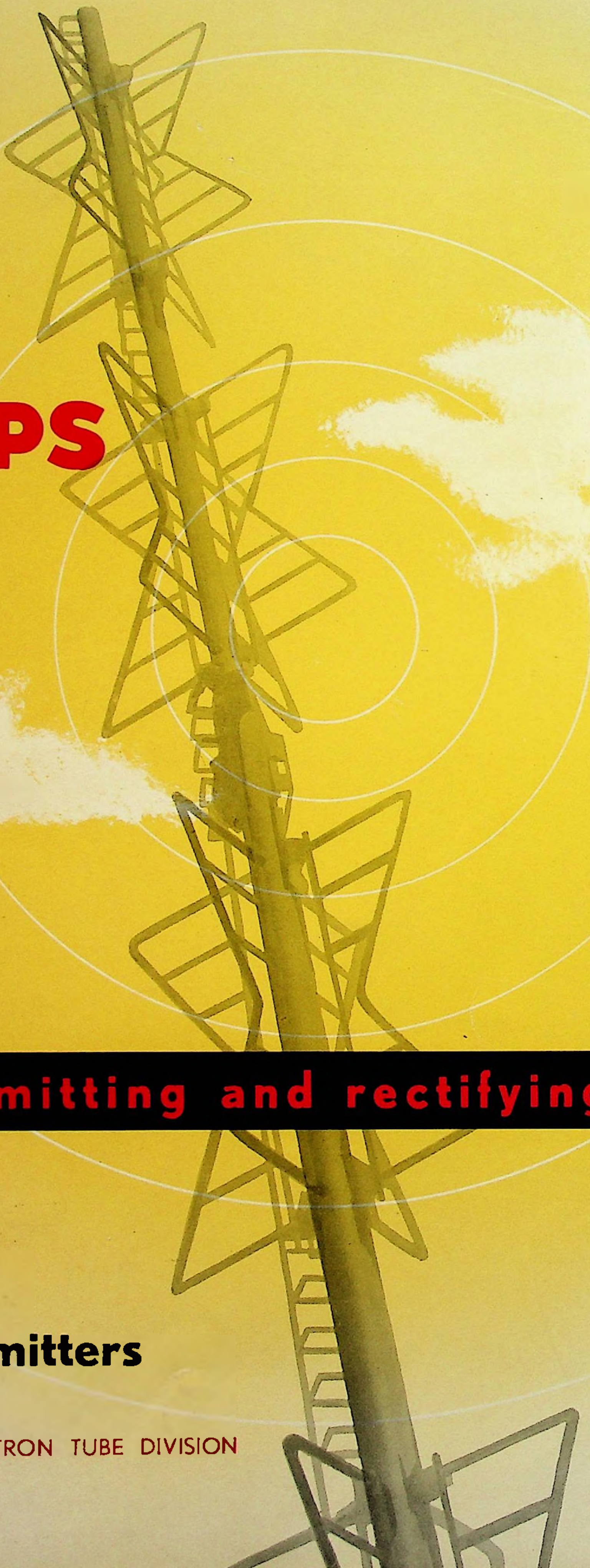

PHILIPS

Transmitting and rectifying tubes

for
T.V.
transmitters

PHILIPS ELECTRON TUBE DIVISION

PREFACE

As a consequence of the demand for more elaborate TV programmes to be transmitted on a wide range, an increasing activity in the field of television broadcasting can be observed.

Because of the specific nature of the transmitted TV signals, the range of a TV transmitter is strongly limited. A number of additional transmitters is therefore required for the transmission of a TV programme over a large area. Seeing that the interference area of a transmitter stretches further than its useful range, different frequency channels have to be allocated to these additional transmitters, as far as mutual interference is to be expected. Moreover, when more than one programme is being broadcast in the same area, again extra channels are required. In general, the small amount of channels in the allocated lower-frequency band I will be insufficient, so that more and more use is made of the higher-frequency bands III, IV and V, in which more channels are available.

With the extension of the number of TV transmitters, a trend to use the higher-frequency bands can be recognised. The demands made on the transmitting tubes for these high frequencies, however, differ from those for band I, so that specially designed tubes became necessary. Obviously these tubes must also answer the special requirements involved in TV broadcasting (large bandwidth).

Though application of the higher-frequency bands necessarily introduces some disadvantages (more interference by "ghosts"), these drawbacks manifest themselves in a lesser degree in sparsely populated areas (islands, valleys), so that in that case small higher-frequency band TV transmitters can be used advantageously, the more so because the lower TV frequencies are preferably reserved for large centres of population.

In this Bulletin descriptions are given of transmitting and rectifying tubes for TV transmitters, preceded by general observations on the requirements made on these tubes and on their use, together with a few practical applications.

CONTENTS

INTRODUCTION

CHARACTERISTICS OF TV TRANSMITTERS

Although in principle there is no difference between common AM sound transmitters and (amplitude-modulated) TV vision transmitters, some practical considerations make it necessary to design a TV transmitter on quite different lines. These considerations are discussed below.

BANDWIDTH

The carrier of an AM sound transmitter is modulated with audio signals having a frequency range from approx. 16 c/s to a few kc/s. TV transmitters, however, are modulated with video signals covering a much wider frequency spectrum, viz. from 0 to approx. 5 Mc/s. Since the channel width of an AM transmitter is proportional to the highest modulation frequency to be transmitted, it is obvious that the channel of a TV transmitter must be very much wider than that of an AM sound transmitter.

OPERATING FREQUENCY

The carrier frequency of an AM transmitter must be at least a few times higher than the highest modulation frequency, so that TV transmitters must operate on short waves (in practice meter or decimeter waves). For this reason all TV channel allocations are in the VHF and UHF bands.

SINGLE SIDEBAND

To reduce the frequency spectrum occupied by a TV transmitter, a single-sideband system is very often applied, in which the greater part of one of the sidebands of the transmitted signal is suppressed. It is obvious that, in order to compensate for this sideband suppression, measures should be taken in the receiver, which ensure that the overall frequency response nevertheless answers standard requirements. This is achieved by giving the receiver a particular frequency response curve.

DC COMPONENT IN THE VIDEO SIGNAL

Another difference between an AM sound transmitter and a TV vision transmitter is to be attributed to a complete video signal containing information about the average brightness of the picture, represented by the d.c. level of the video signal. After the video signal has passed through the RC-coupled amplifiers (which actually occurs in the modulation amplifier of the transmitter), the d.c. component is lost, so that it must be restored before modulation is achieved [1]). D.C. restoration is obtained by means of a clamping circuit that maintains the black level at a constant value.

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[1]) In transformer-coupled circuits the d.c. component is obviously also lost but these are not commonly used in video amplifiers.

SOUND TRANSMITTER

The sound accompanying the vision signal is emitted by a separate transmitter· operating at a frequency lying very close to the vision spectrum. The carrier frequency of the sound transmitter may be either at the higher or at the lower side of the vision carrier, and the modulation system may be either AM or FM, depending on the local standards. A frequency-modulated sound transmitter facilitates the use of the intercarrier system in the receivers.

STANDARDS

Frequency allocations and standards concerning bandwidth and composition of the complete video and audio signals are subjected to regulations imposed by local and/or international authorities. Belgium, France and the United Kingdom have separate standards, whereas the other countries of Western Europe and the United States of America have TV standards according to the CCIR and FCC respectively. The most important items of these standards are tabulated below.

	CCIR	France	U.K.	FCC	Belgium	
Frequency bands (Mc/s) I	41-68	41-67	41-68	54-88	41-68	41-67
III	174-216	162-215		174-216	174-216	162-215
IV (V)	470-960			470-890		
Channel width (Mc/s)	7	13.15	5	6	7	7
Polarisation	arbitr.	hor.	vert.	hor.	arbitr.	hor.
Vision transmitter						
Bandwidth (Mc/s)	5	10.6	3	4	5	5
Sense of modulation	neg.	pos.	pos.	neg.	pos.	pos.
Modulation depth (%)						
sync. pulses	100	0	0	100	100	0
black level	75	25+2.5	30	75-80	75	25+2.5
white level	10	100	100	10	10	100
Number of lines/picture	625	819	405	525	625	819
Number of pictures/sec	25	25	25	30	25	25
Frequency difference between vision and sound carriers:						
$f_{sound} - f_{vision}$ (Mc/s)	+ 5.5	-11.15	-3.5	+4.5	+5.5	+11.15
Sound transmitter						
Type of modulation	F.M.	A.M.	A.M.	F.M.	A.M.	A.M.
Max. freq. deviation (100 % mod.) (kc/s)	50	---	---	25	---	---
Time constant pre-emphasis filter (μsec)	50			75		

SHORT-WAVE CONSIDERATIONS

With a view to the fact that the propagation of very high and ultra-high frequencies resembles that of optical waves, the service area of a TV transmitter depends mainly on the range of view, which in turn depends on the antenna height and the presence of intervening objects, such as mountain ridges, etc. In densely populated areas transmitting antennas are therefore often erected on top of high buildings.

The serviceability of the fringe area is determined by the transmitted power, by the sensitivity of the receivers and by the directional properties of the transmitting and receiving antennas. This imposes a certain minimum value on the transmitting power in each particular case, apart from necessitating the field strength to be raised above that of local interference.

Most conventional high-power transmitting tubes for medium waves are unsuitable for use in the power stage of TV transmitters on account of their high operating frequency. The factors limiting the suitability of tubes at high frequencies are:

(*a*) damping due to transit time effects, occurring when the distances between the electrodes are such that the time taken by an electron to cover these distances becomes comparable with the duration of one cycle of the alternating voltage;

(*b*) phase shifts occurring when the active length of the electrodes exceeds approximately 0.1 of the wavelength;

(*c*) undesired couplings caused by interelectrode capacitances, self-inductances and mutual inductances of the electrodes and their connections;

(*d*) losses due to the heating by RF currents of the electrodes and their connections;

(e) dielectric losses in the glass envelope and other insulators;

(*f*) constructional difficulties of the circuits due to the internal impedances of the tubes constituting a considerable part of the external circuits.

Measures taken in the construction of transmitting tubes to render them suitable for use at high frequencies are i.a.:

(*a*) reduction of the spacing between and the active dimensions of the electrodes;

(*b*) shaping the electrode connections as discs or rings, which are connected to the electrodes along the entire circumference; this makes them adapted for use in coaxial circuits;

(*c*) silver- or gold plating of the electrode connections to achieve good RF conduction;

(*d*) avoiding insulating materials inside the tubes, specially at places subject to high RF field strengths.

The considerations mentioned above concern only the short-wave operation of transmitting tubes without particular applications being taken into account. Additional requirements, however, are involved with the special use of transmitting tubes in vision transmitters. In one of the following sections these requirements will be discussed in greater detail (page 9).

NOTES ON TV TRANSMITTERS

THE VISION TRANSMITTER

BLOCK DIAGRAM

Fig.1 shows a block diagram of a typical vision transmitter.

The oscillator is crystal-controlled in order to obtain the required frequency stability. It is followed by a buffer stage consisting of a class-A amplifier which prevents the following stages from influencing the oscillator. As is common practice in transmitters, frequency multiplication is applied, which has the advantage that the effect of feedback is very small, whilst only a small number of stages operating at the highest frequencies is required.

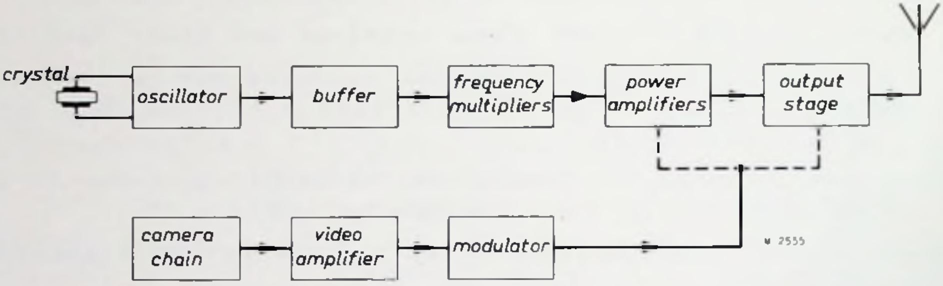

Fig.1. Simplified block diagram of a vision transmitter.

Since the stabilised supply unit, which is necessary for obtaining the required frequency stability of the crystal oscillator, can be realized more easily at a low than at a high level, and frequency multipliers have a relatively poor efficiency, the oscillator is generally made to operate at a low power level. It is therefore also necessary to apply power amplification. Mostly frequency multiplication and power amplification are accomplished in the same stage. The power level is then raised so that it is sufficient to deliver the required driving power for the final power stage.

MODULATION

High- or low-level modulation?

Modulation of the carrier can in principle be performed in any stage, from the oscillator to the final power stage. Practical considerations, however, determine the power level at which modulation is applied. Modulation of the oscillator of the buffer stage must be avoided because this would impair the stability of the carrier frequency [1]). Low-level modulation in one of the early power stages has the drawback that every stage following the modulator must pass a wide frequency band. As a result, these stages have a low efficiency and a low power gain, so that a large number of stages is necessary. Moreover, broadband interstage circuits are difficult to adjust, also with a view to interaction, which can never be entirely avoided.

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[1]) The maximum permissible deviation of the carrier frequency amounts to ± 250 c/s

Since the required modulation power increases with increasing RF power level of the modulation stage, it is clear that low-level modulation has the advantage of only a small modulation power being required. An additional advantage of low-level modulation, especially in single-sideband systems, is that no separate vestigal sideband filter need be used if the resonant circuits of the amplifier stages are detuned with respect to the carrier frequency (see Fig.2).

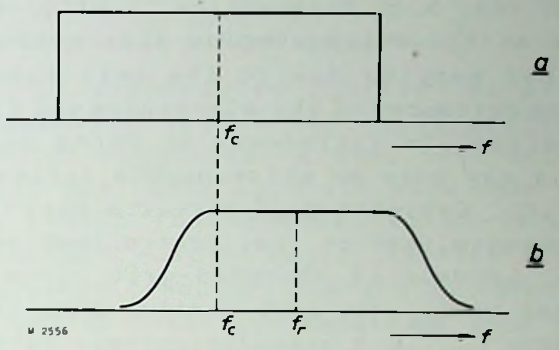

Fig.2. Sideband suppression by detuning of the resonant circuits:

a) frequency spectrum of the modulated carrier wave.

b) overall frequency response curve of the R.F. amplifying stages (f_c = carrier frequency, f_r = resonant frequency of the R.F. circuits.)

High-level modulation, applied in the final power stage, has the advantage of all preceding RF stages being able to operate in the highly efficient class-C adjustment, so that only a small number of intermediate power stages with a high power gain are necessary.

Considering the advantages and disadvantages of low- and high-level modulation, the latter solution is as a rule preferred in the case of a vision transmitter up to approximately 5 kW.

Anode or grid modulation?

Although the modulation characteristic is better in the case of anode modulation than with any other type of modulation, practical difficulties render the use of anode modulation of transmitting tubes in vision transmitters impracticable unless the RF power is relatively low. This is because up till now it has proved unfeasible to construct video amplifiers having adequate amplitude and phase characteristics (transient response) over the entire frequency band at a few thousands of volts and at such a high power level as required for anode modulation of high-power transmitting tubes. In practice anode modulation is therefore confined to low power levels.

Control-grid modulation needs only a relatively small modulation power. The disadvantage of this type of modulation compared with anode modulation is a higher non-linear distortion, which in the case of TV is less important than in audio transmitters because the human eye is less sensitive to contrast deviations than the ear to the occurrence of harmonics. In most vision transmitters control-grid modulation in one of the high-power stages is therefore applied, rather than anode modulation in a preceding stage.

TRANSMITTING TUBES FOR THE OUTPUT STAGE

Triode or Tetrode

Two common types of conventional density-modulated tube that are generally used in the final power stage of transmitters can be distinguished, viz. the triode and the tetrode. In general, triodes are used either in neutralized grounded-cathode circuits or in grounded-grid circuits.

Neutralisation at very high frequencies is often very difficult to perform, because at these frequencies the feedback admittance of the tube is rather complex due to the self-inductances, mutual inductances and capacitances of the electrodes and their connections. Moreover, neutralisation introduces an extra capacitance in the circuit, and this may have an unfavourable influence on the bandwidth (see page 10). Grounded-grid circuits have the advantage that they need not be neutralised or that neutralisation can be achieved by simple means, because in grounded-grid circuits the feedback admittance, formed by C_{ak}, is much smaller than that formed by the feedback admittance C_{ag} in a grounded-cathode circuit.

Much more driving power is, however, required for a grounded-grid circuit than for a corresponding grounded-cathode circuit [1]) because in the former the load is partially common to both the input and output circuit, As a result, in comparison with the grounded-cathode circuit, a grounded-grid circuit needs a high-power driver stage. The overall efficiency of the transmitter, however, is hardly affected, since the difference between the driving power, needed for a grounded-grid circuit and that needed for a corresponding grounded-cathode circuit, is transferred to the output circuit (load). The driving power of, for example, two tubes TBL 6/6000 in push-pull grounded-grid connection amounts to 2240 watts (75 Mc/s, class-C telegraphy), from which 1820 watts, i.e. 80%, is part of the output power, the remainder being lost by grid dissipation and in the grid bias source. The grounded-grid circuit is mostly preferred to the neutralised grounded-cathode circuit, and the larger driver is accepted. The low input impedance of the grounded-grid circuit is particularly favourable for TV, with a view to the resulting large bandwidth of the input circuit.

Certain advantages of a grounded-cathode triode and a grounded-grid triode are combined in the tetrode, viz. a high power gain and easy neutralisation [2]). However, at higher frequencies it may be necessary to use tetrodes in a double grounded-grid circuit (both the control-grid and the screen grid grounded) owing to the internal feed-back admittances. It is obvious that, similar to the grounded-grid triode, a double grounded-grid tetrode also needs a high driving power. Moreover, problems arise concerning the cooling

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[1]) This is valid only up to a given frequency, since with increasing frequency the input admittance of a grounded-cathode circuit increases due to the influences of the self-inductance of the cathode connection inside the tube.

[2]) Although neutralisation of tetrodes is not always required for stability reasons, it may be of advantage for obtaining a symmetrical response curve in the case of band-pass filter coupling.

of the screen grid and the bypassing of this electrode to the cathode, so that in practice the use of tetrodes is limited to approx. 2.5 kW output power per tube. As far as the power supply is concerned, the tetrode possesses the advantage over the triode that the (high) anode supply voltage need not be stabilised. It is true that the screen-grid voltage must be stabilised, but, since this voltage is much lower than the anode voltage, this is easier to achieve than stabilisation of the anode voltage of the triode.

THE TRANSMITTING TUBE AS A LINEAR AMPLIFIER

For transmitting an unmodulated carrier, no problems arise as regards the frequency response and amplitude linearity of the transmitter. Special requirements are, however, imposed on the transmitting tubes and their circuits when used as linear power amplifiers in a vision transmitter, which is due to the wide frequency spectrum that must be amplified with little distortion. Since the highest video frequency has a high value (some Mc/s), it is obvious that special attention should be paid to the bandwidth of the stage in which a modulated TV signal is amplified.

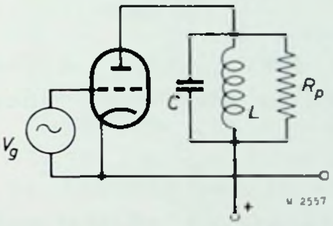

Fig.3. Basic diagram of a tuned R.F. amplifying stage.

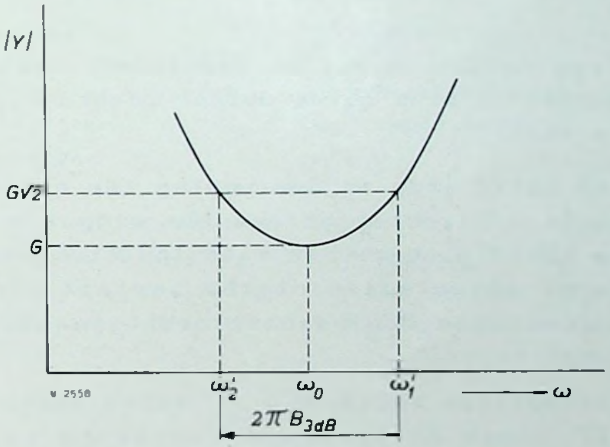

Fig.4. The modulus of the admittance of the resonant circuit of Fig.3 ($|Y|$) as a function of the angular frequency ω.

Fig.3 shows the basic diagram of a tuned RF amplifier. The anode circuit of the tube consists of a parallel-tuned circuit. R_p represents the load (which may be formed either by a following amplifying stage or by the antenna) and the damping of the circuit and the tube.

The 3 dB bandwidth of this circuit can be calculated as follows: the modulus of the admittance $|Y|$ of the circuit is:

$$|Y| = \sqrt{G^2 + (\omega C - 1/\omega L)^2} \qquad (G = 1/R_p) \qquad (1)$$

The graphical representation of $|Y|$ as a function of ω has been plotted in Fig.4. The voltage across the circuit is a maximum when $|Y|$ is a minimum, which occurs when $\omega C - 1/\omega L = 0$. The minimum value of $|Y|$ is G. The values of ω for which the voltage is decreased to $1/\sqrt{2}$ of its maximum value (ω') can be calculated from:

$$G\sqrt{2} = \sqrt{G^2 + (\omega' C - 1/\omega' L)^2}$$

There are two positive roots for ω', viz.:

$$\omega_1' = \frac{GL + \sqrt{G^2L^2 + 4LC}}{2LC} \quad \text{and} \quad \omega_2' = \frac{GL + \sqrt{G^2L^2 + 4LC}}{2LC}$$

The 3 dB bandwidth is defined as: $B_{3\mathrm{dB}} = \omega_1' - \omega_2'/2\pi$, so that after substitution:

$$B_{3\mathrm{dB}} = G/2\pi C \qquad \text{or} \qquad B_{3\mathrm{dB}} = 1/2\pi R_p C \tag{2}$$

R_p can again be expressed in terms of output power and anode current, since

$$W_0 = i_{a1}^2 \cdot R_p \qquad \text{or} \qquad R_p = \frac{W_0}{i_{a1}^2}. \tag{3}$$

where W_0 denotes the output power and i_{a1} denotes the first harmonic component of the fundamental frequency of the anode current. Eq.(3) substituted in eq.(2) gives:

$$B_{3\mathrm{dB}} = \frac{i_{a1}^2}{2\pi C W_0}. \tag{4}$$

From eq.(4) it may be concluded, that, in order to obtain a large bandwidth at a given output power, i_{a1} should be high and C should be small.

The first step in decreasing the capacitance of the circuit is to shunt L directly across the output capacitance (C_o) of the tube, so that C_o, together with the stray capacitances, constitutes the total capacitance of the circuit. In that case a small circuit capacitance can be obtained by using a tube with a small output capacitance.

The maximum value of i_{a1}, which under normal operating conditions (RF class B) is proportional to the direct anode current, is limited amongst others by the saturation current of the cathode. In order to combine a high saturation current and small interelectrode capacitances, the transmitting tube must therefore operate at a high current density.

Eq.(2) applies to the bandwidth of a single-tuned circuit. In practice the coupling between two RF amplifying stages in a TV transmitter is mostly formed by a double-tuned bandpass filter which is overcritically coupled to obtain a larger bandwidth than that of a single resonant circuit. Similar to the bandwidth of a single-tuned circuit being inversely proportional to the circuit capacitance, the bandwidth of a bandpass filter increases as the capacitances of the constituting tuned circuits decreases. Consequently, for obtaining a large bandwidth, not only the output capacitance of the tube to the anode circuit of which the bandpass filter is connected, but also the input capacitance of the following tube must be small [1]).

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[1]) The values of the bandwidth given in the operating conditions of the tubes are always' applicable to a single-tuned circuit

THE GRID-MODULATED AMPLIFIER

Basic circuit

As mentioned previously, mostly control-grid modulation of TV transmitting tubes is applied. Fig.5 shows the basic circuit diagram of a typical modulator stage of a TV transmitter. Tube T_1 is the modulator tube, the anode voltage of which is superimposed on the RF grid voltages of the push-pull power amplifying tubes T_2 and T_3. L_1 is an RF choke to prevent RF voltages from entering the modulator. The RF power from the driver stage is applied to the grid circuit of T_2 and T_3.

