Mc/s the aforementioned effect of self-inductance in the cathode interconnections is quite negligible. The resistance of this connection is likewise very small, even at high frequencies, due partly to the fact that the working temperature of the cathode lies above the Curie point of nickel, so that permeability is 1 and consequently there is but little skin effect.

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8) M. J. O. Strutt and A. van der Ziel, A variable amplifier valve with double cathode connection suitable for metre waves, Philips Techn. Rev. 5, 357-362, 1940.

9) W. G. Wagener, 500-Mc transmitting tetrode design considerations, Proc. Inst. Rad. Engrs. 38, 611-619, 1948.

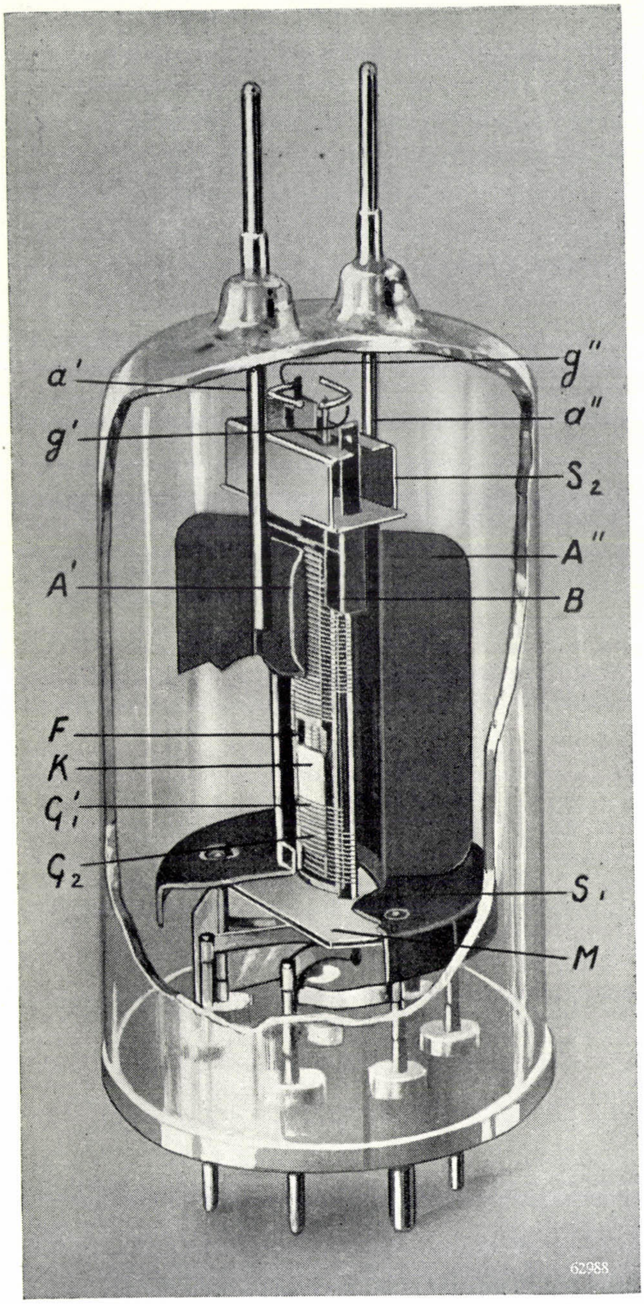

Fig. 3. Photograph of the double tetrode QQE 06/40 cut open to show the inside. K is one of the emitting cathode surfaces, F one of the filaments, G_1' one of the control grids, G_2 the screen grid, A', A'' the anodes, B one of the beam-plates, S_1 the lower screen screening the mica plate M in which the electrodes are fixed. The rods g', g'' are connected to the grids G_1' and G_1'' respectively and together with the anode poles a'' and a' form neutralizing capacitors. The box S_2 connected to the cathodes and the plates B screens the neutralizing capacitors from the electrode systems.