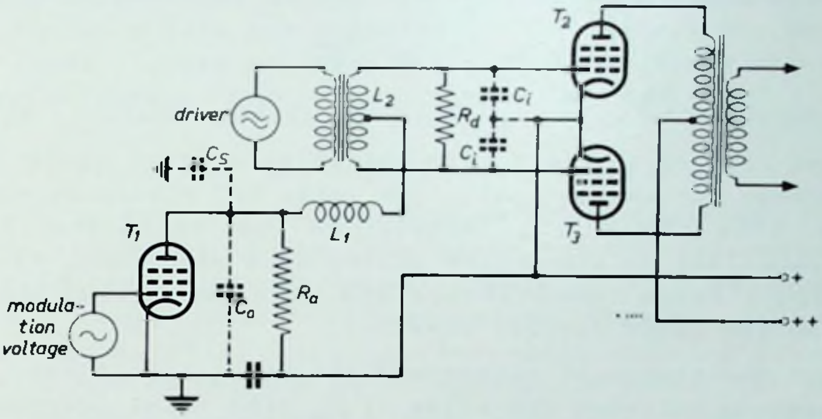

Fig.5. Diagram of a typical modulator stage of a grid-modulated vision transmitter. (C_o = output capacitance of T_1, C_i = input capacitance of T_2 and T_3, C_s = stray capacitances).

To maintain the dc level of the video signal, applied to the input of T_1, the modulator is connected directly to the grids of T_2 and T_3. The cathodes of T_2 and T_3 are connected to the anode supply voltage of T_1, so that the voltage drop across R_a forms the grid bias of T_2 and T_3.

The video bandwidth

The frequency of the signal applied to the control grid of T_1 covers a spectrum ranging from 0 up to a few Mc/s. Due to the presence of the capacitances across R_a, the frequency response curve falls at the higher frequencies. When the impedances of L_1 and L_2 are neglected for the video frequencies, the total capacitance C across R_a is formed by the parallel connection of: (*a*) the output capacitance of T_1 (C_o), (*b*) the parallel connection of the input capacitances of T_2 and T_3 (C_i), and (c) the stray capacitances (C_s) (see Fig.6).

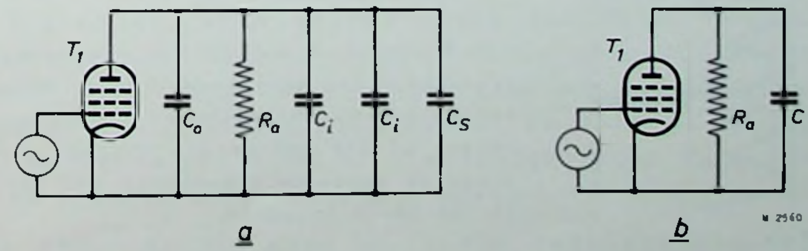

Fig.6a. Equivalent circuit diagram for video signals of the modulator tube T_1 and its anode circuit.
b. Simplified diagram of Fig.6a. ($C = C_o + 2C_i + C_s$).

The circuit of Fig.6b differs from that of Fig.3 in that the inductance L is omitted in the former. Since L does not appear in the formula for the 3 dB bandwidth of the circuit of Fig.3, and no approximations have been introduced in the derivation of this formula, eq. (2) also applies to the circuit of Fig.6b.

Eq.(2) reveals that for obtaining a large bandwidth, the product R_aC should be as small as possible [1]. The resistance R_a can, however, not be lowered infinitely, since the amplitude of the video signal would then become too small. A practical criterion for the performance of the circuit is therefore the product of maximum gain and bandwidth, viz:

$$S \cdot R_a \cdot B_{3\mathrm{dB}} = \frac{S}{2\pi C}. \qquad (5)$$

where S denotes the mutual conductance of the modulator tube.

It follows from eq.(5) that, for obtaining a large bandwidth without affecting the maximum gain, the ratio S/C should be as high as possible. This condition is similar to that valid for the broadband RF amplifier, so that a tube acting as a modulator, too, should have a small output capacitance and a large current density (S depends on the anode current density).

To improve the transient response of the modulator it may, however, be necessary to decrease the value of R_p (the total damping), which is performed in practice by shunting the input circuit of T_2 and T_3 by an extra damping resistor R_d. The driver stage is thus preloaded, which has a favourable effect on the bandwidth of the RF input circuit. At the same time non-linearities, due to the grid current of T_2 and T_3, which only flows during part of the cycle, are decreased. (In the case of grounded-grid triodes the transferred output load also acts as a preload of the grid circuit.)

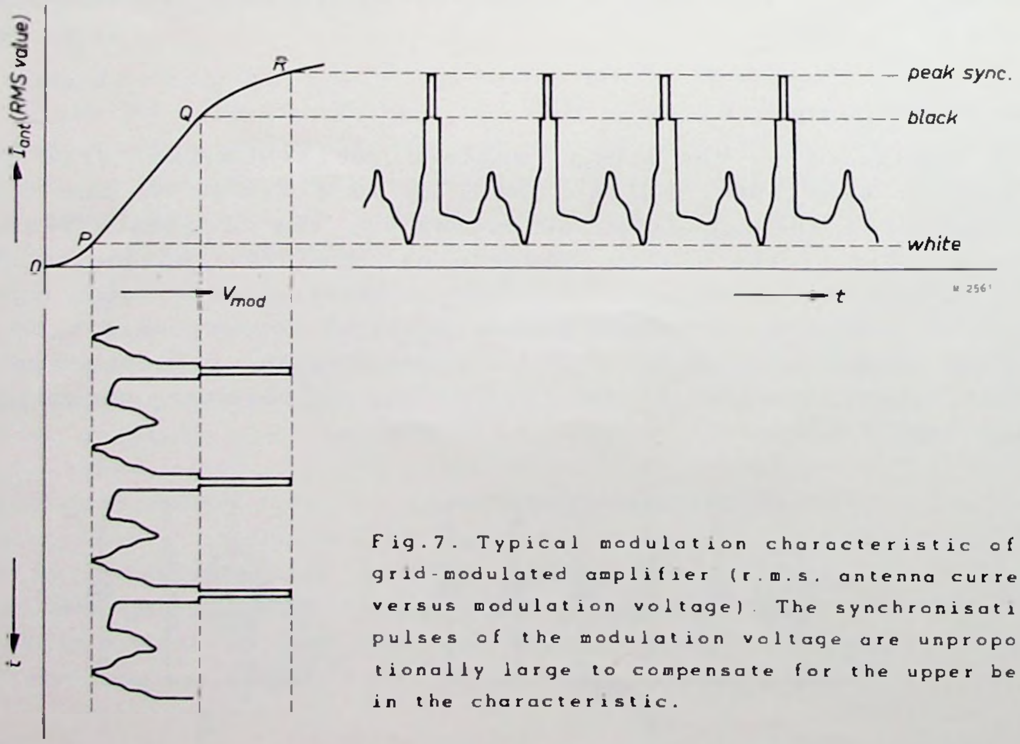

Fig.7. Typical modulation characteristic of a grid-modulated amplifier (r.m.s. antenna current versus modulation voltage). The synchronisation pulses of the modulation voltage are unproportionally large to compensate for the upper bend in the characteristic.

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[1] The requirements on the bandwidth are directly involved with the requirements made on the transient response of the modulator.

The modulation characteristic

The modulation characteristic of a grid-modulated amplifier is not quite straight, but shows two curved parts (see Fig.7 *OP* and *QR*). These curved parts cannot be used for modulating the carrier with the picture information without introducing distortion. Since with negative modulation of a TV signal the minimum signal corresponding to full "white" amounts to 10% of the maximum signal, the part *OP* of the modulation characteristic will generally be beyond the "visible" part of the signal. When moreover provision is made that the maximum "visible" signal (black), does not exceed point *Q* either, the only effect of the upper curved part will be that the synchronisation pulses are compressed. This effect may be compensated by rendering the synchronisation pulses in the video amplifier unproportionally high (sync. stretching, see Fig.7.)

Influence of tube types

The input impedance of the power stage is of much importance, as far as the influence of the tube types and the circuitry on the modulator is concerned. At output powers up to 5 kW, preferably tetrodes are used in the final power stage. They not only ensure a high power gain, which results in a small driving power being necessary, but also require little modulation power. The modulator can therefore be equipped with a relatively small tube with a small output capacitance resulting in a large bandwidth.

At output powers exceeding 5 kW, grounded-grid triodes are mostly used as linear amplifiers, because modulation of these large RF powers would require an impracticably large modulation power. When such triodes are grid-modulated, the grids should be earthed capacitively, the value of the capacitance being such that it forms a short circuit for RF currents. This capacitance may, however, not be too large since the bandwidth of the modulator would then become insufficient.

When a grounded-grid circuit is modulated, it should be remembered that the (unmodulated) driving power is for the greater part transferred to the load, so that a certain minimum amount of unmodulated power is always present in the output circuit. Care should therefore be taken that the transferred power from the driver never exceeds the lowest modulation level. Otherwise the driver should be modulated as well.

THE SET-UP OF THE POWER STAGE

Single-tube, parallel and push-pull circuits

When designing an output stage for a TV vision transmitter the question may arise, whether the stage should be composed of a single-tube circuit, of two or more tubes in parallel or of two tubes in push-pull. No stringent prescriptions can be given, since in cases where the pros and cons are to be weighed up, the preference and/or the experience of the designer can turn the scale. Some general remarks will therefore suffice.

The output stage should come up to the requirements set on the operating frequency, output power and bandwidth. A rough selection can be made by only taking into account those transmitting tubes that can amply be operated at the required frequency.

As a rule single-tube operation will be preferred when a suitable tube is available that agrees with the set-up of the transmitter.

When, however, the driver and the output coupling with the sideband filter or feeder is symmetrical, additional balanced-to-unbalanced transformers are required, which may render the use of a single tube objectionable, and preference may be given to a push-pull circuit. A push-pull circuit may also be used when the output power of one tube is insufficient, and no suitable larger tube is available. It stands to reason that, where only power considerations are concerned, a parallel circuit or a combined push-pull and parallel arrangement will do as well.

The question: single tube, push-pull or parallel circuit is narrowly related to the construction of the tubes. Co-axial tubes are specially suitable for use in cavity resonators or co-axial line circuits, and will therefore as a rule be used in single-tube circuits. Tubes the electrode connections of which are formed by pins, are less convenient for use in cavity resonators or co-axial line circuit.

Since in a push-pull circuit the input and output capacitances of the tubes are connected in series, the corresponding circuit capacitances are half those of the individual tubes. The corresponding load resistance is, however, doubled, so that the product *RC* remains unchanged. In a parallel circuit of two tubes the

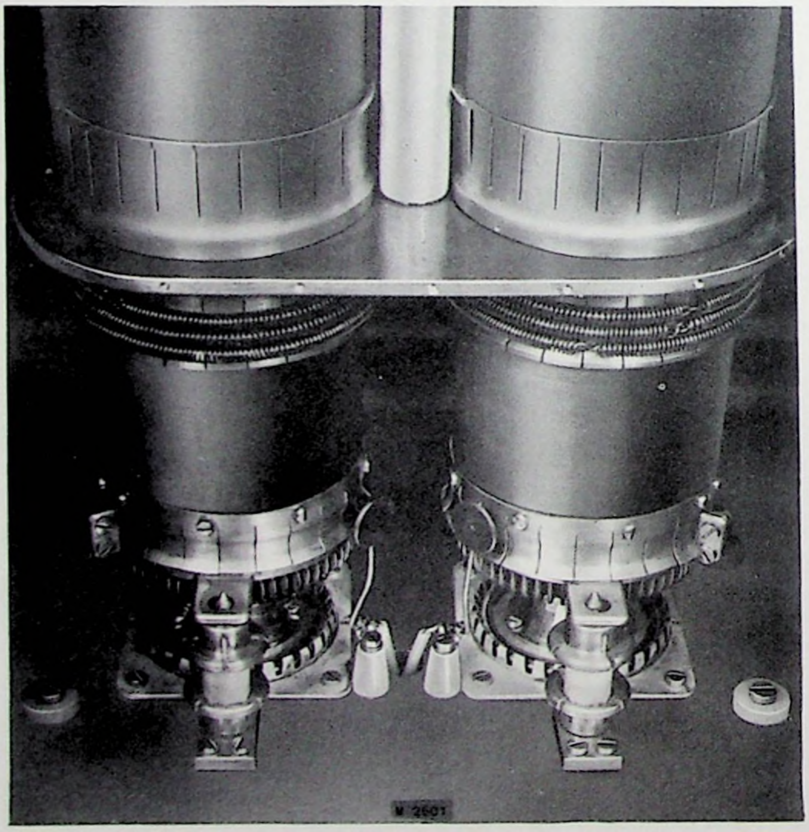

Fig. 8. Photograph of the anode circuit of a push-pull amplifier equipped with tetrodes. The neutralising capacitors are formed by two small circular plates near the anode connectors of the tubes. These plates are crosswise connected to the control grids, which are situated below the (earthed) metal screen. The screen grids of the tubes are capacitively connected to this screen.

capacitances of the input and output circuits are twice the corresponding capacitances of the tubes, but the load resistance is halved, so that in this case, too, the product RC remains the same. It may, however, be of interest, in view of the coupling and bandwidth, to keep either R or C low, which will influence the choice to be made.

Neutralisation of a push-pull circuit is relatively simple as a consequence of the 180° phase difference between the voltages on both tubes (Fig.8), but, especially at high frequencies, it is difficult to ensure an even distribution of the driving power and dissipation of both tubes because of unavoidable asymmetries in the circuit and the tubes.

In principle, no by-pass capacitors are needed for the fundamental frequency in push-pull circuits since for this frequency no RF voltage is present at the centre of the resonant circuits. Bypassing is, however, necessary for the odd harmonics, and with a view to the unavoidable asymmetries. Both the parallel and the push-pull circuit should be carefully designed to avoid the risk of parasitic oscillations.

THE RESONANT CIRCUITS

Two types of resonant circuit may be used in the final power stage of TV transmitters: the balanced transmission line and the unbalanced resonant circuit, which for ultra-high frequencies and high-power tubes is mostly shaped as a cavity resonator. The balanced transmission line is the most adequate resonant circuit for the push-pull arrangement, whereas, owing to its construction, the cavity resonator suits the single co-axial tubes. When, with increasing frequency, the minimum reactance obtainable with balanced transmission lines (even if they are extended with $\lambda/2$) would become too large, a co-axial line or cavity resonator with its high quality factor and its small reactance combined with a co-axial tube is the most suitable solution.

At lower frequencies the dimensions of the cavities would become impracticably large, so that other means of tuning are then used.

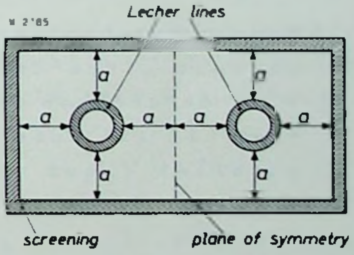

Fig.9. Correct dimensioning of the screening of balanced transmission lines for cancelling the proximity effect.

Cavity resonators offer the advantage that the whole resonant circuit is completely encased and hence screened, whereas balanced transmission lines need an additional screening to prevent radiation and to facilitate a symmetrical construction. The screening of balanced transmission lines should be carefully designed (see Fig.9) with a view to the proximity effect, which causes the RF current density of the lines and also that of the tube seals to be distributed unevenly along the circumference. As a result, the tube seals may become overheated, which might lead to destruction of the tube 1).

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1) The proximity effect is due to the mutual current displacement in two (or more) adjacent conductors in analogy with the skin effect being due to current displacement in the conductor itself.

When push-pull circuits are used, care should be taken that the couplings with the driver and the load are symmetrical, so that both tubes are evenly driven and loaded. When an inductive asymmetrical coupling is used, it may therefore be favourable to screen the coupling loop from the balanced transmission lines by means of a Faraday shield (Fig.10).

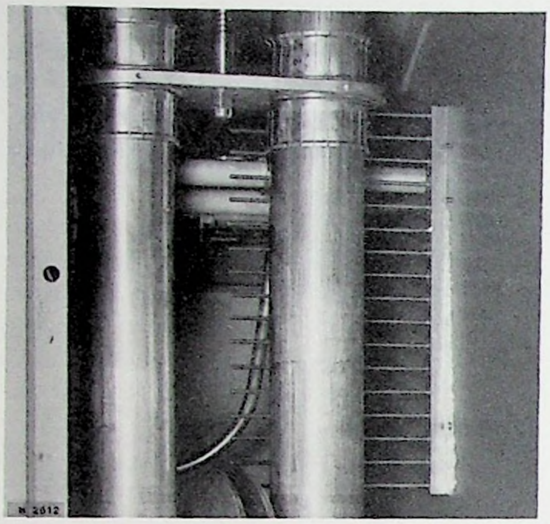

Fig.10. Photograph of a balanced transmission line with coupling loop and Faraday shield. The magnetic lines of force penetrate through the screen, whereas the electrical lines of force are intercepted.

Dimensioning

To ensure a simple inductive coupling with the transmission lines, these are generally so designed as to have a rather low characteristic impedance. This means that with a co-axial line the ratio of the diameter of the outer conductor to that of the inner conductor is small, whilst in the case of a balanced line the mutual distance is small with respect to the diameter of the conductors.

When a resonant line section is used as the input (or output) circuit of an amplifying stage, the physical length of the line depends on the input (or output) impedance of the tube. When, in the case of a short-circuited $\lambda/4$ section acting as a parallel tuned circuit, this impedance is capacitive, the physical length of the line should therefore be smaller than $\lambda/4$ (Fig.11).

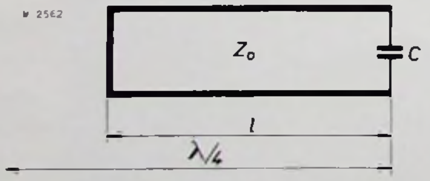

Fig.11. Short-circuited transmission line, shunted by a capacitance C. To obtain resonance the length l must be smaller than $\lambda/4$.

The impedance of a short-circuited loss-free transmission line can be expressed by:

$$Z = jZ_0 \tan \beta l, \qquad (6)$$

where Z_0 = characteristic impedance of the line.
β = phase constant of the wave on the line ($= 2\pi/\lambda = \frac{\omega}{v}$)
l = length of the line.

It follows from eq.(6) that Z is inductive if

$$k\pi < \beta l < \frac{2k+1}{2} \cdot \pi \qquad \text{or} \qquad k\lambda/2 < l < (2k+1)/2 \cdot \lambda/2,$$

k being an integer. When only $k = 0$ is considered: $0 < l < \lambda/4$. To obtain resonance the following condition should be satisfied:

$$Z + \frac{1}{j\omega C} = 0,$$

or

$$jZ_0 \cdot \tan \beta l = j/\omega C,$$

whence

$$l = \lambda/2 \text{ arc tan } 1/Z_0\omega C = \frac{v}{\omega} \text{ arc tan } 1/Z_0\omega C \qquad (7)$$

Eq.(7) reveals that at resonance the line is longer as the characteristic impedance of the line will be smaller. For coupling purposes it may be preferable that the line is as long as possible so that a low value of Z_0 is required.

Bandwidth of the tuned transmission line

When a resonant circuit is formed by a transmission line section, the bandwidth depends not only on the product RC, but also on the ratio R/C, the bandwidth increasing with decreasing value of this ratio.

Fig.12. Diagram of a resonant line section, loaded by a resistance R, the bandwidth of which is determined in the text.

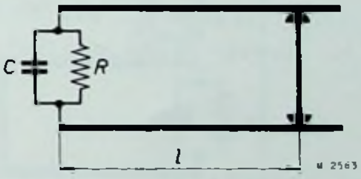

Fig.12 shows a parallel-tuned circuit consisting of a short-circuited transmission line section with length l ($<\lambda/4$) and a capacitance C, which is usually formed by the tube capacitance. The load is represented by R.

The admittance Y of the circuit is:

$$Y = G + j\omega C - jY_0 \text{ cotan } \beta l.$$

where: $G = 1/R$

Y_0 = characteristic admittance of the line, and

β = phase constant $(= \omega/c)$[1])

The modulus of Y is $|Y| = \sqrt{G^2 + (\omega C - Y_0 \text{ cotan } \beta l)^2}$

Resonance will occur, when $\omega C - Y_0 \text{ cotan } \beta l = 0$; so that $|Y|_{min} = G$.

The angular frequencies, at which $|Y|$ assumes the value $|Y|_{min} \cdot \sqrt{2}$ can be calculated from

$$\omega C - Y_0 \text{ cotan } \beta l = \pm G, \qquad \text{or} \qquad \omega C - Y_0 \text{ cotan } \frac{\omega l}{c} = \pm G.$$

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[1]) The dielectric of the line is assumed to be air.

When the roots of these equations are denoted by ω_1 and ω_2:

$$\omega_1 C - Y_0 \text{ cotan } \frac{\omega_1 l}{c} = + G \quad \text{and} \quad \omega_2 C - Y_0 \text{ cotan } \frac{\omega_2 l}{c} = - G.$$

The 3-dB bandwidth of the circuit is given by:

$$B_{3dB} = \frac{\omega_1 - \omega_2}{2\pi}$$

ω_1 and ω_2 cannot be expressed explicitly, but may be determined graphically. In the diagram of Fig.13, the admittances ωC_1, Y_0 cotan βl_1, $\omega C - Y_0$ cotan βl_1, $+G_1$ and $-G_1$ have been plotted as functions of ω with given values for f_0 (resonant frequency), C_1, Y_0 and R_1 (drawn lines). The bandwidth B is determined by the intersection points of the lines

$$\omega C_1 - Y_0 \text{ cotan } \beta l_1$$

and the lines $+G_1$ and $-G_1$. The influence of the ratio R_1/C_1 can be seen by the corresponding determination of the bandwidth B_2 with the same constants f_0 and Y_0, but with a value of $C_2 = 4C_1$ and $R_2 = R_1/4$ (dashed lines). It is seen that B_2 is much larger than B_1, although the product $R_2 \cdot C_2 = R_1 C_1$.

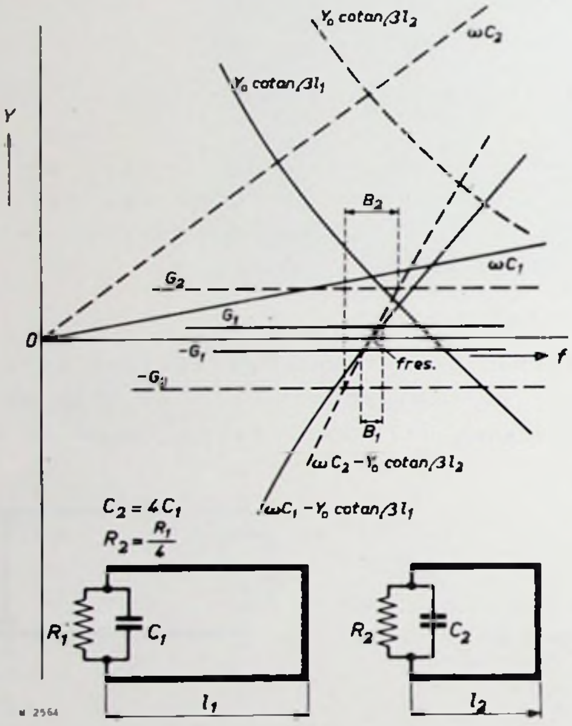

Fig.13. Diagram for determining the bandwidth of the circuit of Fig.12.

With a view to obtaining a large bandwidth it is therefore favourable to have a relatively large value of C, provided the product RC remains unchanged. A large value of C can, however, only be obtained by reducing the line length considerably, which leads to difficulties when an inductive coupling is employed. The coupling in the case under consideration is therefore preferably carried out by connecting the feeder directly or via a λ/4 transformer to the circuit, as depicted in Fig.14. The characteristic impedance of the λ/4 transformer should be made equal to $\sqrt{Z_{0f} \cdot R}$, Z_{0f} being the characteristic impedance of the feeder. To separate the direct voltage of the resonant circuit from the feeder, the coupling with the λ/4 transformer may be accomplished capacitively.

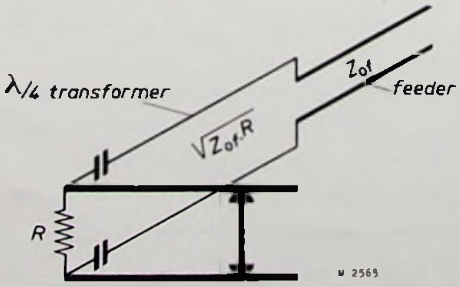

Fig.14. Coupling of the feeder to the output circuit via a λ/4 transformer.

Mechanical and electrical short-circuits

When a short-circuited transmission line is used as a resonant circuit, the short-circuit is very often established by a movable bridge or piston provided with contact springs (see Fig.8). Since heavy *RF* currents flow through the short-circuit, the contact between these springs and the conductors of the transmission line should be extremely good; it should also be well defined, which is even more important. This is illustrated in Fig.15, showing the contact between the spring and the conductor. If contact is made at point *A*, the resonant wavelenght of the line is determined by the distance *PA* (being λ/4). If, however, e.g. due to vibration, the contact is shifted to *B*, the resonant wavelenght is given by the distance *PB*. Especially at very high frequencies, at which *AB* is not negligible compared with *PA* and *PB*, the resonant curve of the line may be shifted to an inadmissible extent. It is therefore recommended to use in such case a non-contacting bridge or plunger with a length of λ/4, open at both sides (see Fig.16). The lower end is thus transformed into an electrical short-circuit at the upper end.

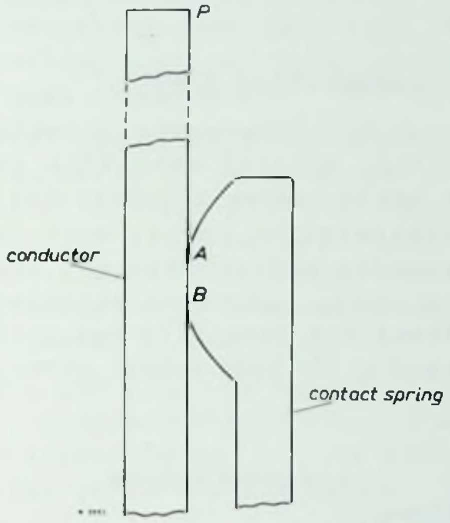

Fig.15. Enlarged representation of the contact between contact spring and conductor. The exact point of contact is of great importance if the line is short.

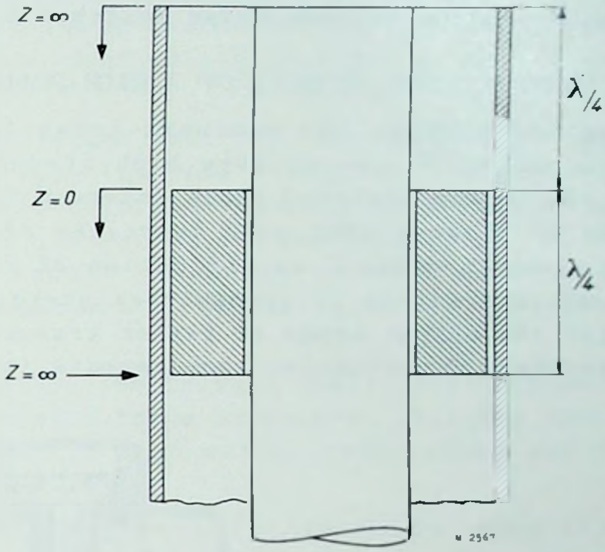

Fig.16. Non-contacting λ/4 piston, which provides the electrical short-circuit of the coaxial line.

THE DRIVER STAGES

A driver stage of a transmitter differs from its power output stage in the following respects: (*a*) a much smaller power need be delivered; (*b*) the output power is fed into the input circuit of an amplifying stage instead of the antenna feeder, and (c) frequency multiplication is often applied in this stage.

In the driver stage almost exclusively tetrodes are used, which facilitates the obtaining of a high power gain and a good stability.

Since broad-band balanced-to-unbalanced transformers (baluns) are difficult to construct the driver stages will mostly be constructed in the same manner as the final power stage; when e.g. the latter is built up as a push-pull circuit, the preceding stages will as a rule be push-pull circuits as well. When, on the other hand, the final power stage is of the co-axial type because of the co-axial tubes available for high output powers and high operating frequency, the pre-stages may be either of the push-pull or of the single-tube type.

To limit the number of power supplies, the tubes incorporated in the driver stages are often so chosen that their anode supply voltage corresponds with the screen-grid supply voltage of the following stage. In that case care should be taken during switching on and off that no screen grid voltage is applied to the tube prior to the anode voltage being switched on.

CONSTRUCTIONAL DETAILS OF A HIGH-POWER TRANSMITTING TUBE

In addition to the measures taken to render transmitting tubes suitable for use at very high frequencies, special attention is paid to the design of tubes intended for use in vision transmitters. It is obvious that some functions of transmitting tubes, such as low-power class-C amplification of frequency multiplication, are not inherent in TV transmitter operation only, but tubes intended for the output stage of vision transmitters are specially designed to meet the particular requirements imposed by the high output power,

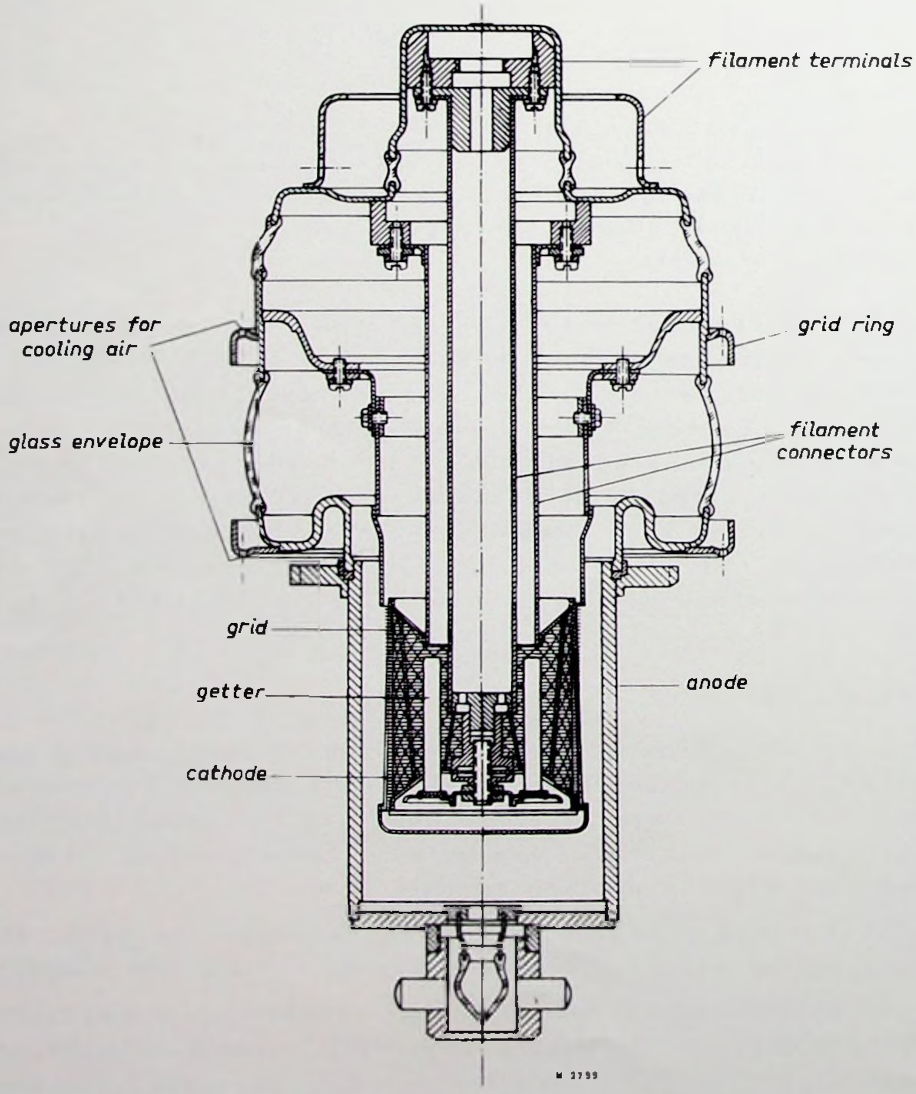

Fig. 17. Cross-section of the disc-seal transmitting triode TBL 6/20.

the high operating frequency and the large bandwidth required. The following description of the tube TBW 6/20 clearly illustrates the measures that were taken to cope with these requirements.

DESIGN AND CONSTRUCTION OF THE TBW 6/20

The TBW 6/20 is a water-cooled transmitting tube of the triode type, designed for use as a high-power amplifier in TV transmitters at frequencies up to 220 Mc/s.

Under class-B telephony conditions the tube can deliver a continuous output power of 12 kW at 220 Mc/s. There is also an air-cooled version of this tube type, the TBL 6/20. Except for the different cooling systems, both types are identical in performance and electrode connections.

The tube is built up coaxially in its entirety. All electrodes are connected to metal discs or rings that are sealed onto the glass envelope (see Fig.17). This construction facilitates mounting in coaxial cavities or, when a push-pull circuit is used, in a balanced transmission line circuit. When the tube is used in a grounded-grid connection the anode and cathode circuits are mutually screened by the grid.

The TBW 6/20 has been designed for requiring a small driving power in a grounded-grid circuit and at a large bandwidth. This has been obtained by giving the tube both a high mutual conductance and a high amplification factor.

The high mutual conductance has been obtained by keeping the spacing between the cathode and the grid extremely small and by using a cathode with a large surface. By adequate design of the electrode system, in which the anode-to-grid spacing and the pitch of the grid are of paramount importance, it proved possible to obtain an amplification factor of 60 and a mutual conductance of 60 mA/V, the "island effect" being avoided.

The cathode

The cathode (filament) is of the so-called "mesh" type. It consists of a number of thin thoriated tungsten wires that are inserted

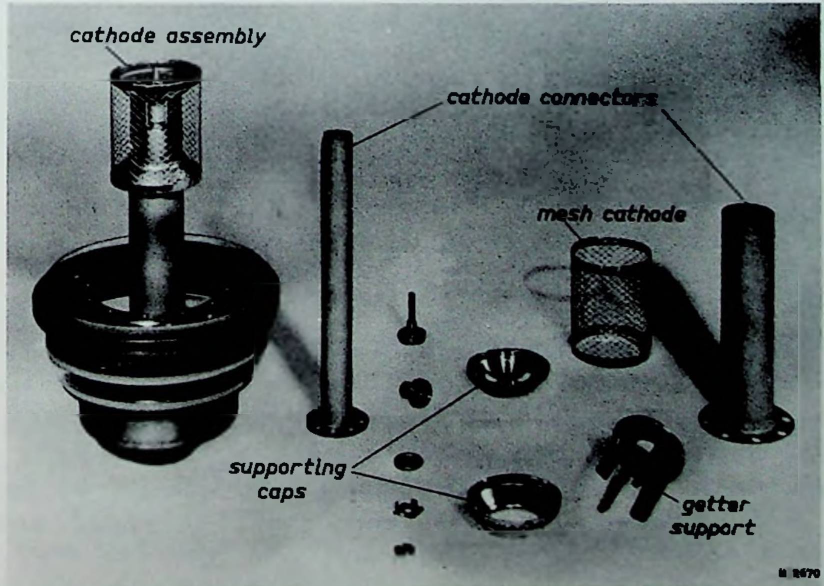

Fig.18. Cathode assembly of the TBL 6/20 (left) and component parts (right).

helically between two molybdenum rings, half of them being wound clockwise and half of them anti-clockwise, so as to form a mesh-cylinder (see Fig.18). By means of this construction and the correct choice of the wire diameter and the spacing between the wires, the ideal shape of a cathode (a closed - equipotential - cylinder) is approximated, the heater power, however, being considerably lower than would be required for a conventional cathode of the same dimensions.

The mesh cathode has the following features:
(*a*) large effective area compared with the heater power;
(*b*) low RF resistance;
(*c*) rugged construction;
(*d*) suited for coaxial connections.

The upper and lower ring of the cathode are connected to the terminals by means of wide tubes with a thin wall, so that a rugged mounting of the cathode in the tube has been obtained together with a small moment of inertia, this being of particular importance when the tube might be subjected to severe shocks. To improve the ruggedness of the filament wires, a large number of crossings of the wires are welded.

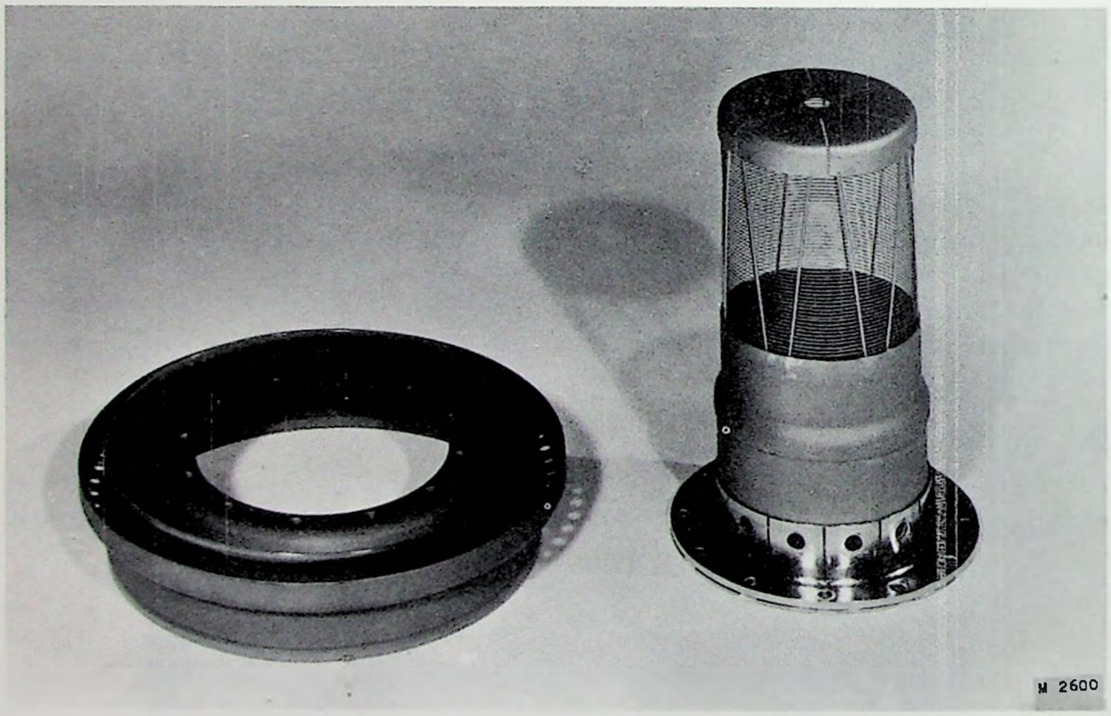

Fig.19. Photograph of the grid assembly of the TBL 6/20.

The grid

The grid wires consist of a molybdenum core covered with platinum, the latter being favourable as regards the prevention of primary-grid emission. The grid wires can withstand a high dissipation inherent in a high current density. Since the grid-to-cathode spacing is small, the grid supports are mounted at the outside of the grid, and so connected to the end caps that small trapeziums are formed, thus warranting a great rigidity (see Fig.19). The grid assembly is attached to the corresponding connecting ring by means of a hollow molybdenum cylinder.

The anode

The anode is shaped as a hollow copper cylinder with a thick wall, and surrounds the grid co-axially. It forms part of the tube envelope, so that it can be cooled through direct contact with the cooling medium. An air cooler can be soldered directly to the anode, whilst for the TBW 6/20 a separate water cooling jacket is available.

Similar to the outer part of the anode ring, the outer part of the grid is provided with small apertures to pass air for cooling the seals.

THE SOUND TRANSMITTER

The FM system for the sound part of TV transmitters, accepted by the C.C.I.R., has the following advantages over AM:
(*a*) possibility of decreasing interference;
(*b*) excellent quality of reproduction;
(*c*) facility of applying the principle of intercarrier sound.

In connection with point (c), the frequency difference between the carrier frequency of the vision transmitter and the centre frequency of the FM sound transmitter must be maintained within narrow tolerances. For this reason the centre frequency of the FM transmitter is very often synchronized by a signal obtained by mixing the frequency of the master oscillator of the vision transmitter with that of an additional crystal oscillator that generates the required difference frequency.

For detailed information on transmitting and rectifying tubes for FM transmitters, reference is made to the publication: Transmitting and Rectifying Tubes for FM Broadcast transmitters 1).

DIPLEXER, FEEDER AND ANTENNA

Since both the vision and the sound transmitter have the same transmitting antenna, means must be provided to prevent these transmitters from influencing each other via the antenna (reflections).

This is accomplished by using a "diplexer", that is a coupling device between the vision and the sound transmitter on the one hand, and the antenna on the other.

The diplexer is mostly constructed as a co-axial tubing that incorporates several high- and low-pass filters.

The feeder, which connects the diplexer to the antenna, may have considerable length, because in many cases the antenna is at a large distance from the transmitter. As a result, the feeder must have low losses per unit length, and it is therefore frequently of the co-axial line type with a characteristic impedance matching the radiation resistance of the antenna. To prevent flash-over and to reduce losses, this feeder is often filled with dry nitrogen or dry air.

It is customary to use a specially constructed antenna (e.g. super-turnstile) so as to obtain a high antenna gain and, in the case of horizontal polarisation, a circular radiation pattern.

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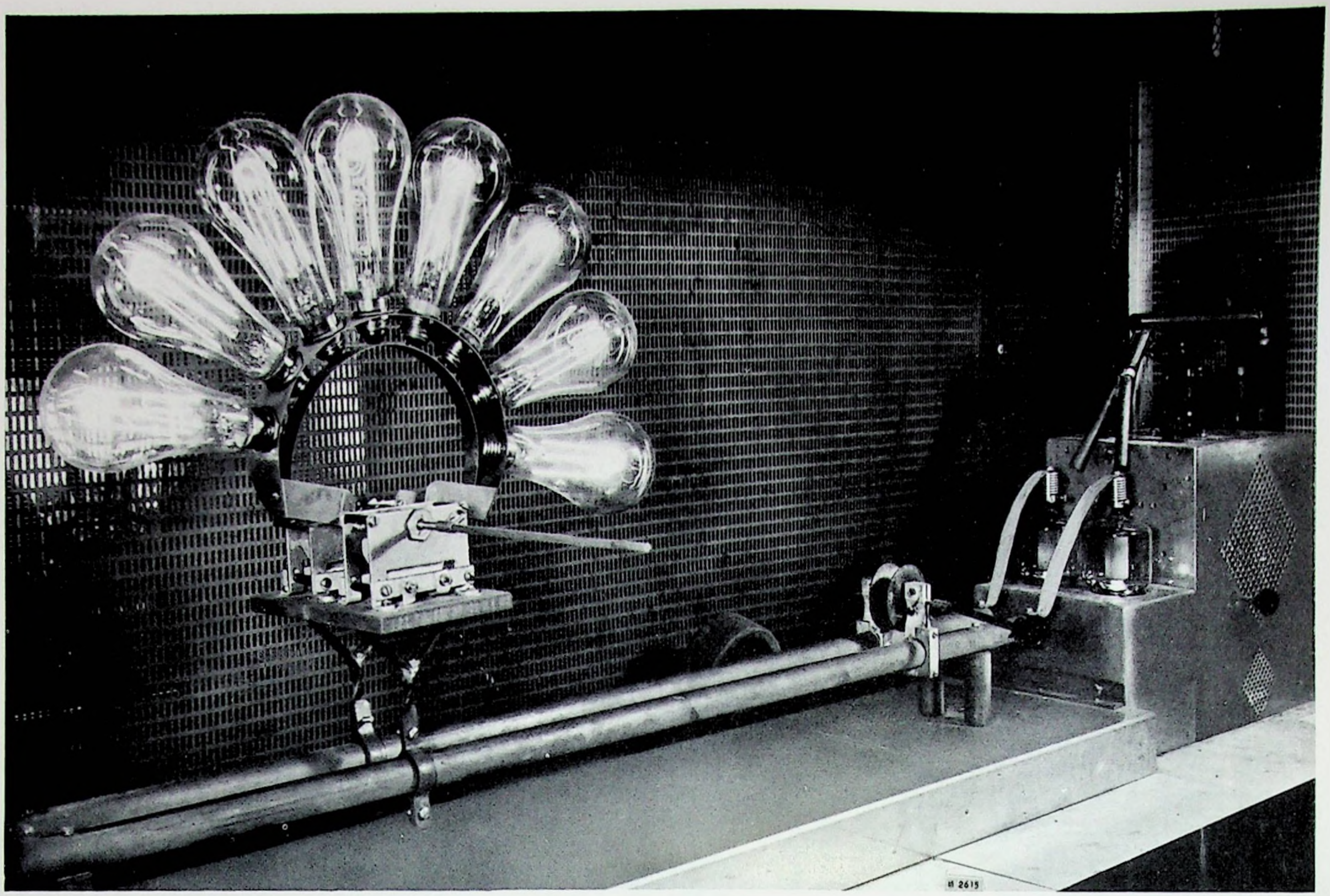
1) Attention is drawn to the fact that this publication deals with broadcast transmitters operating at a frequency band differing from that of TV transmitters.



43 Mc/s push-pull amplifier with the tubes QB 3.5/750 (right) for lifetest purposes. At the left the load of the balanced anode circuit can be seen consisting of a number of parallel circuited carbon wire lamps. The tubes are cooled by a low-velocity air stream applied to the top of the bulbs.

THE POWER SUPPLY

THE HIGH-TENSION RECTIFIER

The power supply unit for a high-power transmitting tube does not differ fundamentally from that of low-power supply units, but there are some practical differences owing to the higher voltages to be generated and the larger currents to be supplied. As a consequence, high-power supply units are equipped with gas-filled rectifying tubes because of their high efficiency. Mostly three-phase rectification is applied in order to prevent a symmetrical load to the three-phase power line, and because of the small ripple voltage that can be obtained with a relatively small smoothing filter.

Gas-filled rectifying tubes need a choke input filter because otherwise the heavy charging current of the buffer capacitor would deteriorate the emitting properties of the cathode (filament).

Since the eye is very sensitive to differences of the brightness in the TV picture, which might be caused by unintentional output variations of the transmitter, supply voltages that influence the output power of a TV vision transmitter must be well stabilised, i.e. screen-grid voltages of tetrodes and pentodes and anode voltages of triodes. This stabilisation can be performed in a circuit in which negative feedback is applied, which, moreover, offers the possibility of adjusting the d.c. output voltage within certain limits. Another possibility of obtaining a stabilised d.c. voltage is the use of grid-controlled rectifying tubes [1]). With the aid of such tubes it is possible to construct rectifier circuits that have the following properties:

(a) The direct output voltage is electronically stabilised, so that the transmitting tube(s) involved can be operated very close to the limiting values, since the influence of mains voltage fluctuations on the d.c. output voltage is strongly reduced.

(b) The direct output voltage can be adjusted within wide limits. This is of great importance when the transmitter circuits must be tuned or neutralised, which is generally performed with reduced voltage.

(c) At an overload or short circuit, the HT is switched off within half a cycle of the mains voltage, so that the risk of the transmitter being damaged is avoided.

High-power tetrode transmitting tubes are generally provided with two separate power supply units for the anode and the screen voltages because the voltage difference between these electrodes is so large that a contingent screen-grid resistor connected to the anode supply voltage would dissipate a considerable power.