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 made in the form of a ladder. The extremely thin horizontal grid wires are curved so that when they expand the distance between the grid and the cathode is not reduced and thus there is no risk of short-circuiting.

The control grids are made of molybdenum wire plated with a thin layer of gold. This plating reduces the resistance at high frequencies and minimizes the risk of thermionic emission from the grid.

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. But at the same time 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 the control grid belonging to it, and in the absence of such compensation the valve might tend to oscillate. 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 welded onto one of the extended support rods of the control grid belonging to the other anode (see fig. 3). The capacitance is practically equal to that between an anode and its corresponding control grid. In this way a neutralization is obtained which is entirely independent of the frequency at which the valve is working.

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

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

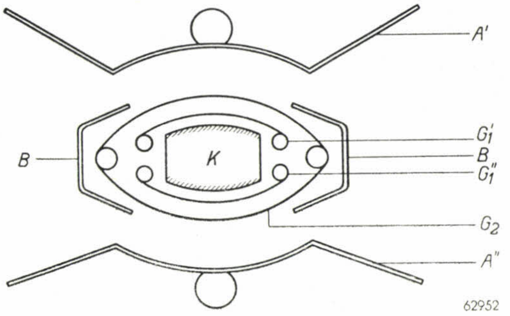

Fig. 4. Horizontal cross section of the QQE 06/40 valve. For the meaning of the letters see fig. 3.

electrons cannot reach the screen grid when the anode current is large.

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 valve.

As is the case with receiving valves, in the QQE 06/40 a mica disc is used for fixing the mutual positions of the electrodes. This plate is screened from the strong electric field of the anodes, so that there are practically no dielectric losses in the mica, which again makes for good efficiency.

Except for the anodes, whose leads and supporting rods pass through the top end of the hard-glass envelope (fig. 3), the rest of the electrode system is mounted on a base of sintered glass [10]), into which seven rods of molybdenum have been fused. Three of these rods extend farther into the envelope than the others and carry the screening of the mica plate. This screening plate together with the beam-plates welded onto it form a framework, in which the cathode and the grids are fixed. Thus an exceptionally rugged construction is obtained, which makes the valve resistant to severe shocks.

Electrical properties

As already mentioned, the cathode is heated by means of two filaments interconnected at one end. These filaments can be connected either in parallel or in series as required, in view of the fact that some motorcars have 6 V batteries while others have batteries of 12 V; the total consumption is thus 6.3 V, 1.8 A or 12.6 V, 0.9 A respectively.

The D.C. anode voltage is max. 600 V at frequencies below 250 Mc/s, max. 400 V at frequencies above 300 Mc/s and max. 500 V in the intermediate frequency range; the screen-grid voltage is 250 V. These voltages can be derived from a rotary converter or from a transformer working together with a vibrator. The dissipation of each of the anodes may amount to 20 W and that of the screen grid to 7 W.

The input capacitance measured between the two control grids is about 6.7 pF, while the output capacitance between the two anodes is about 2.1 pF.

The feed-back of each anode upon its corresponding control grid is quite insignificant, thanks to the built-in neutralizing capacitors, so that the QQE 06/40 cannot 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, which can be taken, for instance, from an EL 41 valve.

The highest frequency at which the QQE 06/40 can still operate with a reasonable efficiency is about 430 Mc/s (wavelength 0.70 m). It can work at still higher frequencies but then the power gain is no greater than that of an equivalent triode.