THE GRID-BIAS SOURCE

The negative grid bias of transmitting tubes operating in class C that are not grid-modulated may be obtained either fully automatically by means of a grid leak resistor or partly automatically in

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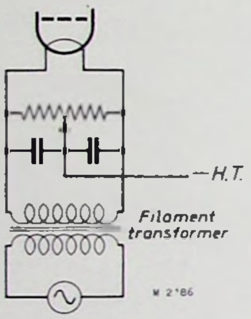
[1]) See, for example, the Bulletin 20/206/D/E entitled: "Control device for H.T. supply units of transmitters".

combination with a fixed grid bias, the latter having the purpose of safeguarding the tube when the driving power fails [1].

Depending on the power level, buffer stages operating in class A have either a separate supply unit to provide the grid bias or a cathode resistor.

FILAMENT SUPPLY

Since in practice the high-power transmitting tubes are always directly heated, special attention must be paid to the a.c. supply of the filaments in order to ascertain whether the requirements made on the maximum permissible hum component in the output signal have been fulfilled. One of the most frequently used methods to reduce hum is depicted in the circuit diagram of Fig.20, showing the connection of the filament to the negative terminal of the HT supply via a potentiometer by means of which the hum component in the anode current can be adjusted to a minimum. Both halves of the potentiometer are bypassed to provide a low impedance RF path.



Another method for reducing hum, often used with transmitting tubes connected in push-pull or in parallel, consists in applying the Scott circuit, in which the filaments of the tubes are fed with 90° phase difference.

Fig.20. Example of the connection of a directly heated cathode for hum compensation.

The filament voltages of the transmitting tubes with a thoriated tungsten filament have a tolerance of ± 5%; if mains voltage fluctuations of more than 5% can be expected, the filament voltage should therefore be stabilised. This is generally accomplished by means of saturated transformers or current-regulating tubes.

ARRANGEMENT OF THE SUPPLY UNITS AND LIMITING VALUES

Although it is usually aimed at to reduce the number of different supply units by a correct choice of the supply voltages in the various stages, every unit is often provided with its own power supply when the set-up of a transmitter is such that all stages are constructed as separate units. In some cases this construction enables the last driver stage to act as a final power stage if the actual power stage should happen to fail [2]. Moreover, the transmitter can then easily be extended by an additional power stage driven by the former final stage.

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[1] When only a grid leak resistor is used, failing of the driving power causes the operating point of the tube to shift towards higher anode currents, thus giving rise to inadmissibly high anode dissipations. A protecting device, set at a value slightly exceeding the normal anode current, or a suitable RF sensing device in the output circuit should then be used.

[2] The final power stage can obviously only be changed over when modulation has already been achieved in a preceding stage.

The figures given for the limiting values for each type are absolute limits beyond which the serviceability of the tube may be impaired with a view to life and satisfactory performance. Therefore, in order not to exceed these limiting values, the equipment designer has the responsibility of determining an average design value for each rating in such a way that the absolute values will never be exceeded under any usual condition of supply voltage variation, equipment component variation, load variation or due to a normal variation of tube characteristics.

THE RECTIFYING TUBES

Two types of gas-filled rectifying tube coming into consideration for the supply of high-power transmitting tubes can be distinguished, viz. mercury vapour and xenon-filled tubes. The difference in operation between both types is attributable to the properties of the gases; at room temperature mercury is a liquid with a saturated vapour, whereas xenon is an unsaturated gas.

The vapour pressure of mercury-vapour rectifiers is determined by the lowest temperature occurring in the tube, which in turn depends on the ambient temperature and the heat flow inside the tube. The maximum permissible inverse peak voltage between the cathode and the anode, being one of the factors determining the usefulness of rectifying tubes for a given application, decreases with increasing vapour pressure. On the other hand, the tube life is favourably affected by a high vapour pressure. To ensure both a reasonable maximum inverse peak voltage and a long tube life, the limits of the ambient temperature range, given by the tube manufacturer, should on no account be exceeded.

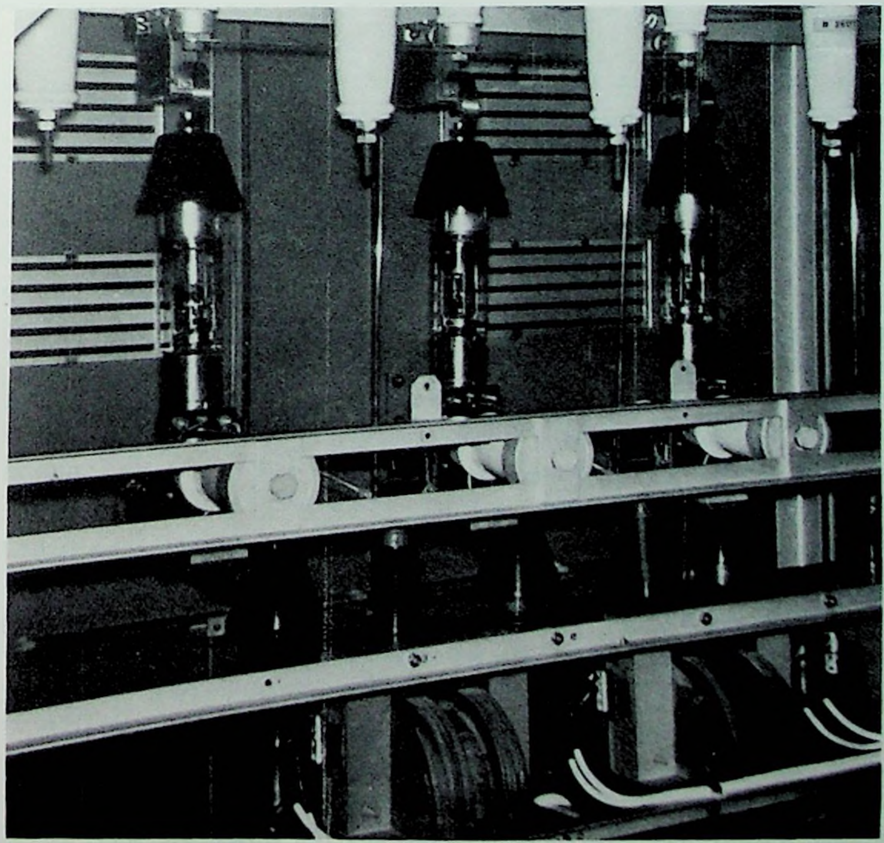


Fig.21. Photograph of the rectifying tubes in a 3-phase, half wave rectifier, equipped with the tubes DCG 12/30.

When a mercury-vapour tube is taken into operation after transport, the liquid mercury must first be removed from the electrodes, which is achieved by switching on the filament voltage for a considerable length of time. Preheating during a shorter interval is also necessary every time the tube is switched on to obtain the desired vapour pressure required for a long tube life. After a certain time interval the anode voltage may be switched on (this waiting time is quoted in the tube data for each individual type).

Mercury-vapour tubes must be used in vertical position with the base down to ensure that the mercury condenses in the lower part of the tube. For the same reason some types are provided with an external cap that surrounds the upper part of the tube, thus keeping the temperature of this part higher than that of the bottom when the tube is switched off (see Fig.21).

Provided mercury-vapour rectifiers are handled according to the directions for use, their lives may be very long.

Xenon-filled rectifying tubes require only a short waiting time. Owing to the nature of the gas, the tubes can be used under strongly divergent climatological conditions within a wide ambient temperature range (from -50 °C to +75 °C), so that they are very suitable for use in unattended transmitters. They can, moreover, be mounted in any position.

Another feature of xenon-filled rectifying tubes is the approaching end-of-life being manifested by an increasing anode temperature and not by arc-back, as in the case with mercury-vapour tubes. If the anode of a xenon-filled tube becomes red-hot during operation, this is a warning that the tube should be replaced.

GENERAL INSTRUCTIONS FOR THE USE OF TRANSMITTING AND RECTIFYING TUBES

ELECTRICAL

When transmitting tubes arrive at the transmitting station, they must be electrically tested to make sure that they have not been damaged during transport. This does not only apply to tubes that are immediately used, but also to stand-by and spare items.

It is emphasized that the limiting values, given for transmitting tubes are *absolute maxima* that should on no account be exceeded, either during tuning of the transmitter, by mismatching, mains voltage fluctuations, deviations in the values of the circuit elements or normal spread of the tube properties. Each "limiting value" should be regarded independent of other values. If, for instance, the limiting value of the input power W_{ia} is lower than the product of the limiting value of the d.c. anode voltage V_a and the d.c. anode current I_a, this means, that $V_{a\ max}$ and $I_{a\ max}$ may not occur simultaneously. Unless explicitly mentioned otherwise, the limiting values refer to d.c. values.

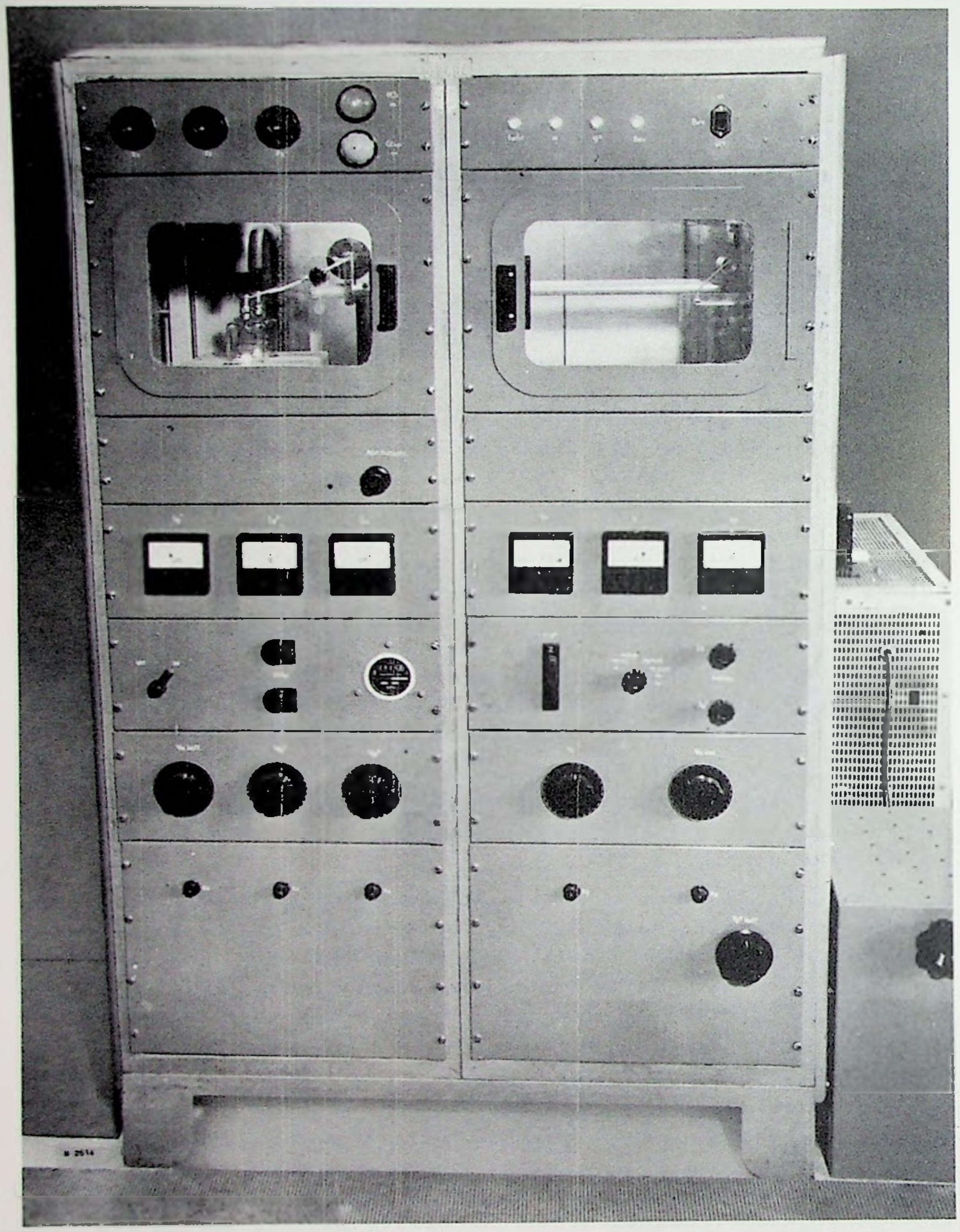
Stress is laid on the fact that guarantee is only given when the tube is used in combination with the accessories specially designed for the tube involved, or with equivalent items that are approved by the tube manufacturer.

For transmitting tubes with internal anodes simultaneous switching-on of the filament voltage, screen-grid and anode voltages is permissible. When tubes with external anodes are concerned, the screen-grid and anode voltages should not be applied until the cathode has reached its operation temperature; the latter can be checked by ascertaining whether the filament current has reached its nominal value.

For rectifying tubes the necessary minimum delay between switching-on the filament and the anode voltage is given under the technical data. The actual delay required depends on the ambient temperature during starting, and can be read from the curve giving the temperature increase of the condensed mercury versus the time that has elapsed after switching on the tube in cold condition.

The published value of the maximum permissible filament current during switching-on refers to the absolute maximum of the instantaneous value under the most unfavourable conditions. In the case of a.c. supply this highest value is present when switching-on takes place at the instantaneous peak value of the highest r.m.s. value of the filament voltage that may occur.

To limit the filament peak currents use can be made of a filament transformer with high magnetic leakage or of a series choke or resistor in the primary of the transformer. This choke or resistor may be short-circuited by means of a relay after a delay of e.g. 15 seconds. Generally one switching step will suffice.



Dynamic life-test on two tubes QB 3/300 in a 120 Mc/s push-pull amplifier. Meters on the front panel indicate the performance of the tubes during life.

A simple check as to whether the filament current is not exceeded during switching-on can be made with the aid of a calibrated cathode-ray oscilloscope connected directly to the filament terminals of the tube [1]).

COOLING

COOLING OF ALL-GLASS TUBES

The tubes with internal anodes and a thoriated tungsten filament described in this Bulletin ("all-glass" tubes), are cooled by air circulation. To keep the temperature of the envelope and the electrode seals within safe limits, these parts generally need additional cooling by means of a low-velocity air flow, particularly when operating at very high frequencies, since RF heating of the electrodes and their connections then becomes noticeable.

COOLING OF TUBES WITH EXTERNAL ANODE

As the anode of these tubes forms part of the tube envelope, the cooling medium can make contact with the entire external anode surface. Since the anodes of the tubes are made of copper, a good heat conduction from the inside to the outside of the anode is ensured. The large radiation cooling surface enables the tubes to be used at a relatively high dissipation.

Most tube types with external anodes have an air-cooled and a water cooled version. Both versions have the same electrical properties, but some water-cooled types allow for a greater anode dissipation than normally required.

The anodes of the tubes intended for forced-air cooling are provided with longitudinal fins along which the air is forced. The required air pressure is as a rule generated by a blower. To provide the cooling of the grid seals and the filament terminals, a proportion of the cooling air should be directed to these parts, or a small additional blower should be used for this purpose.

Although, in principle, there is no difference between blowing or sucking the cooling air, preference is generally given to blowing because of the higher efficiency of the blower when handling cold air. When hot air in the transmitter cabinet is undesirable, sucking of the cooling air may nevertheless be preferred.

Since the heat-handling capacity of water is higher than that of air, the piping of a water-cooling system can be much smaller than the air ducts in the case of forced-air cooling. The use of water cooling is, however, more complicated than that of forced-air cooling in view of the relatively low specific resistance of water. A special isolating circuit between the anode (which has a high potential with respect to earth) and the earthed parts of the cooling system (tap of the water supply, pump, outlet etc.) is therefore required. The high resistance is provided by a long water column in an isolating tube, which, in order to save space, is formed as a serpentine or as a helix, wound on an insulating drum.

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[1]) If the oscilloscope were connected to the filament connectors, an error in the reading of the oscilloscope might be introduced due to the considerable voltage drop across the contact resistance between the filament terminals and their connectors.

The simplest water cooling system is obtained by connecting the cooler of the tube to the water supply. This system can only be used economically if sufficient water is available at low cost and if the quality of the water answers the requirements made on its specific resistance and its hardness, the latter determining the quantity of deposits on the anode [1]. If water of this kind is not available in sufficient quantities, a closed circulating water cooling system containing distilled water must be used. A simplified diagram of such a system is depicted in Fig.22 by way of example.

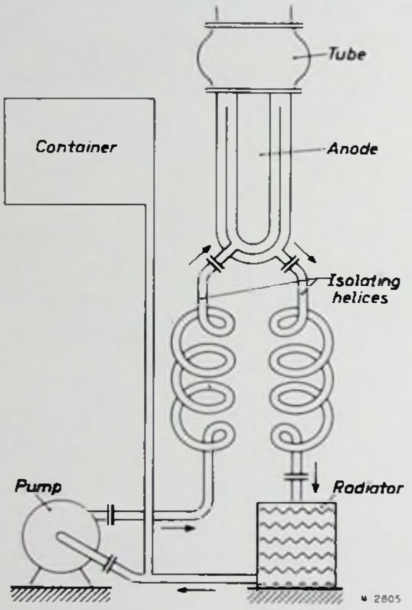

Fig.22. Schematic diagram of a closed water-cooling system. The arrow points indicate the direction of water flow.

The water flow originated by the pump is passed via an isolating helix to the cooler surrounding the anode of the tube. Via another helix the water flows through a radiator, which takes off the heat the water has gained while passing the anode cooler. In order to keep the water pressure constant, an expansion tank is incorporated in the water circuit. If the tank is open at the top, the contact of the distilled water with the air may cause CO_2 to be absorbed by the water, deteriorating its purity. Therefore the tank is sometimes closed and pressurised with nitrogen, the latter preventing the absorption of CO_2 and acting as a buffer volume. As a rule these measures are not necessary.

With water-cooled anode tubes it is often necessary to cool other parts of the tube as well, such as grid and filament seals. This is achieved by directing an air flow to these parts.

Cooling characteristics are given for each type of tube dealing with data concerning the quantity of cooling medium required per minute, the temperature and the pressure drop in the cooler. When designing a water cooling system, it should be taken into account that the highest pressure drop of the system generally occurs in the isolating tubing.

PROTECTION OF TRANSMITTING TUBES

It is obvious that, in order to protect transmitting tubes against damage, adequate circuit design and correct operating conditions are of prime importance. Means should also be provided to avoid risk of damage due to unintentional phenomena, by incorporating devices in the circuitry that protect the tubes against excessive voltages, currents, temperatures, etc.

The protecting devices generally employed are fuses, current overload relays, contact thermometers, R.F. sensing relays, air vanes and water-flow relays.

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[1]) A specific resistance of minimum 4000 $\Omega/cm/cm^2$ will as a rule be sufficient. The temporary hardness (concentration of CaO) should be less than 10 °D.

As a rule fuses are used only in low-current circuits; for high-power circuits overload relays are mostly employed. The most important safety measures are described below.

PROTECTION AGAINST FAILURE OF THE COOLING SYSTEM

With forced-air or water-cooled transmitting tubes, failure of the cooling system will cause the temperature of the anode and seals to become excessive, which may have serious consequences, such as puncture of the anode and/or cracks in the envelope, melting of solder, etc. The cooling system should therefore be provided with a protecting device that switches off the supply voltage(s) as soon as the cooling fails. Provision must even be made to prevent the filament voltage from being applied when the cooling is not in operation. Air cooling systems are normally equipped with an air vane connected to a relay, which is actuated as soon as the air velocity becomes too low. In water-cooling systems a water relay comes into action when the pressure drop between the inlet and the outlet of the cooler is too low. Additional differential contact thermometers or over-temperature relays can indicate faulty operating conditions.

PROTECTION AGAINST OVERLOAD OF THE CONTROL GRID

Excessive grid current (grid dissipation) may occur when the anode voltage fails or when the matching of the output circuit is upset. It is therefore desirable to insert in the grid d.c. circuit a grid-current overload relay that switches off the supply voltage(s) of the tube as soon as the grid current becomes too high.

PROTECTION AGAINST EXCESSIVE ANODE DISSIPATION

The anode dissipation of a tube, being the difference between (*a*) the anode d.c. input power W_{ia} and (*b*) the output power W_o plus R.F. losses, may be exceeded by an increase of W_{ia} or a decrease of W_o. The decrease of the output power may be caused by mismatching of the output circuit, which may occur as a result of the antenna or feeder being disconnected, icing, detuning, etc. An R.F. sensing device or reflectometer can protect the tube against such events.

A differential contact thermometer, inserted in the inlet and outlet of the cooling system together with a flow control, is the most complete device for protecting the anode against excessive dissipation.

PROTECTION AGAINST EXCESSIVE SCREEN-GRID AND ANODE CURRENTS

When the anode voltage of a tetrode transmitting tube fails, its screen-grid current and consequently the screen-grid dissipation increases and may even become so large that the screen grid is destructed. When a separate supply unit is used, the anode d.c. circuit should therefore be provided with a no-voltage relay that is actuated as soon as the anode voltage fails and switches off the screen-grid voltage, or with a screen-grid current overload relay. The switching system of a tetrode tube should be so arranged that the screen-grid voltage cannot be applied before the anode voltage has been switched on.

Occasionally a screen-grid resistor may also prevent the screen-grid current becoming too high.

Another failure that may have serious consequences is the occurrence of an excessive anode current. This may be due to breakdown of capacitors or to failure of the driving power. An overload relay in the anode or cathode circuit prevents the anode current from becoming too high. A relay in the cathode circuit has the advantage of being at a low potential with respect to earth. It should be bypassed to prevent the R.F. current, having a much higher value than the direct current, from flowing through it.

If a flash-over should occur in the tube, which might be caused by lightning, the tube may be seriously damaged by the d.c. power stored in the capacitor of the smoothing filter of the power supply. For this reason a resistor of e.g. 25 Ω should be inserted in the anode d.c. circuit of the tube.

PROTECTION OF RECTIFYING TUBES

When, due to a temperature increase, the vapour pressure of mercury-vapour rectifying tubes increases, the maximum permissible inverse peak voltage between the anode and the cathode decreases. If in such a case the maximum permissible value drops below the actual inverse peak voltage, the tubes arcs back, which results in a heavy inverse anode current surge. As for the tube, the cathode coating can then be damaged. This phenomenon is generally prevented be connecting fuses in series with each rectifying tube or by a quick-action relay inserted in the supply circuit, cutting out as soon as the current exceeds a given value.

In many cases surge currents, such as may occur as a result of breakdown of capacitors, are kept below their limiting values by the resistance of the transformer windings and/or the magnetic leakage of the transformer. If this is not the case, current-limiting resistors in series with the secondary windings of the transformer can be used for this purpose.

The time delay of the overload relay should be such that the duration of the surge never exceeds the maximum permissible current value. It should be stressed that the surge current may not occur regularly or during switching.

When the ambient temperature of mercury-vapour rectifying tubes happens to be too high, the gas pressure in the tube can be lowered by directing a cooling air jet onto the lower part of the bulb, just above the base [1]). Another possible solution is to apply thermostatic control of the ambient temperature.

To avoid the risk of errors being made concerning the switching sequence, switching-on of the anode voltage of a mercury-vapour rectifying tube is often performed by an automatic switch, the action of which is delayed with respect to the switching-on of the filament voltage.

MAINTENANCE

High-power transmitting tubes should not only be protected against electrical overloads, but also against mechanical injury. They should therefore be manipulated with adequate care.

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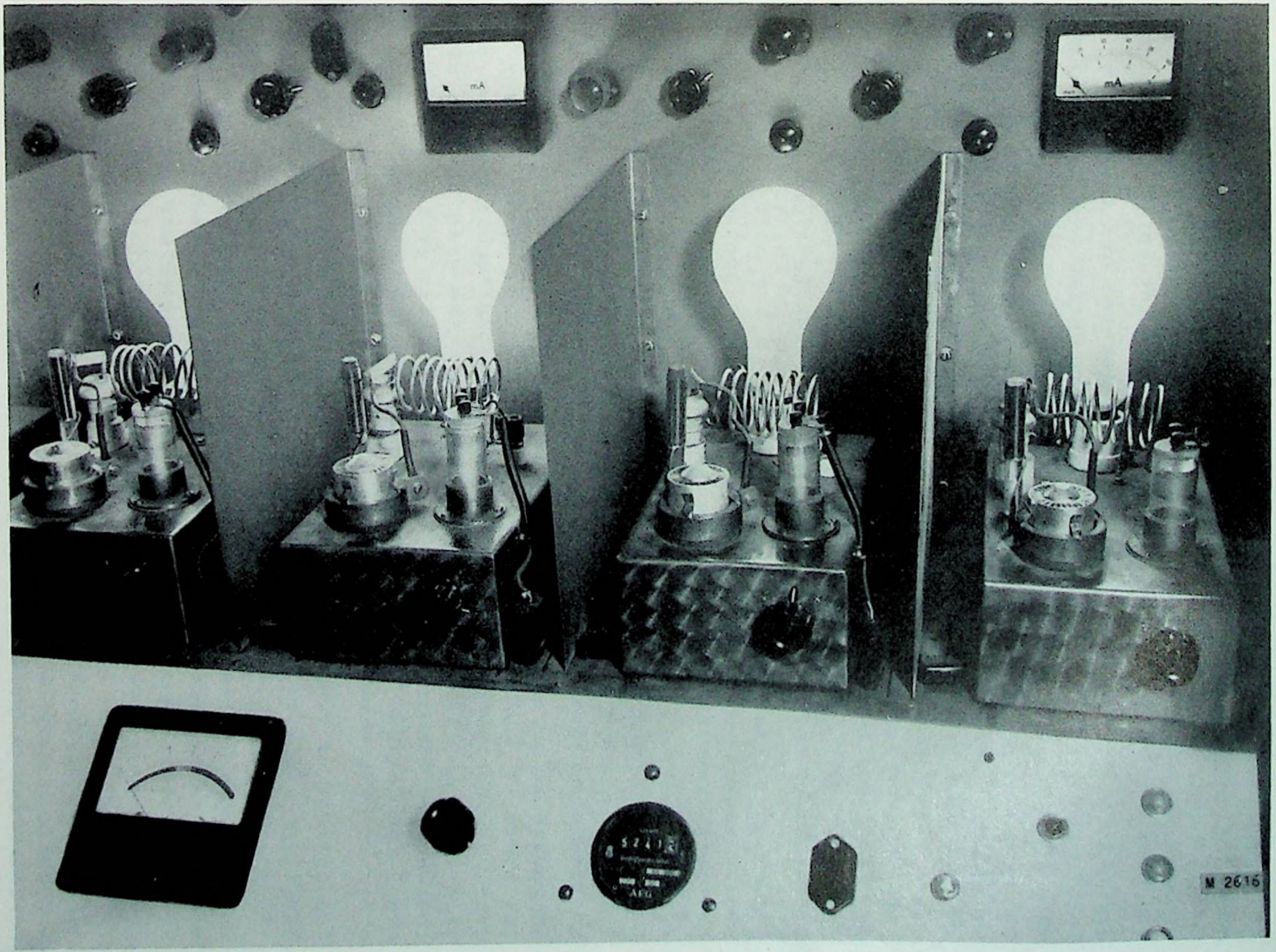
[1]) It should be remembered that the upper part of mercury-vapour rectifying tubes should never be cooled, for in that case the mercury would condense in this part of the envelope.



Self-oscillating life-test set-up at 43 Mc/s of the QEL 1/150 tubes. The output power is dissipated in incandescent lamps.

Although thoriated filaments are sufficiently rugged for normal use, they should not be exposed to severe shock because of their brittleness, specially in cold condition. The same applies to the glass envelopes. Tubes with external anodes should be supported at the anode or its cooler, these being the heaviest parts of the tube.

For safety reasons the tubes should be stored and transported in their original packing, and rough handling during packing (nailing) and transport should be avoided.

The glass parts of the tubes must be protected against sudden temperature variations. Drops of liquids or cold metal parts should therefore be prevented from contacting the hot bulb. Neither should glass tubes that are out of operation but still hot, be brought into contact with metal parts, such as metal table tops.

The set-up of a transmitter should be such that strong R.F. fields cannot cause dielectric heating of the glass or inductive heating of the metal parts. Care should also be taken to avoid sparking.

Before mounting the transmitting tube in its holder, the glass parts should be meticulously cleaned. The same applies to the metal contacts when the tube has been stored for a long period [1]).

After a transmitting tube has been installed and the connections have been inspected, first of all the cooling is applied and the filament voltage switched on, in order to activate the getter and to remove residual gases.

It should be borne in mind that the anode and screen-grid voltage may never be applied prior to the control-grid bias, nor may the driving power be applied prior to the anode voltage and the screen-grid voltage (or at least part of both); the grid current might then become too high, giving rise to overheating of the grid. Moreover, the cathode surface may be damaged by returning electrons as a result of transit time effects.

The correct switching-on sequence of tubes with a fixed grid bias is therefore: (1) filament voltage; (2) grid bias; (3) anode voltage; (4) screen-grid voltage; (5) driving power.

In the case of *automatic* bias by means of a grid leak resistor, a somewhat different procedure must be followed because the grid bias is only present when driving power is applied. For this case the switching-on sequence is as follows: (1) filament voltage; (2) anode voltage (fully or partly); (3) screen-grid voltage partly (10 to 20 %); (4) driving power.

For the same reason, neutralisation should never be performed with full driving power without any voltage on the anode and/or screen grid. Neutralisation and tuning of the transmitter circuits with reduced driving power is generally recommended, although in this case some readjustment will be necessary at full power, in connection with the electronic impedances of the tubes depending on the d.c. adjustments (space charge variations).

It is furthermore recommended that stored transmitting tubes with external anode are put into operation for a short time twice a year. It is easiest to perform this in the transmitter itself.

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[1]) The silver-plated parts of new transmitting tubes are covered with an anti-corrosive wax to prevent these parts from becoming less conductive.

APPLICATIONS

A 5 KW VISION TRANSMITTER

Fig.23 shows the block diagram of a commercial TV vision transmitter. At 100% modulation (sync. peak) the transmitter delivers an output power of 5 kW in Band I.

High-level modulation is applied in the final power stage, equipped with two air-cooled tetrode transmitting tubes QBL 5/3500 in push-pull. In the frequency multiplication stages two tubes QQE 06/40 are used as a tripler and doubler respectively. The last QQE 06/40 (doubler) delivers its output power to the driver stage; the latter is equipped with two tubes QB 3/300 and precedes the final power amplifier.

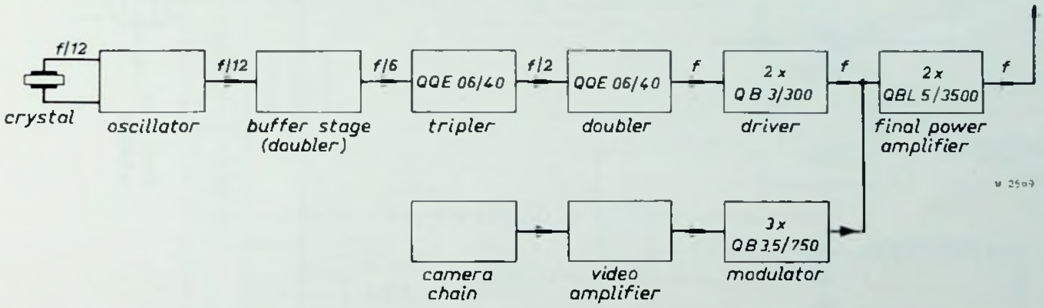

Fig.23. Block diagram of a commercial vision transmitter.

THE DRIVER AND FINAL POWER AMPLIFIER

Fig.24 shows the circuit diagram of the driver and final power stages. The output power from the last frequency multiplier is applied to the grid circuit of the driver. Tuning of this grid circuit is achieved by the variable split-stator capacitor C_1. The screen grids are earthed for RF by means of C_2.

With a view to the different cabinets in which the stages under consideration are housed, the anode circuit of the driver and the grid circuit of the final power amplifier are coupled by means of a transmission line. The inductive coupling of this transmission line with both circuits is variable, whilst the inductances are series-tuned by variable capacitors C_3.

To improve the bandwidth of the modulator and that of the input circuit of the final (linear) amplifier, the grid circuit of the latter is heavily damped by the resistor R_1.

Since d.c. re-insertion of the video signal is applied at the grid of the modulator tube T_5, the anode of T_5 is directly connected to the grids of T_3 and T_4. The grids of T_3 and T_4 thus have a positive potential with respect to earth, so that the other electrode voltages of the final amplifier are also raised. This is achieved by means of an additional voltage source of 1500 V between earth and the common terminal of the anode and screen-grid power supplies.

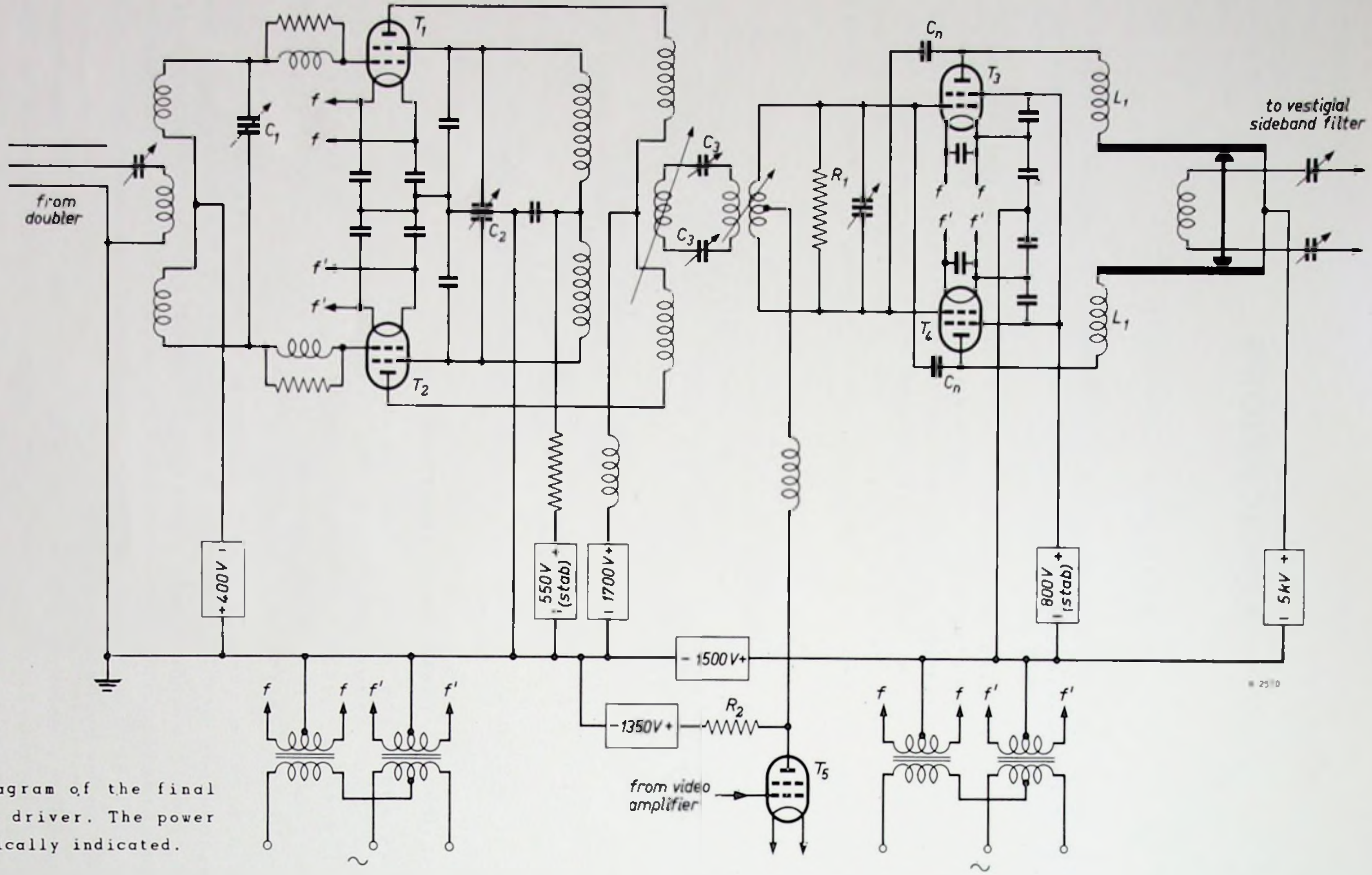

Fig. 24. Circuit diagram of the final power stage and its driver. The power supplies are schematically indicated.

The anode circuit of the final power amplifier is composed of the coils L_1 and a balanced transmission line section, tunable by a shorting bridge.

Cross-neutralisation of the QBL 5/3500 tubes is applied via the capacitors C_n.

To reduce hum, the filaments of the tubes QB 3/300 and those of the tubes QBL 5/3500 are fed from a Scott circuit connected to the three-phase mains.

To avoid output power variations due to mains voltage fluctuations, the supply units of 550 V and 800 V are electronically stabilized.

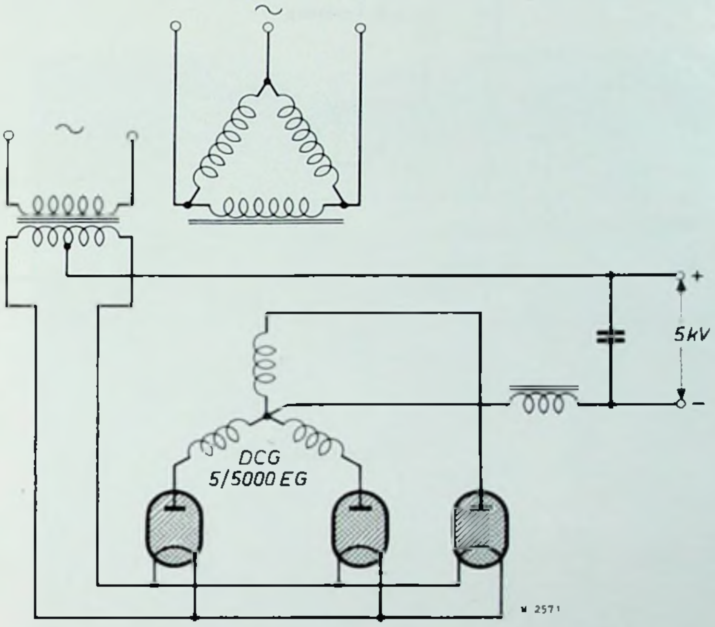

Fig.25. 5 kV power supply for the anode voltage of the tubes in the final power stage.

THE MODULATOR

The modulator consists of three tubes QB 3.5/750 connected in parallel. The anode circuit of the modulator tubes comprises, in addition to the resistor R_2, a correction network for the higher video frequencies. The d.c. level of the video signal is re-inserted in the grid circuit of the modulator tubes by means of a clamping circuit. The video amplifier, which precedes the modulator, needs a voltage of 0.5 V peak-to-peak for obtaining the required modulation depth.

THE 5 kV SUPPLY UNIT

In the high-tension rectifier for the QBL 5/3500 tubes, three-phase half-wave rectification is applied by three tubes DCG 5/5000 EG (see Fig.25). The primaries of the mains transformer are normally connected in delta, but to reduce the output voltage for tuning purposes they can also be star-connected.

EXPERIMENTAL OUTPUT STAGE WITH TWO TUBES TBW 12/100

A short description is given of an experimental power stage, operating in Band I and equipped with two water-cooled triodes TBW 12/100. This stage is capable of delivering a continuous output power of 100 kW at a bandwidth of 7 Mc/s. The frequency is variable between 48 and 67 Mc/s.

Fig.26 shows a simplified diagram of the power stage. The tubes are connected in grounded grid, and form together a push-pull

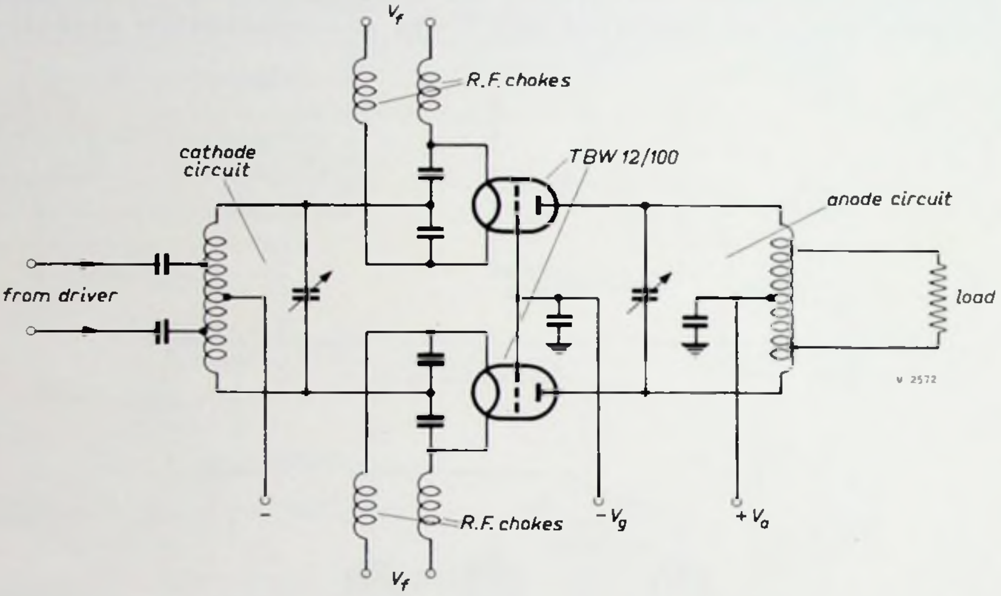

Fig.26. Simplified circuit diagram of the experimental output stage with the tubes TBW 12/100.

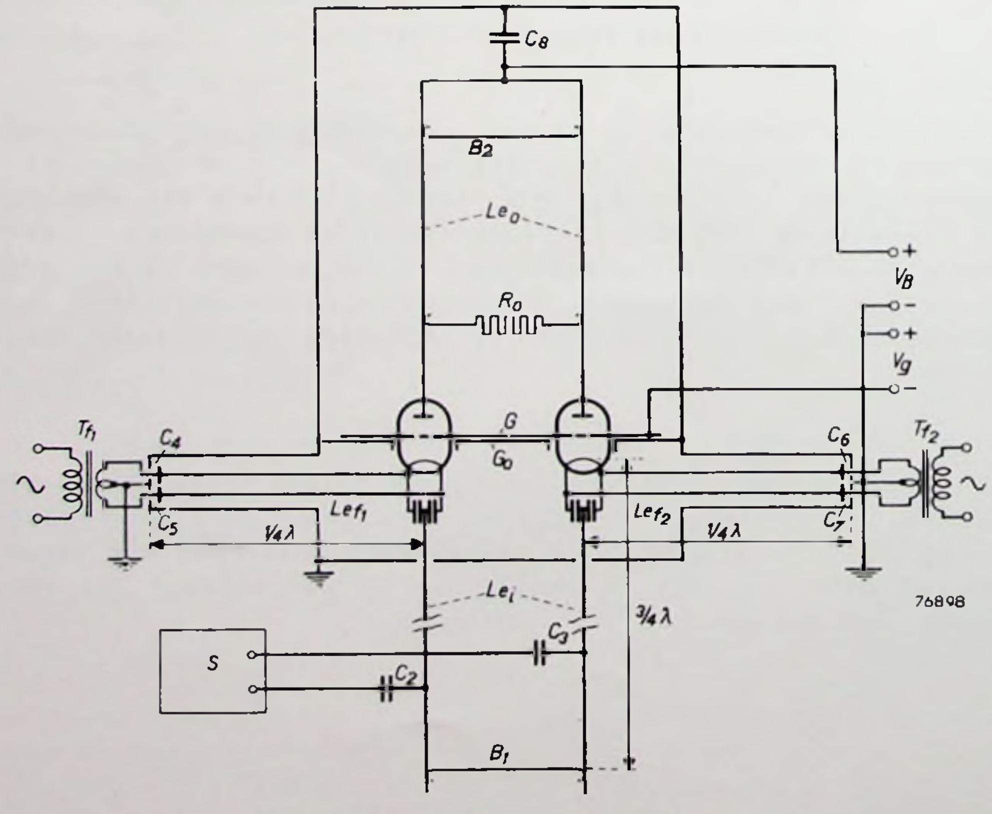

Fig.27. Actual circuit diagram of the output stage.

circuit. The modulated signal from the driver is capacitively applied to a tapping of the cathode circuit. Since the filaments of the tubes have an RF potential with respect to earth, they are connected to the supply via RF chokes.

Fig.27 shows the worked-out circuit diagram. The cathode and anode circuits are represented by tuned balanced transmission line sections. Due to the relatively high input capacitance, the electrical length of the cathode circuit is 3λ/4; the length of the anode circuit is λ/4. The load resistor can be shifted along the transmission line to match the load to the output circuit. The cathode and the anode circuits can both be tuned by movable shorting bridges.

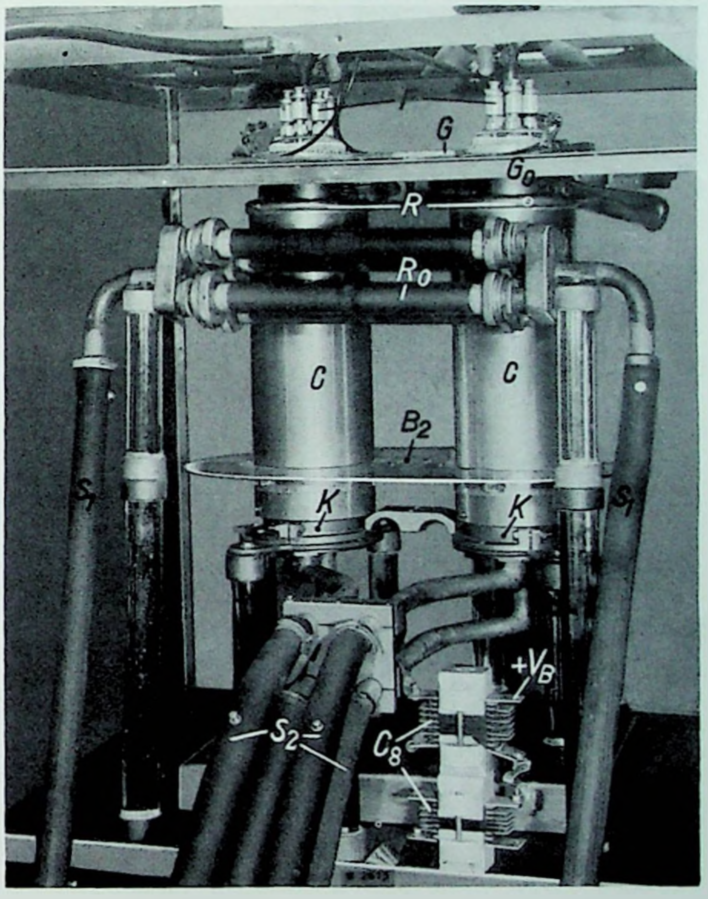

Fig.28. Photograph of the anode circuit; G = perforated anti-corona ring, through which cooling air is blown onto the seals. C = Lecher lines. B_2 = shorting bridge. R_o = load resistor. K = cooler. S_1 and S_2 = cooling water hoses for the load resistance and the tubes respectively. C_8 = by-pass capacitor.

The RF chokes, connecting the filament terminals to the supply, are represented by λ/4 transmission lines, capacitively short-circuited at the ends.

The grid discs of the tubes are connected to a plate that is capacitively coupled to the chassis by means of mica.

Fig.28 shows a photograph of the anode circuit of the stage.

220 Mc/s OSCILLATOR WITH THE TBW 6/6000 OR THE TBL 6/6000

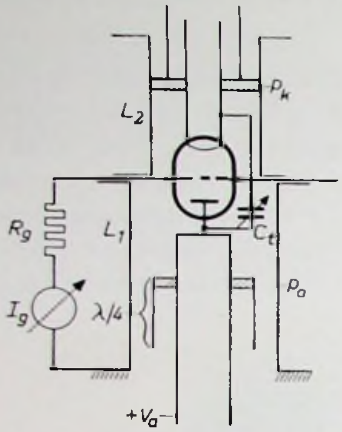

Fig.29. Basic diagram of the 220 Mc/s oscillator.