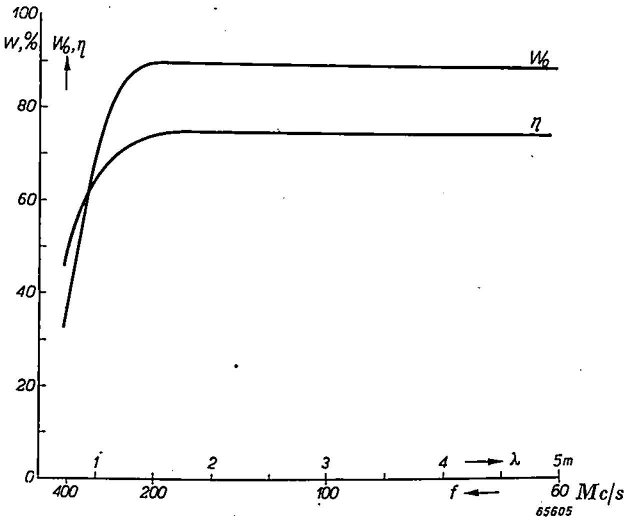

Fig. 5. Output W_0 and efficiency η [11]) of the QQE 06/40 valve as functions of the wavelength λ and the frequency f.

In *fig. 5* the output and the efficiency [11]) have been plotted as functions of the wavelength. It is seen, for instance, that at frequencies below 200 Mc/s 90 W can be generated with an efficiency of about 75%, and that at a frequency of 300 Mc/s these figures are 70 W and 65% respectively.

The double tetrode QQC 04/15

Construction

In cases where a lower output suffices there is need of a smaller and less expensive valve, and it is with a view to meeting this need that the QQC 04/15 valve has been developed, an illustration of which is given in *fig. 6*.

The construction is analogous to that of the QQE 06/40 in that the QQC 04/15 is likewise a double tetrode with one screen grid common to both the electrode systems (see the cross section in *fig. 7*).

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[10]) E. G. Dorgelo, Sintered glass, Philips Techn. Rev. 8, 2-7, 1946.

[11]) As usual, here efficiency is understood to be the ratio of the output W_0 to the D.C. power fed to the anodes.

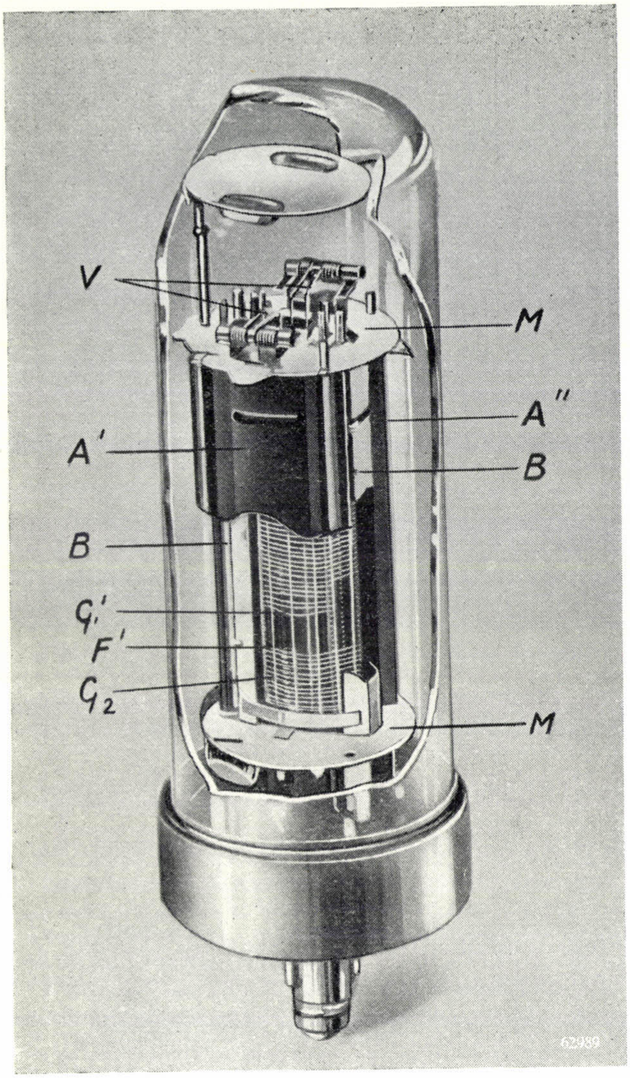

Fig. 6. Photograph of the double tetrode QQC 04/15 cut open to show the inside. F' one of the directly heated cathodes, G_1' one of the control grids, G_2 screen grid, A', A'' anodes, B beam-plates, M mica disc, V springs keeping the filaments stretched.