Below a short description is given of a grounded-grid oscillator with the tube TBW 6/6000 or TBL 6/6000, operating at a frequency of 220 Mc/s.

Fig.29 shows the basic circuit diagram of this oscillator. The grid seal of the tube is connected to a metal plate that separates the anode circuit from the cathode circuit. These circuits are formed by tuned co-axial transmission line sections. Feedback is provided by a variable capacitor connecting the cathode to the anode.

Fig.30 shows a cross-section of the anode circuit of the oscillator. The air-cooled TBL 6/6000 is inserted in a hollow tubing *A* that forms the inner conductor of the output circuit, the outer conductor being formed by the hollow cylinder *B*. The piston p_a with a length of $\lambda/4$, which makes contact with the inner conductor only, provides the tuning of the anode circuit. The $\lambda/4$ transmission line section, formed by the piston and the cylinder *B*, transforms the lower open end into an RF short-circuit at the upper end. By moving the plunger, the resonant frequency of the anode circuit is therefore varied. The piston can be shifted by means of the guide rods *F* operated by a threaded spindle *G* and gear *H*.

Cooling air is blown through the hollow cylinder *A*. The plate *K* is divided into two halves, so that the tube can easily be inserted or removed. A normal grid connector, which is soldered on this plate and also consists of two semi-circular plates, ensures a reliable concentric contact with the grid disc of the tube. The outer wall *B* of the anode circuit is provided with a large flange at the top. This flange has been given sufficiently large dimensions to ensure adequate capacitive earthing to the plate *K*, which is connected to the grid. This plate is insulated from the flange by a disc of teflon.

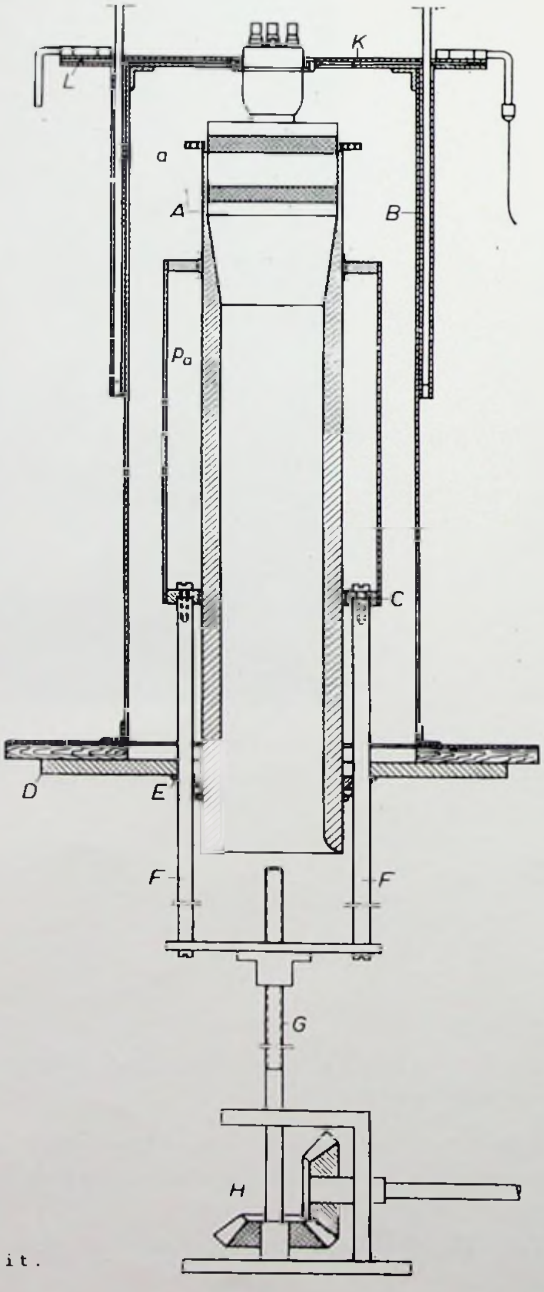

Fig.30. Cross-section of the anode circuit.

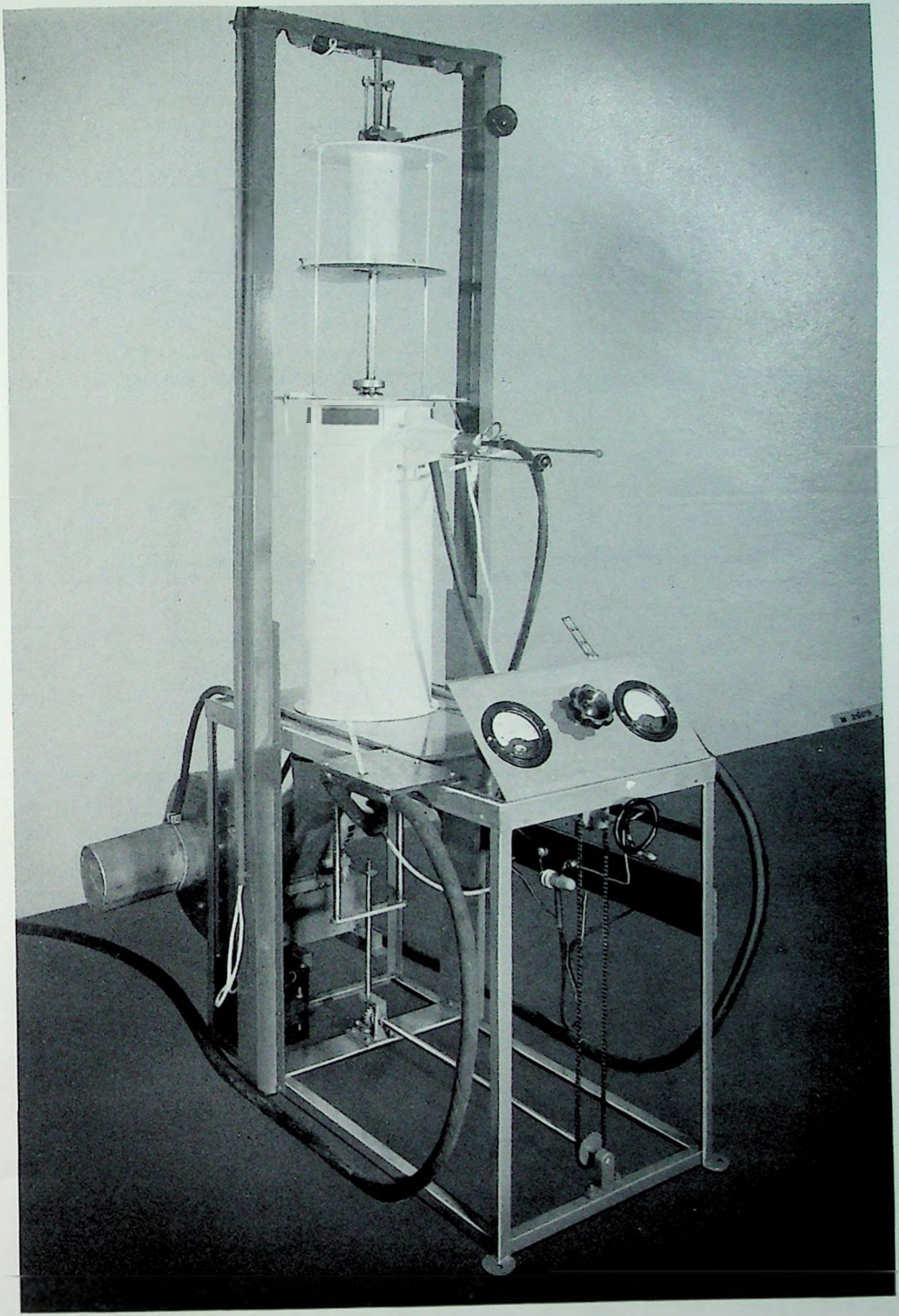

Fig.31. Photograph of the complete oscillator with the cathode circuit lifted.

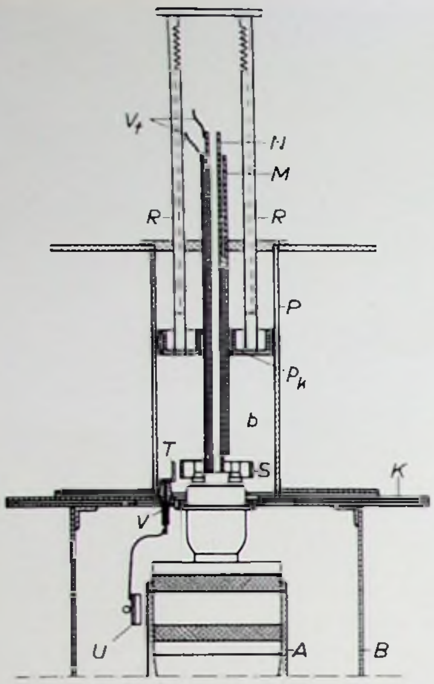

Fig.32. Cross-section of the cathode circuit.

The cathode circuit (see Fig.32) consists of the tube M, the piston p_k, the hollow cylinder P and the plate K. The tubes M and N, which also carry the filament supply, are insulated from each other by a tube of teflon.

Tuning of the cathode circuit is accomplished by the piston p_k that can be shifted by means of a rack and pinion. The filament leads are bypassed by means of capacitors, feedback being provided by the capacitors T and U.

A photograph of the oscillator is depicted in Fig.31. Typical electrical data are:

d.c. anode voltage	4000 V
d.c. anode current	1.25 A
grid current	200 mA
grid leak resistor	1000 Ω
anode d.c. input power	5 kW
output power	3.25 kW
anode dissipation	1.75 kW
efficiency	65 %

5 KW TV TRANSMITTER

A short description is given of a TV transmitter (installed in Stockholm [1])) operating in Band III (174 - 216 Mc/s), and delivering an output power of 5 kW (sync. peak). The output power of the sound transmitter is 2.5 kW. The performance of the transmitter is based on the CCIR standards.

Fig.33 shows a simplified block-diagram of the transmitter, indicating the power levels and the frequencies of the various stages.

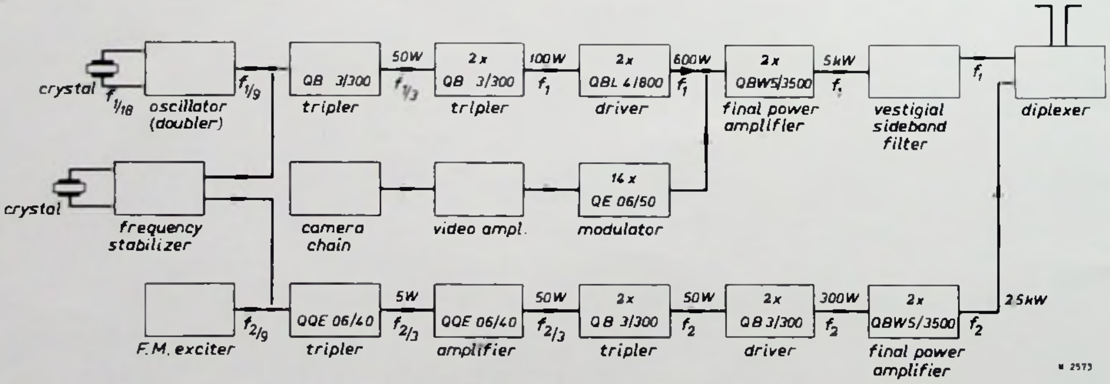

Fig.33. Block diagram of a 5 kW TV transmitter for Band III.

The carrier frequency of the vision transmitter is obtained from a crystal oscillator, generating a frequency of 1/18th of the transmitted signal. After having been doubled, the signal passes two triplers, the former being equipped with one tube QB 3/300 and the latter with two tubes QB 3/300 in push-pull.

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[1]) Designed by dr. Werthen of the Technical University of Stockholm.

The driver stage, in which no frequency multiplication takes place, consists of a push-pull circuit with two tubes 4 X 500 A (QBL 4/800), and delivers an output power of 600 Watts.

THE FINAL POWER STAGE

Fig. 34 shows a simplified circuit diagram of the final power stage. The input and output circuits are composed of tuned balanced transmission line sections. The electrical length of the input circuit is approximately 3λ/4, the input capacitance of the tubes being too large to allow the use of a λ/4 line section. To shorten the physical length of the line, a shunt capacitor is used, with the aid of which the line can also be tuned.

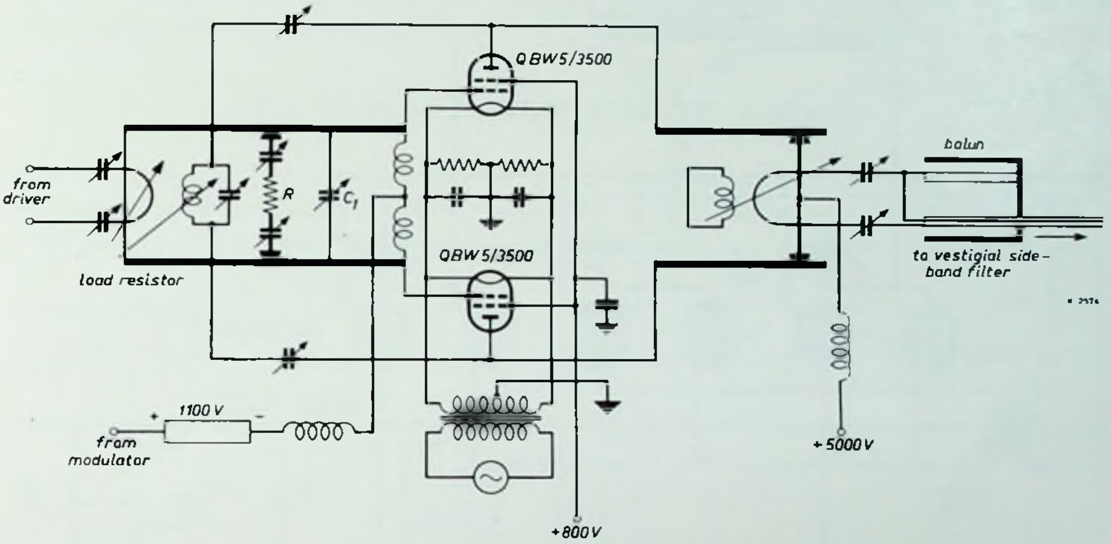


Fig. 34. Simplified circuit diagram of the final power stage.

The driver is inductively coupled to the input circuit; the coupling is adjustable to obtain optimum power conversion. Only a small proportion of the power delivered by the driver stage is needed for full drive of the tubes QBW 5/3500 (approx. 50 W); the remainder is consumed in the water-cooled resistor R (300 Ω) in order to reduce the distortion due to absorption modulation by grid current. Moreover, by adding R, the load resistance of the modulator is decreased, thus improving the bandwidth of the modulator.

The anode of the modulator tube is d.c. coupled to the grids of the tubes QBW 5/3500. The filaments of these tubes are directly earthed, which has been made possible by connecting a constant voltage of -1100 V in series with the modulator voltage, so that the grid bias is equal to the direct anode voltage of the modulator minus 1100 V (800 - 1100 = -300 V).

The output circuit is composed of two inductively coupled resonant circuits, the first of which is formed by a balanced transmission line section connected to the anodes of the output tubes. Tuning is achieved by means of a short-circuiting bridge that can be shifted along the line. Fine adjustment is provided by a short-circuited inductance, which has a variable coupling with the first resonant circuit.

The second circuit is formed as a balanced-to-unbalanced transformer, and can be tuned by a variable capacitor.

Neutralising is performed by a resonant circuit, coupled capacitively to the anodes of the tubes and inductively to the input circuit.

THE POWER SUPPLY

The anode voltage of the two tubes QBW 5/3500 (5 kV) is obtained from a three-phase full-wave rectifier, equipped with six tubes DCG 5/5000 GB. Fig.35 shows a slightly simplified circuit diagram.

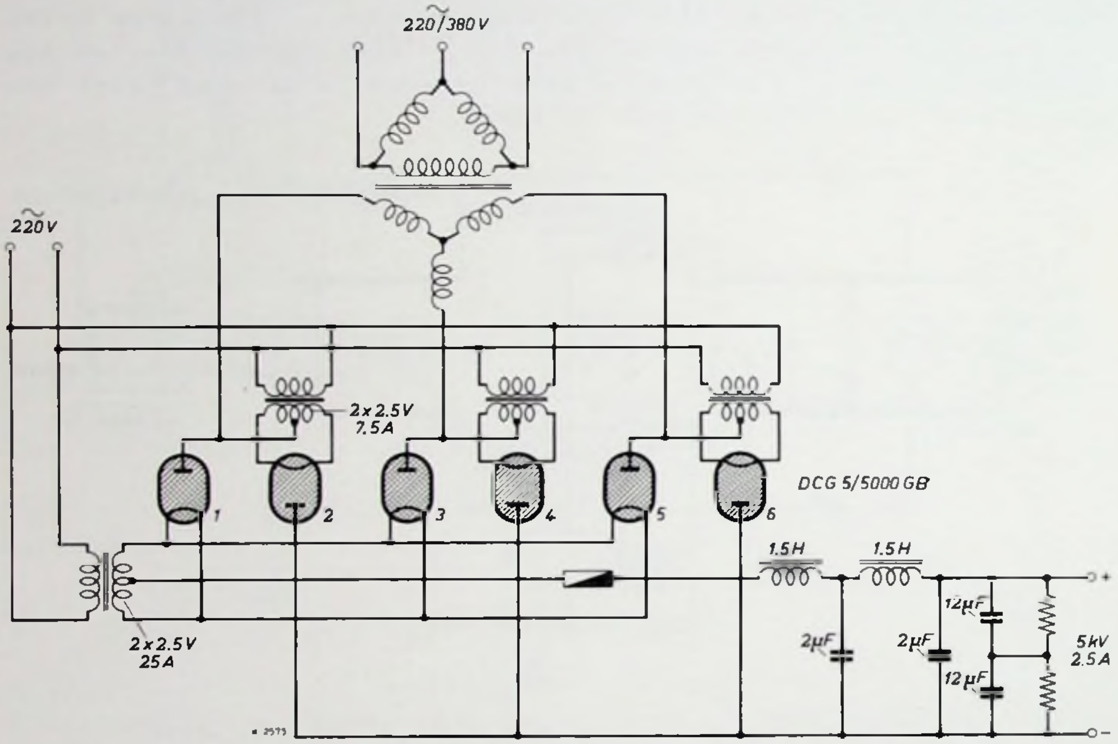


Fig.35. Slightly simplified diagram of the 5 kV power supply for the anodes of the QBW 5/3500 tubes.

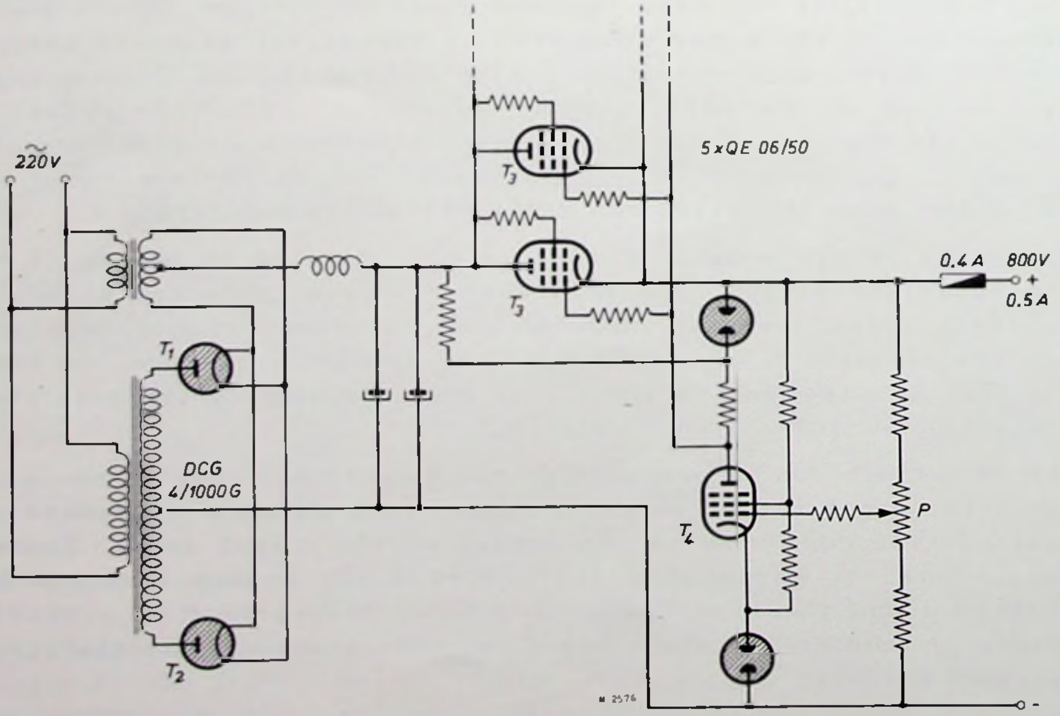


Fig.36. Stabilised power supply unit for the screen grids of the QBW 5/3500 tubes.

Since the cathodes of the tubes 2, 4 and 6 have different potentials, they are provided with separate supply transformers, the secondaries of which are highly insulated from the primaries.

The screen-grid voltage of the QBW 5/3500 tubes is obtained from a stabilised supply unit. Stabilisation is achieved by d.c. feedback, so that mains voltage fluctuations and direct voltage variations are both reduced to a large extent. Fig.36 shows the circuit diagram of this power supply unit. Two-phase half-wave rectification is applied, accomplished by two mercury-vapour rectifying tubes DCG 4/1000 G. The output voltage is kept constant by the voltage drop across five tubes QE 06/50 in parallel. These tubes are controlled by a pentode amplifying tube (T_4). The d.c. output voltage can be adjusted by means of the potentiometer *P*. A fuse of 0.4 A prevents the screen-grid current from becoming excessive.

220 Mc/s OSCILLATOR WITH THE TBW 6/20

Below a description is given of a 220 Mc/s oscillator with the water-cooled transmitting triode TBW 6/20. At an efficiency of 50%, the oscillator can deliver an output power of approximately 10 kW.

CONSTRUCTION

Fig.37 shows a cross-section of the oscillator. The TBW 6/20

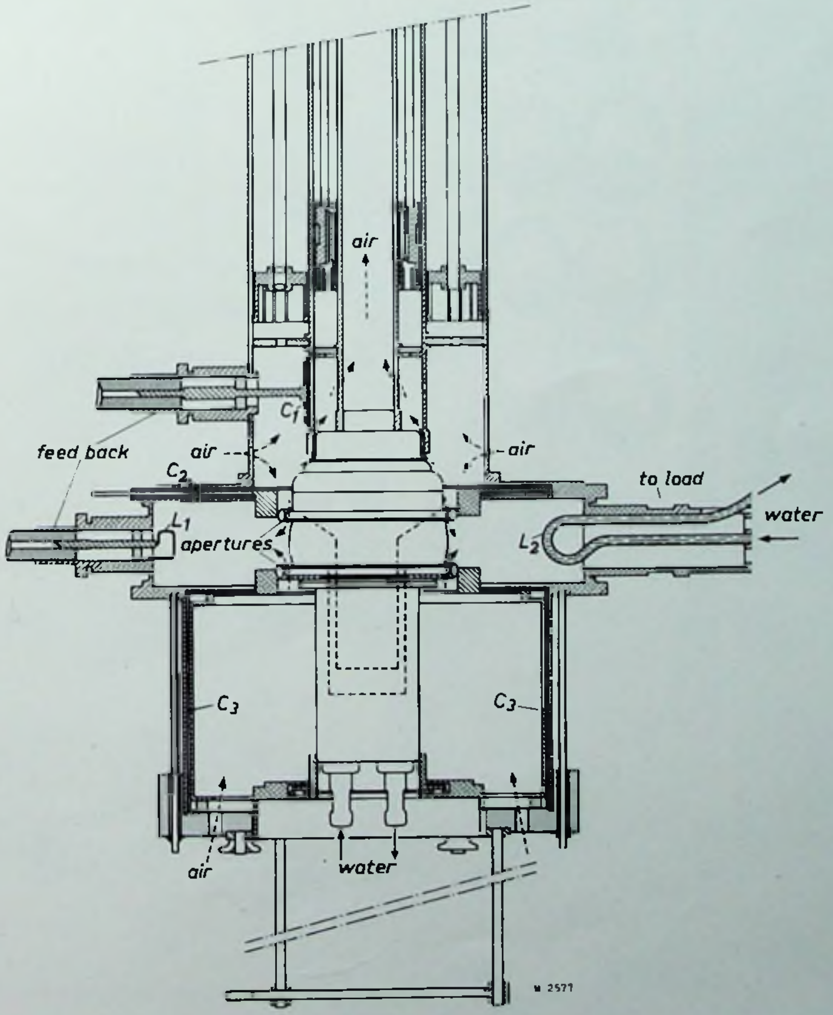


Fig.37. Cross-section of the 220 Mc/s oscillator with the TBW 6/20.

operates in a grid separation circuit with tuned anode and cathode circuits, the latter being adjustable. Feedback is provided by an additional connection between the two tuned circuits.