One point of difference, however, lies in the cathodes, which in this construction are directly heated and each consists of a V-shaped, oxide-coated filament. Such a cathode requires less heating power than that needed for a corresponding indirectly-heated cathode, whilst also the thermal inertia is much less. The cathode of the QQC 04/15, which consumes 4.3 W, reaches its working temperature 1.5 seconds after switching on, so that, in order to avoid unnecesary draining of the battery, the filament current can quite well be switched off while the transmitter is not working.

The two V-shaped filaments are connected in series and the common point is connected to a base pin.

A directly heated cathode causes a greater input damping than an indirectly heated one, and for this reason it was not necessary to use neutralizing capacitors in the QQC 04/15, but on the other hand a relatively larger driving power is needed.

The envelope is made of soft glass. This, it is true, cannot withstand such a high temperature as the hard glass of the QQE 06/40, but it has the advantage that the valve can be manufactured on the machines equipped for the mass production of receiving valves. Thus the QQC 04/15 has the appearance of a receiving valve (fig. 6), namely that of one of the key type.

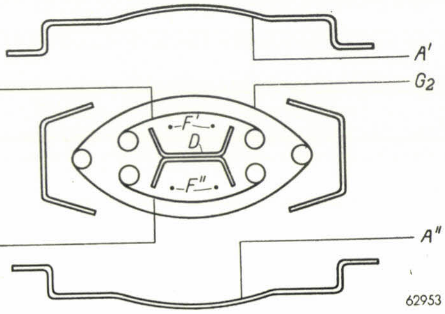

Fig. 7. Horizontal cross section of the QQC 04/15 valve. F', F'' cross section of the two V-shaped, directly heated cathodes, between which is a screen D. The other letters are as indicated in fig. 4.

A difference compared with normal receiving valves lies in the base pins, which are of chrome iron and coated over their entire length with a thin layer of copper, in such a way, of course, that the leads are vacuum-tight. The resistance of this layer at very high frequencies is much less than that of non-coated pins [12]).

The QQC 04/15 is well able to withstand the mechanical shocks occurring in automobiles and trains, just as well as the other valves used in the transmitter and in the receiver.

Electrical properties

At a voltage of 6.3 V the filament current of the QQC 04/15 is 0.68 A. When a 12 V battery is used two of these valves can be connected in series.

The D.C. anode voltage is max. 400 V and the screen-grid voltage 200 V. Each of the anodes has a dissipation of 8 W and the screen grid 7 W.

When used in push-pull the QQC 04/15 has an input capacitance of 5.7 pF and an output capacitance of 1.7 pF. The capacitance between an anode and its corresponding control grid is 0.05 pF.

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[12]) Cf. K. Rodenhuis, Two triodes for reception of decimetric waves, Philips Techn. Rev. **11**, 79-89, 1949 (No. 3), in particular p. 81.

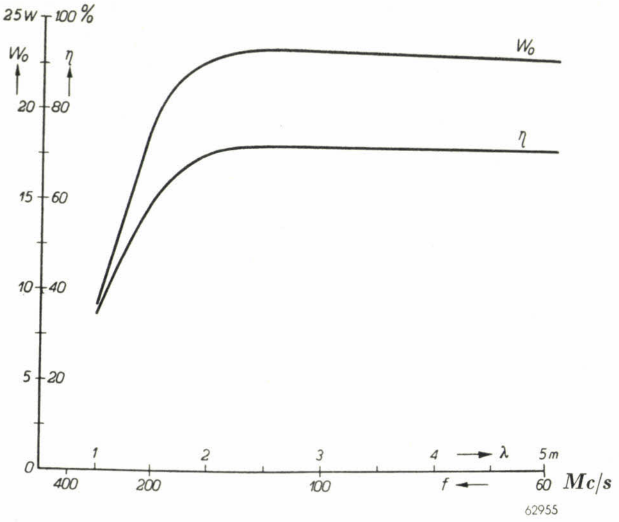

Fig. 8. Output W_0 and efficiency η [11]) of the QQC 04/15 valve plotted as functions of the wavelength λ and the frequency f.