The anode circuit is formed by a cylindrical cavity, radially placed around the tube, the flat walls being coupled to the grid and the anode respectively. The cathode circuit consists of a co-axial transmission line section connected between the outer terminal of the filament and the grid. The inner terminal of the filament is decoupled for RF via another co-axial line, which acts as a stopper circuit.

Tuning of the cathode circuit and the stopper circuit is accomplished by short-circuiting pistons. To insulate both filament terminals for d.c., the piston of the stopper circuit is split up in two, both parts being capacitively coupled.

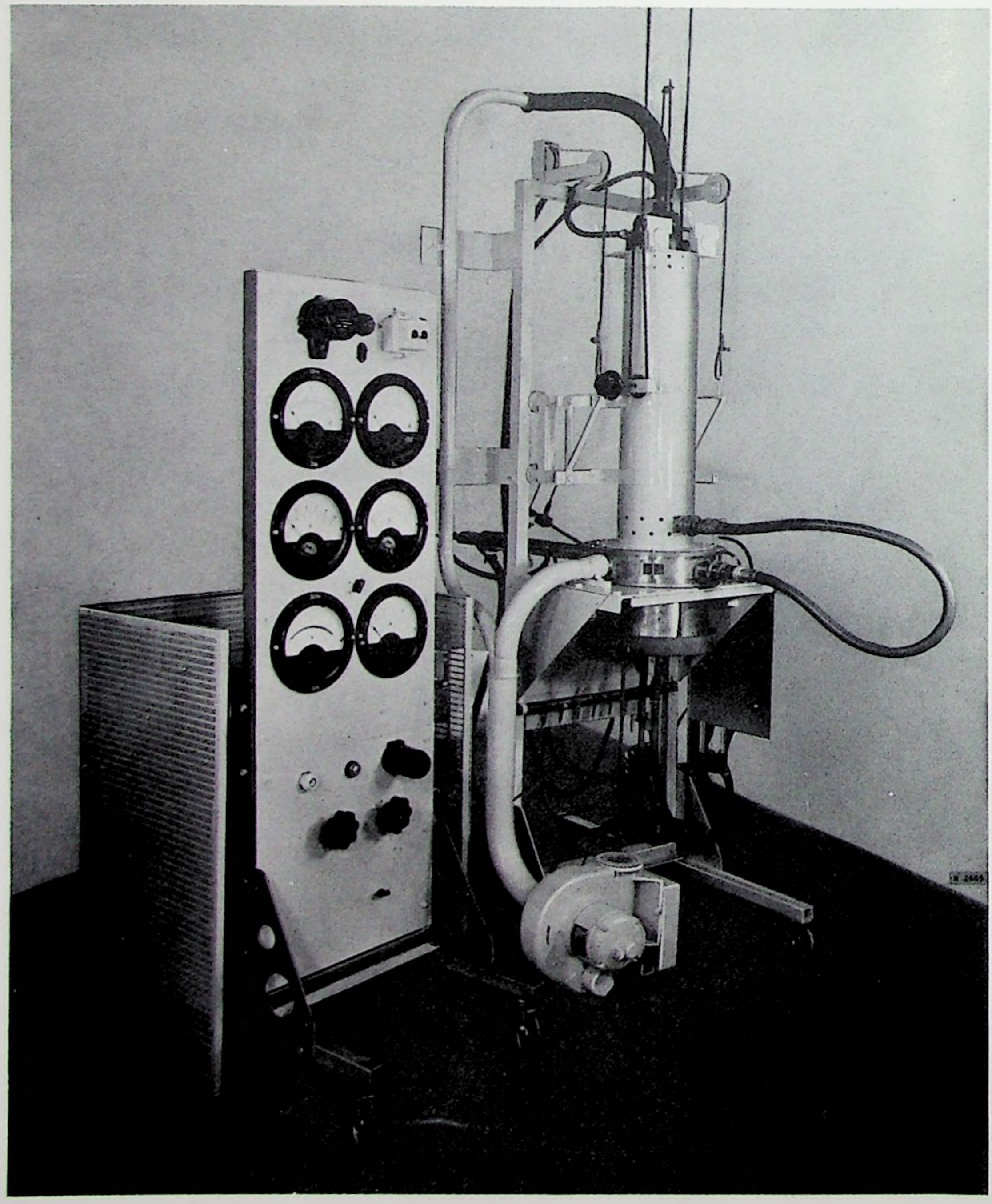


Fig.38. Photograph of the oscillator.

The outer terminal of the filament has a direct connection with the earthed outer wall of the oscillator; the grid and the anode are capacitively connected to the circuit via the capacitors C_2 and C_3 respectively.

The feedback power is taken inductively from the anode cavity by means of the coupling loop L_1, and applied to the cathode circuit via a co-axial cable and the capacitor C_1.

Via another coupling loop (L_2), which consists of a metallic tube through which cooling water is directed, the output power is taken off.

COOLING

Apart from the water cooling of the anode, air cooling is required for the metal-to-glass seals of the tube. The cooling air is sucked from the top of the inner filament connection of the tube and from the anode cavity. (In Fig.37 the air outlet cannot be seen.) The air flows through the apertures of the electrode connections, thereby cooling the seals. Only a small quantity of air is required to keep the seal temperatures below their maximum permissible value, so that a small blower suffices.

Fig.38 shows a photograph of the oscillator.

ELECTRICAL DATA

The anode supply voltage of the TBW 6/20 is obtained from a three-phase, half-wave rectifier circuit and amounts to 4 kV. The anode current and grid current of the oscillator tubes are 4.8 A and 0.9 A respectively. The grid leak resistor has a value of 67 Ω.

PUSH-PULL AMPLIFIER WITH TWO TUBES TBW 6/20

The amplifier described here was designed for carrying out measurements on the TBW 6/20 as a linear amplifier operating in Band III. The results of these measurements are given under the Technical Data of the tube.

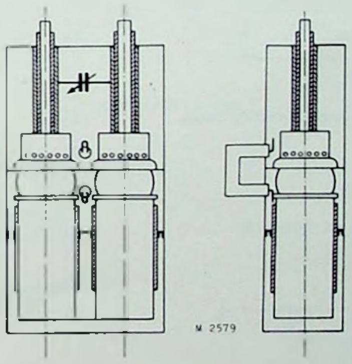


Fig.39. Simplified cross-section of the TBL 2/300 amplifier.

The tubes are connected in grounded-grid and are driven by two tubes TBW 6/6000 in push-pull.

The mechanical set-up of the amplifying stage is shown in Fig.39. The tubes are mounted vertically in a closed cabinet. The grid discs of the tubes are directly connected to a horizontal shield that divides the cabinet in an upper and lower compartment, containing the cathode and the anode circuit respectively.

The resonant circuits are formed by short-circuited balanced transmission line sections. The anode circuit, which has an electrical length of $\lambda/4$, is formed by a pair of cylindrical conductors surrounding the anodes that are short-circuited by a movable bridge. This bridge makes contact with the walls of the compartment to prevent power from entering the space below the shorting bridge. To provide a separation for d.c. between the anodes and the grids, the cylindrical conductors are composed of two co-axial pipes that are capacitively interconnected by an insulating layer of teflon.

The short-circuited cathode line in the upper compartment has been given an electrical length of $3\lambda/4$, which proved to be necessary in connection with the relatively large input capacitance of the tubes. To reduce the physical length of the line, the latter has been shortened by means of a variable capacitor, which is placed close to a voltage maximum and at the same time provides the tuning of the cathode circuit.

The construction of the cathode circuit is similar to that of the anode circuit. Moreover, the inner and outer terminals of the filament have been interconnected for RF by co-axial pipes, capacitively connected via another layer of teflon.

Neutralising is provided by two loops, coupled with the input and output circuit respectively and interconnected via a shielded balanced transmission line.

PUSH-PULL AMPLIFIER WITH THE TUBES TBL 2/300 FOR BAND V

Fig.40 shows two cross sections of a push-pull grounded-grid amplifier with the tubes TBL 2/300. At 900 Mc/s this amplifier can deliver an output power of approx. 310 W at a bandwidth of more than 6 Mc/s between the 1 dB points. The required driving power is 120 W.

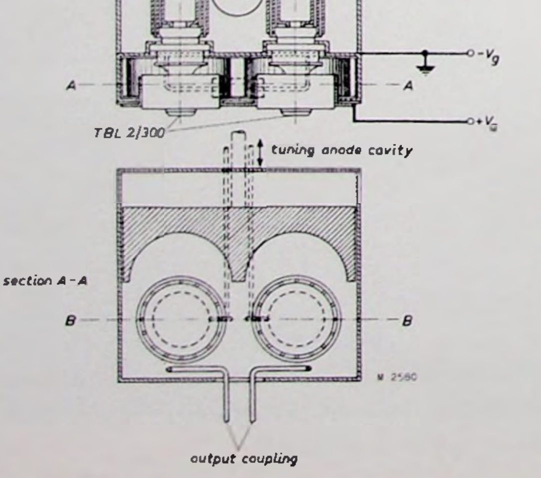


Fig.40. Two cross-sections of a push-pull amplifier with two tubes TBL 2/300 operating in Band V.

The tubes are mounted vertically in a closed cabinet, the input and output circuits being separated by a metal wall to which the grids of the tubes are directly connected. The cathode circuit in the upper part of the cabinet consists of a balanced transmission line section tuned by a short-circuiting bridge. The electrical length of this resonant circuit is $3\lambda/4$.

The cylindrical conductors of the line are capacitively coupled to the filament terminals via mutually insulated co-axial tubes. The driving power is applied symmetrically to a tapping on the line.

The anode circuit is composed of a resonant cavity, which is tunable by a metal block, which forms the rear wall of the cavity and can be shifted to and fro. When doing so, the volume and consequently the resonant frequency of the cavity is varied.

The output coupling is achieved by a symmetrical loop, which is partly formed by the upper wall of the cavity.

In order to provide d.c. insulation between the anodes of the tubes and the grids, the former are capacitively connected to the circuitry.

OSCILLATOR WITH THE TBL 2/300 OPERATING IN BAND V

Fig.41 shows the cross-section of a grounded-grid oscillator with the forced-air cooled transmitting tube TBL 2/300. Similar to the TBL 6/20, the TBL 2/300 is built up co-axially, so that the tube is very suitable for use in the co-axial circuit of Fig.41.

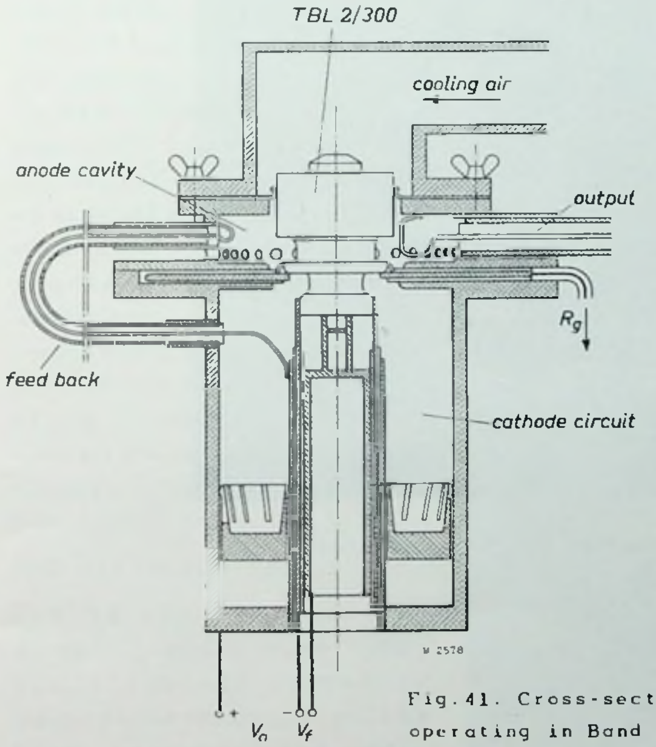


Fig.41. Cross-section of the TBL 2/300 oscillator operating in Band V.

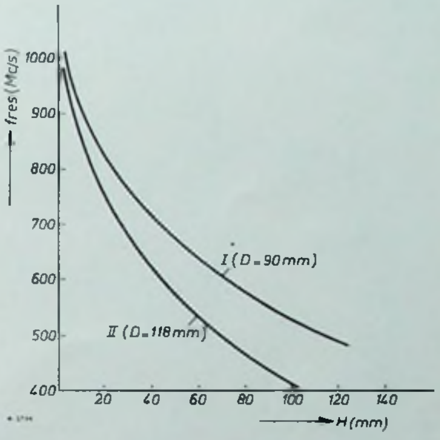


Fig.42. Oscillation frequency of the oscillator of Fig.41 as a function of the height of the anode cavity for two values of its diameter.

The anode circuit is formed by a co-axial transmission line section, which is tunable by means of a short-circuiting piston.

The anode is directly connected to the outer wall of the oscillator, whilst the grid and the cathode are capacitively coupled to the circuitry.

Cooling air is applied via a dome at the top of the oscillator, from which the air is blown through the radiator of the tube into the anode cavity, and finally escapes through apertures into open air.

The anode cavity, which mainly determines the oscillator frequency, cannot be tuned continuously. It is, however, possible to change the resonant frequency by using additional mounting parts in such a way that the volume of the cavity is increased or decreased. Fig.42 represents the resonant frequency of the anode cavity as a function of its height (*H*) for two different values of the diameter (*D*).

Fig.43 shows a photograph of the oscillator with the power supply rack.

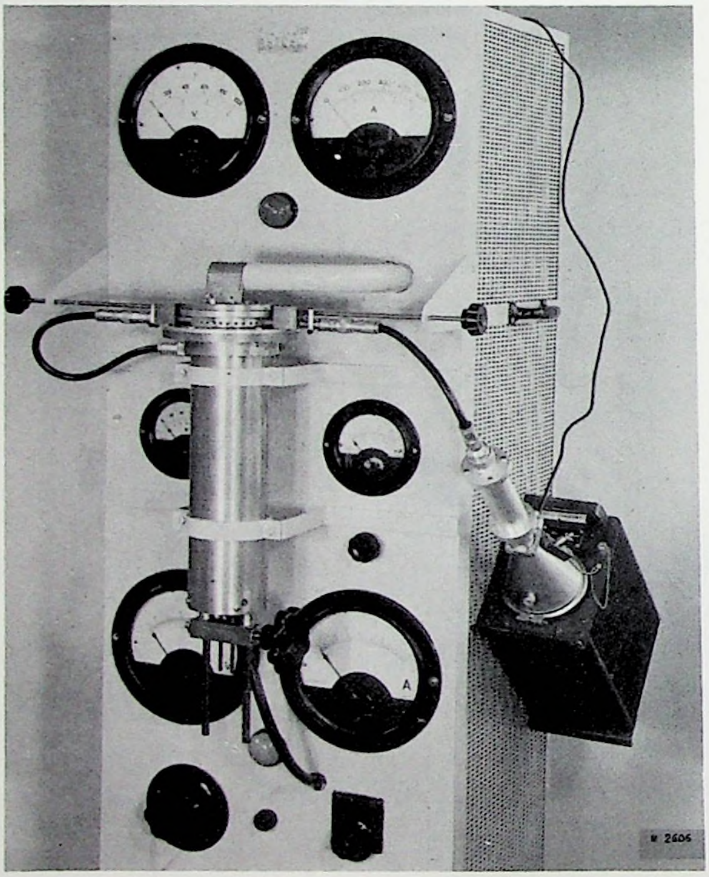


Fig.43. Photograph of the oscillator.

DESCRIPTIONS OF TRANSMITTING TUBES

The transmitting tubes described below can be classified in two groups, namely:

(1) tubes without forced cooling (internal anode);
(2) tubes with forced cooling (external anode).

All tubes of the first group, with the exception of the low-power double tetrode QQE 06/40, are directly heated and of the so-called "all-glass" construction, i.e. the whole envelope of the tube is made of glass. The types with forced cooling are either cooled by forced air or water. Most of these types have both an air-cooled and a water-cooled version; the electrical properties of these versions are quite or nearly the same.

Proper functioning of the transmitting tubes can be guaranteed only if accessories have been supplied or approved by the tube manufacturer. In general this applies to sockets, clips etc., whilst for tubes with forced cooling it concerns particularly insulating pedestals and water jackets.

In addition to the general data, such as filament data, static characteristics, (mutual conductance, amplification factor, capacitances, constant current characteristics etc.) and cooling characteristics, only data concerning operation in TV transmitters that are of interest, or may be expected to be so, are included, so that e.g. operating conditions of anode-modulated high-power transmitting tubes have been omitted.

THE ALL-GLASS TYPES

Fig.44 shows a specimen of an all-glass tube type. The electrode system is mounted vertically on the base, except for the anode the only connection of which with the envelope is at the top of the bulb. This guarantees a long insulating path along the envelope, which is important in view of high anode voltages.

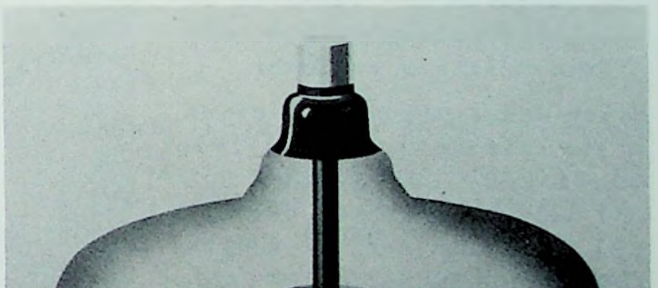


Fig.44. Cut away view of a typical all-glass transmitting tube.

The screen grid is connected to a horizontal screen that minimizes the capacitances between the anode and the connections of the control grid and the filament, the latter being sealed through the base. The screen, moreover, prevents heat radiation of the anode from reaching the base.

The base is made of powder glass, so that the electrode leads could be kept very short. Consequently the capacitances between and the inductances of the leads are very small.

Except for the type QB 3/200, the anodes of the all-glass tubes are made of graphite, which ensures a very effective heat radiation.

With some types the anode is provided with ring-shaped ridges that have the purpose of reducing the temperature gradient of the glass bulb.

Data of the all-glass tetrode transmitting tubes QB 3/200, QB 3/300, QB 3.5/750, QB 5/1750 are given below.

TUBES WITH FORCED COOLING

The anode of both the forced-air and water-cooled types is part of the tube envelope (external anode, see Fig.45). The anodes of the tubes to be cooled by forced air are provided with a radiator.

Below descriptions are given of the tetrode types QEL 1/150, QBL 4/800, QBL 5/3500 and QBW 5/3500 and of the triodes TBL 2/300, TBL 6/6000, TBW 6/6000, TBL 6/20, TBW 6/20, TBL 12/100 and TBW 12/100.

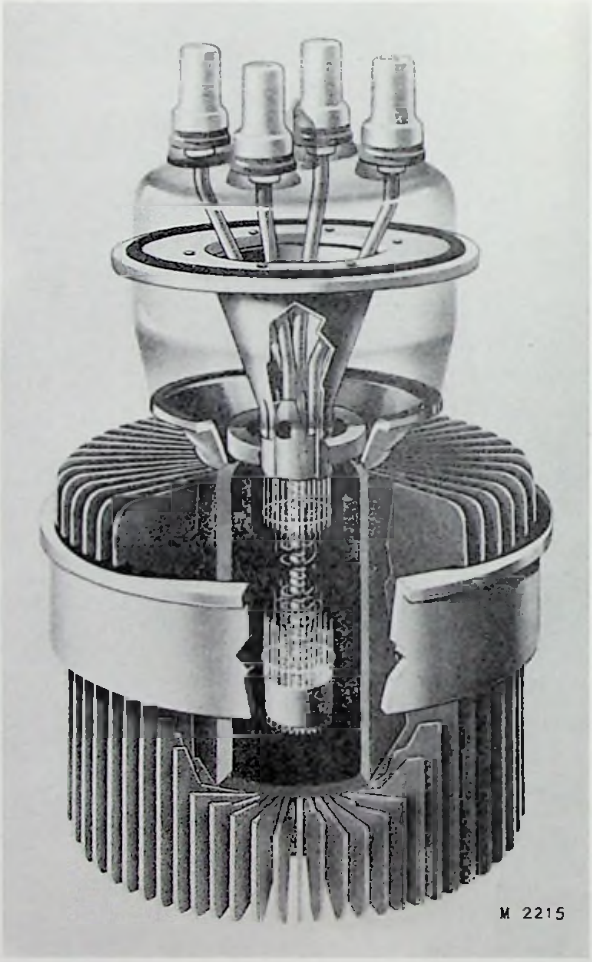
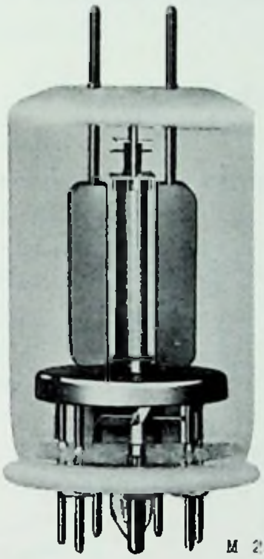


Fig.45. Cut away view of a typical forced-air cooled transmitting tube.

Indirectly heated double tetrode QQE 06/40

The QQE 06/40 is an indirectly heated double tetrode for use at frequencies up to 500 Mc/s. At frequencies up to 250 Mc/s the tube can deliver an output power of 85 W under class-C telegraphy conditions.

The QQE 06/40 can be used as oscillator, amplifier, frequency multiplier and modulator. In small (local) TV transmitters the tube can be used as grid modulated class-C amplifier in the final stage of the vision transmitter, as such delivering a sync peak output power of 100 W at 220 Mc/s (two systems in push-pull).



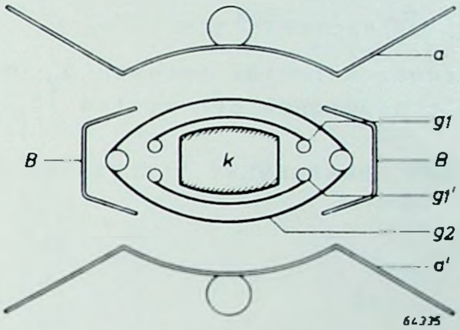


Fig.46.(left) Photograph of the QQE 06/40.

Fig.47.(right) Horizontal cross-section through the QQE 06/40. (*B* = beam plates).

Typical features of the QQE 06/40 are its low operating voltages and the small inductances of its electrode connections. The construction of the electrode system can be seen in Fig.47 showing a cross-section of the tube. The two tetrode systems have the cathode and the screen-grid in common. As a result, the inductances of the connection between the cathodes of both sections and that between the screen-grids are reduced to a minimum.

Secondary emission from the anode is prevented by beam plates, which cause a fairly large space charge between the screen-grid and the anode.

In the lower part of the tube, a horizontal screen, which is connected to the cathode, reduces the capacitance between the anode and the base connections.

At frequencies higher than 150 Mc/s it is necessary to cool the tube envelope and the anode seals by a low-velocity air flow under normal operating conditions.

The heaters of both systems can be circuited either in series or in parallel.

The American designation of the QQE 06/40 is the type number 5894. The tube can be considered as a modern successor to the 829 B, which in most cases can be fully replaced by the QQE 06/40, the most important differences referring to inductances and capacitances.