Fig. 8 shows the output and efficiency of this valve as functions of the wavelength. The output at frequencies of 150 and 300 Mc/s, for instance, is respectively 22.5 W and 9 W, with efficiencies of over 70% and 34%.

Mobile installations with the new valves

Philips' Telecommunication Industry (Hilversum, Holland) is turning out a mobile installation, type SRR 192, with the transmitter and the receiver built together in a metal case that can be carried in the boot of a car (*fig. 9*). The control panel, the microphone and the loudspeaker are mounted in front of the driver's seat. The whole of the installation is tropic-proof.

The transmitter has a QQE 06/40 as output valve and offers the choice of two frequencies within a range of 300 kc/s. Frequency-multiplication is obtained by means of three EF 42 valves and one EL 41 valve. Frequency modulation is applied.

When this apparatus is used for a fixed station it can be supplied from the A.C. mains. Between two of these sets, one mobile and the other installed at a fixed point with an aerial 25 m above the ground, in open country a range of 20 to 25 km can be covered.

For further particulars reference is made to the article quoted in footnote [3]).

One of the authors of the present article (P.Z.) has designed a smaller mobile installation which likewise works on the frequency-modulation system and has a carrier frequency of 186.24 Mc/s [13]). This employs four QQC 04/15 valves, one of which in the output stage and three for frequency multiplication.

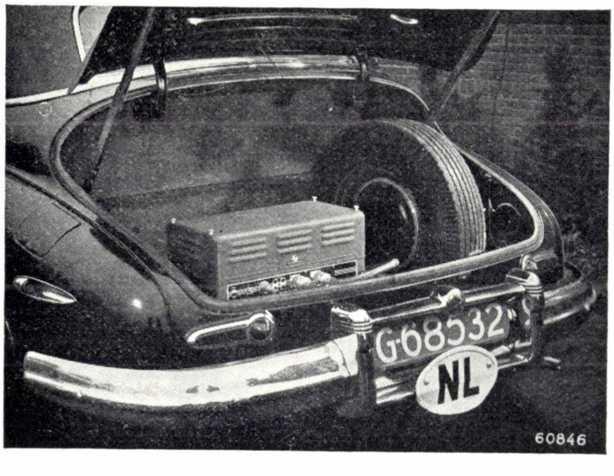

Fig. 9. Mobile transmitter and receiver, type SRR 192, in the boot of a motorcar.

Summary. Following upon some introductory remarks concerning mobile radio stations such as are now being used for communication between automobiles or trains (mutually and with a fixed point), a description is given of two transmitting valves that have been specially developed for this purpose. These are both double tetrodes (types QQE 06/40 and QQC 04/15) in which the two electrode systems are so constructed that the screen grids form mechanically one whole, by this means completely avoiding the complications arising from stray self-inductance in separate screen-grid leads. In an output stage the two electrode systems of a valve are preferably used in push-pull. For frequency multiplication they can be connected in cascade. The QQE 06/40 type has an indirectly-heated cathode of a special construction, owing to which only a very little driving power and thus few stages are needed. Two built-in neutralizing capacitors provide for good stability. The cathodes of the QQC 04/15 type of valve are directly heated and consequently there is little thermal inertia. At frequencies of 200 Mc/s and below the QQE 06/40 can generate 90 W with an efficiency of about 75%, and at 300 Mc/s the output is 70 W with 65% efficiency. For the QQC 04/15 these figures are respectively about 22.5 W with over 70% and 9 W with 34% efficiency.

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[13]) This design is fully described in "QQC 04/15 Double Tetrode for Mobile Transmitting Equipment", a technical publication issued by the Electronic Tube Division of Philips, Eindhoven, Holland.