TECHNICAL DATA

Cathode: oxide coated, indirectly heated

Heater voltage	V_f	=	6.3	12.6	V
Heater current	I_f	=	1.8	0.9	A
Pins			5-(1+7)	1-7	

CAPACITANCES

Per system	C_a	=		3.2	pF
	C_{g1}	=		10.5	pF
	C_{ag1}	<		0.085	pF
In push pull	C_o	=		2.1	pF
	C_i	=		6.7	pF
	$C_{ag'} - C_n$ [1]	=	max.	0.035	pF

TYPICAL CHARACTERISTICS

Amplification factor between g_2 and g_1	μ_{g2g1}	=	8.2	
Mutual conductance per system (I_a = 30 mA)	S	=	4.5	mA/V

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS

(in mm)

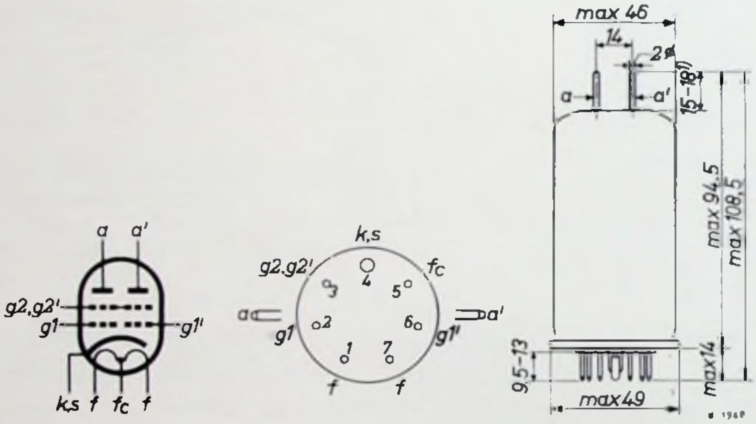


Fig. 48.

Base	:	Septar
Socket	:	40202
Clips	:	40623

MOUNTING POSITION

Vertical with base up or down

Horizontal with anode pins in one horizontal plane

MAXIMUM TEMPERATURE

Bulb and anode seals	max.	200 °C
Bottom pin seals	max.	180 °C

NET WEIGHT 60 g

SHIPPING WEIGHT 155 g

---

[1] C_n = neutralizing capacitance.

H.F. CLASS C TELEGRAPHY (2 systems in push-pull)
(f = max. 250 Mc/s)

LIMITING VALUES

Anode voltage	V_a	=	max.	750	V
Anode input power	W_{ia}	=	max.	2x60	W
Anode dissipation	W_a	=	max.	2x20	W
Anode current	I_a	=	max.	2x110	mA
Screen-grid voltage	V_{g2}	=	max.	300	V
Screen-grid dissipation	W_{g2}	=	max.	2x3.5	W
Control-grid bias	V_{g1}	=	max.	175	V
Control-grid current	I_{g1}	=	max.	2x5	mA
Resistance between control grid and cathode	R_{g1}	=	max.	50	kΩ
Voltage between cathode and heater	V_{kf}	=	max.	100	V

OPERATING CONDITIONS

Frequency	f	=	250	Mc/s
Anode voltage	V_a	=	750	V
Control-grid bias	V_{g1}	=	-80	V
Screen-grid voltage	V_{g2}	=	250	V
Anode current	I_a	=	2x80	mA
Control-grid current	I_{g1}	=	2x1.5	mA
Screen-grid current	I_{g2}	=	17	mA
Alternating grid voltage (peak-to-peak value)	V_{g1g1}	=	250	V
Screen grid dissipation	W_{g2}	=	4.25	W
Anode dissipation	W_a	=	2x17.5	W
Output power	W_o	=	85	W
Efficiency	η	=	71	%

H.F. CLASS C ANODE AND SCREEN GRID MODULATION (calculated values)
two systems in push-pull, continuous service.

LIMTING VALUES (f = max. 250 Mc/s)

Anode voltage	V_a	=	max.	600	V
Anode input power	W_{ia}	=	max.	2x45	W
Anode dissipation	W_a	=	max.	2x14	W
Anode current	I_a	=	max.	2x92	mA
Screen-grid voltage	V_{g2}	=	max.	300	V
Screen-grid dissipation	W_{g2}	=	max.	2x3.5	W 1)
	W_{g2}	=	max.	2x2.3	W 2)
Control-grid bias	$-V_{g1}$	=	max.	175	V
Control-grid current	I_{g1}	=	max.	2x5	mA
Resistance between control grid and cathode	R_{g1}	=	max.	50	kΩ 3)
	R_{g1}	=	max.	25	kΩ 4)
Voltage between cathode and heater	V_{kf}	=	max.	100	V

---

1) Screen-grid modulation via a choke.

2) For all other modulation methods

3) Per system

4) Per tube

OPERATING CONDITIONS (f = max. 250 Mc/s)

Anode voltage	V_a	=	600	V
Screen-grid voltage	V_{g2}	=	250	V
Control-grid bias	V_{g1}	=	-80	V
Anode current	I_a	=	2x75	mA
Screen-grid current	I_{g2}	=	18	mA
Control-grid current	I_{g1}	=	2x1.6	mA
Control-grid peak voltage	V_{g1p}	=	130	V
Screen-grid dissipation	W_{g2}	=	4.5	W
Anode input power	W_{ia}	=	2x45	W
Anode dissipation	W_a	=	2x13	W
Output power	W_o	=	64	W
Efficiency (modulation depth 100%)	η	=	71	%
Screen grid peak voltage	V_{g2p}	=	90	V
Modulation power	W_{mod}	=	45	W

GRID MODULATED H.F. CLASS C AMPLIFIER FOR TV SERVICE

(negative modulation, positive synchronisation, two systems in push-pull) (calculated values)

LIMITING VALUES (f = max. 220 Mc/s)

Anode voltage	V_a	=	max.	750	V
Screen-grid voltage	V_{g2}	=	max.	300	V
Control-grid bias	$-V_{g1}$	=	max.	175	V
Anode current	I_a	=	max.	2x120	mA 1)
Anode input power	W_{ia}	=	max.	2x75	W 1)
Anode dissipation sync	W_a	=	max.	2x22.5	W 1)
Screen-grid dissipation	W_{g2}	=	max.	2x6	W 1)
Control-grid current	I_{g1}	=	max.	2x8	mA 1)

OPERATING CONDITIONS (two systems in push-pull)

Frequency	f	=	170 - 220	Mc/s
Bandwidth (-3dB)	B	=	6	Mc/s
Anode voltage	V_a	=	600	V
Screen-grid voltage	V_{g2}	=	200	V
Control-grid voltage sync	V_{g1}	=	-35	V
black			-50	V
white			-70	V
Alternating grid voltage (peak-to-peak value)	V_{g1g1p}	=	124	V
Anode current, sync	I_a	=	238	mA
black			148	mA
Screen-grid current, sync	I_{g2}	=	60	mA
black			21	mA
Control-grid current, sync	I_{g1}	=	16	mA
black			4	mA
Driving power, sync	W_{ig1}	=	10	W 2)
Output power, sync	W_o	=	100	W
black			56	W

---

1) The values may not occur continuously but only during the synchronisation pulses.

2) Circuit losses and losses in damping resistor included.

H.F. CLASS C TRIPLER, two systems in push-pull
(f = max. 250 Mc/s)

LIMITING VALUES

Anode voltage	V_a	=	max.	750	V
Anode input power	W_{ia}	=	max.	2x60	W
Anode dissipation	W_a	=	max.	2x20	W
Anode current	I_a	=	max.	2x110	mA
Screen-grid voltage	V_{g2}	=	max.	300	V
Screen-grid dissipation	W_{g2}	=	max.	2x3.5	W
Control-grid bias	$-V_{g1}$	=	max.	175	V
Control-grid current	I_{g1}	=	max.	2x5	mA
Resistance between control-grid and cathode	R_{g1}	=	max.	50	kΩ
Voltage between cathode and heater	V_{kf}	=	max.	100	V

OPERATING CONDITIONS

Frequency	f	=	50/150	50/150	75/225	Mc/s
Anode voltage	V_a	=	500	400	400	V
Control-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
Control-grid current	I_{g1}	=	2x3	2x2.5	2x1.5	mA
Screen-grid current	I_{g2}	=	10	16	20	mA
Alternating grid voltage (peak-to-peak value)	$V_{g1g1'}$	=	360	360	360	V
Driving power	W_{ig1}	=	2x0.6	2x0.5	2x0.3	W
Screen-grid dissipation	W_{g2}	=	2.5	4	5	W
Anode input power	W_{ia}	=	2x30	2x29	2x26	W
Anode dissipation	W_a	=	2x20	2x20	2x20	W
Output power	W_o	=	20	18	12	W
Efficiency	η	=	33	31	23	%

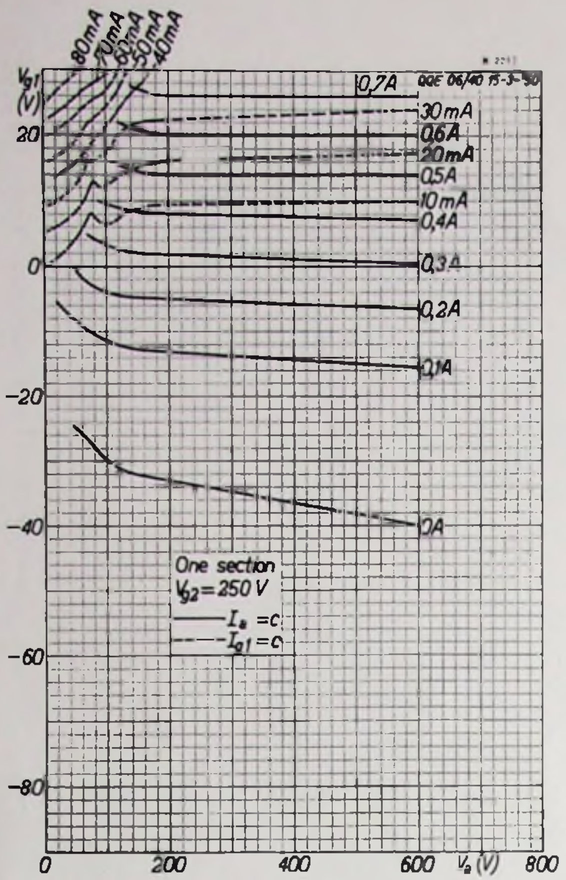


Fig. 49. Constant-current characteristics (I_a and I_{g1}) of the QQE 06/40 at a screen-grid voltage of 250 V.

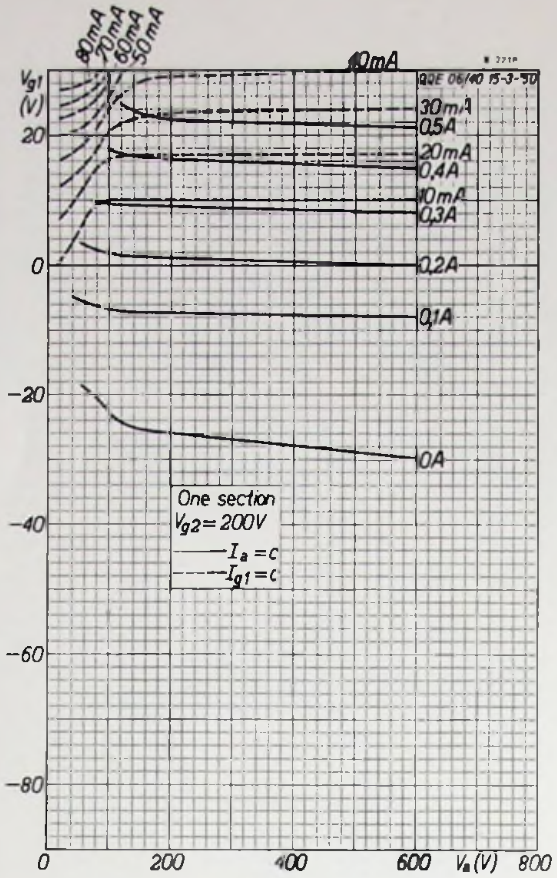


Fig. 50. Constant-current characteristics (I_a and I_{g1}) of the QQE 06/40 at a screen-grid voltage of 200 V.

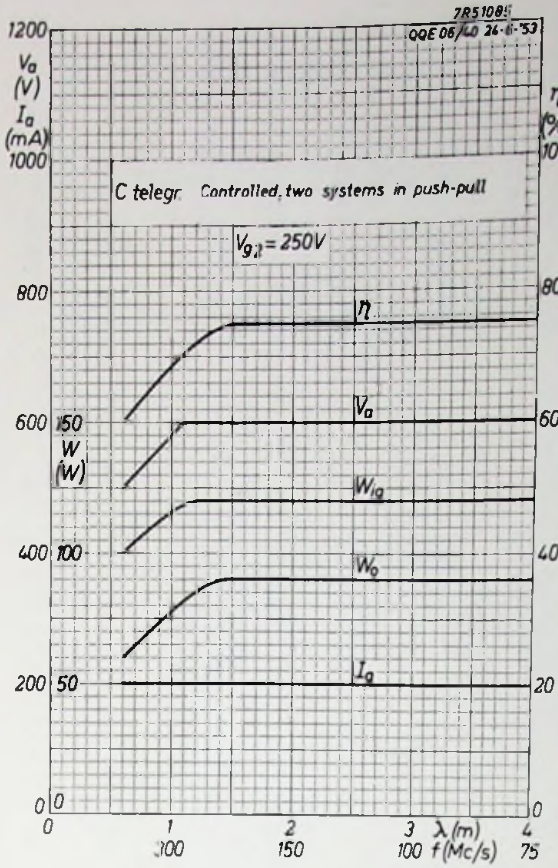


Fig. 51. Anode voltage (V_a), anode current (I_a), anode input power (W_{ia}), output power (W_o) and efficiency (η) of the QQE 06/40 as a function of frequency under class C telegraphy conditions for two systems in push-pull at a screen-grid voltage of 250 V.

All-glass transmitting tetrode QB 3/200

The QB 3/200 is a directly heated all glass transmitting tube for use as power amplifier and frequency multiplier at frequencies up to 250 Mc/s. At frequencies up to 220 Mc/s it can deliver an output power of 110 W under class C telegraphy conditions.

In contrast to the other-glass types, the QB 3/200 is provided with a molybdenum anode.

The tube is a near equivalent to the American type number 4-56 A.

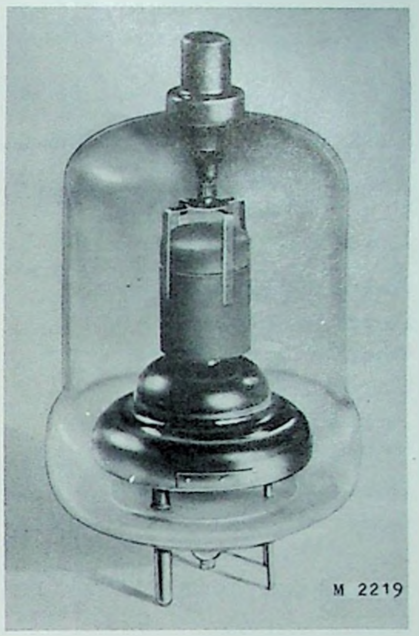


Fig.52. Photograph of the QB 3/200.

TECHNICAL DATA (tentative)

Filament: thoriated tungsten, directly heated

Filament voltage V_f = 6 V
Filament current I_f = 3.5 A

CAPACITANCES

C_a = 2.1 pF
C_{g1} = 8 pF
C_{ag1} = 0.08 pF

TYPICAL CHARACTERISTICS

Amplification factor between g_2 and g_1 μ_{g2g1} = 5
Mutual conductance (I_a = 125 mA) S = 4 mA/V

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS (in mm)

Socket : 40202
Clip : 40624

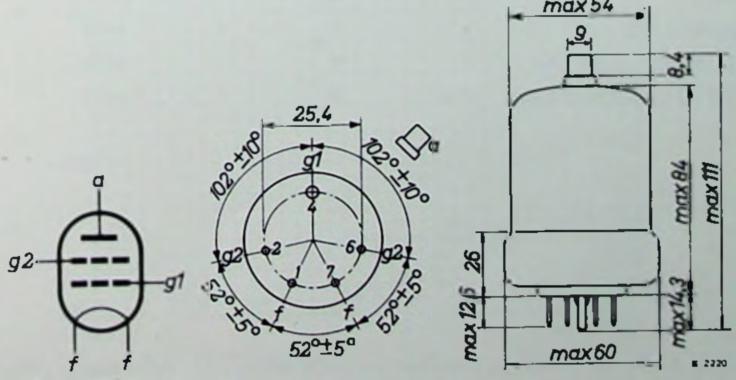


Fig.53.

MOUNTING POSITION

Vertical with base up or down

MAXIMUM TEMPERATURES

Bulb : max. 225 °C
Seals : max. 225 °C

NET WEIGHT : 85 g

SHIPPING WEIGHT : 800 g

H.F. CLASS C TELEGRAPHY

LIMITING VALUES

Anode voltage	V_a	=	max.	3000	V
Anode current	I_a	=	max.	150	mA
Anode input power	W_{ia}	=	max.	350	W
Anode dissipation	W_a	=	max.	65	W
Screen-grid voltage	V_{g2}	=	max.	400	V
Screen-grid dissipation	W_{g2}	=	max.	10	W
Control grid bias	$-V_{g1}$	=	max.	500	V
Control grid dissipation	W_{g1}	=	max.	5	W

OPERATING CONDITIONS (f = 220 Mc/s)

Anode voltage	V_a	=	1500	V
Screen-grid voltage	V_{g2}	=	250	V
Control-grid bias	V_{g1}	=	85	V
Anode current	I_a	=	117	mA
Screen-grid current	I_{g2}	=	35	mA
Control-grid current	I_{g1}	=	20	mA
Alternating-grid voltage (peak value)	V_{g1p}	=	190	V
Driving power	W_{ig1}	=	10	W
Screen-grid dissipation	W_{g2}	=	8.75	W
Anode input power	W_{ia}	=	175	W
Anode dissipation	W_a	=	65	W
Output power	W_o	=	110	W
Efficiency	η	=	63	%

H.F. CLASS C ANODE AND SCREEN GRID MODULATION

LIMITING VALUES

Anode voltage	V_a	=	max.	2500	V
Screen-grid voltage	V_{g2}	=	max.	400	V
Control-grid bias	$-V_{g1}$	=	max.	500	V
Anode current	I_a	=	max.	120	mA
Anide dissipation	W_a	=	max.	45	W
Screen-grid dissipation	W_{g2}	=	max.	10	W
Control-grid dissipation	W_{g1}	=	max.	5	W

OPERATING CONDITIONS (f = 220 Mc/s)

Anode voltage	V_a	=	1500	V
Screen-grid voltage	V_{g2}	=	250	V
Control-grid bias	V_{g1}	=	-85	V
Anode current	I_a	=	80	mA
Screen-grid current	I_{g2}	=	27	mA
Control-grid current	I_{g1}	=	12	mA
Alternating-grid voltage (peak value)	V_{g1p}	=	185	V
Screen-grid dissipation	W_{g2}	=	6.7	W
Anode input power	W_{ia}	=	120	W
Anode dissipation	W_a	=	45	W
Output power	W_o	=	75	W
Efficiency	η	=	63	%
Modulation depth 100%				
Alternating screen-grid voltage (peak value)	V_{g2p}	=	250	V
Modulation power	W_{mod}	=	60	W

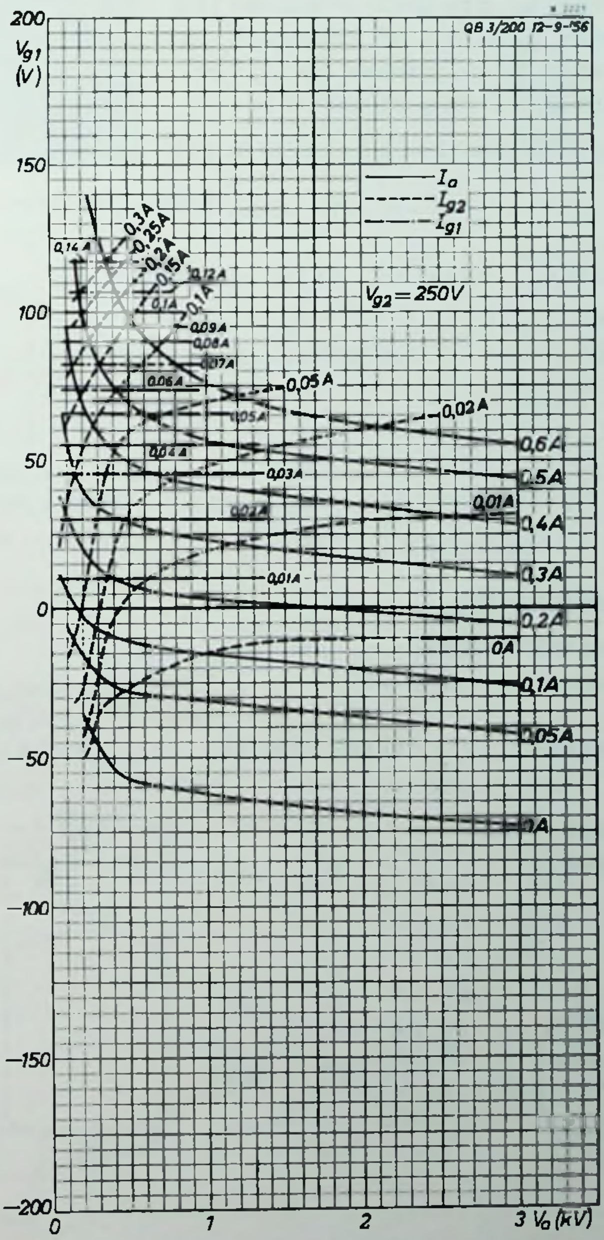


Fig. 54. Constant-current characteristics of the QB 3/200.

All-glass transmitting tetrode QB 3/300

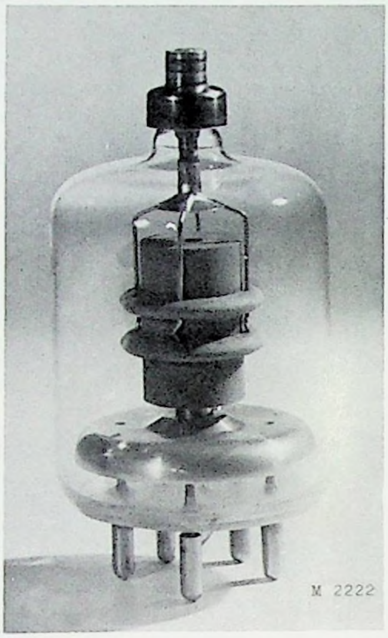


Fig. 55. Photograph of the QB 3/300.

The QB 3/300 can be used as amplifying tube at frequencies up to 200 Mc/s. At frequencies up to 120 Mc/s full ratings may be applied whereas at these frequencies it can deliver an output power of 375 W under class C telegraphy conditions. Apart from being suitable as driver, the QB 3/300 can also be used in the final power stage of TV vision transmitters [1].

When the tube is used at or near its maximum ratings at frequencies above 50 Mc/s, it will be necessary to direct a low-velocity air flow on the anode seal and the base. In order to prevent overheating of the screen-grid pins by RF currents, it is recommended that both screen-grid terminals be connected to the circuitry.

The American type designation of the QB 3/300 is 6155.

TECHNICAL DATA

Filament : thoriated tungsten, directly heated

Filament voltage	V_f	=	5	V
Filament current	I_f	=	6.5	A

CAPACITANCES

C_a	=	3.5	pF
C_{g1}	=	10.8	pF
C_{ag1}	=	0.05	pF

TYPICAL CHARACTERISTICS

Amplification factor between g_2 and g_1	μ_{g2g1}	=	6.2	
Mutual conductance (I_a = 40 mA)	S	=	2.2	mA/V

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS (in mm)

Socket : 40211/01

Clip : 40624

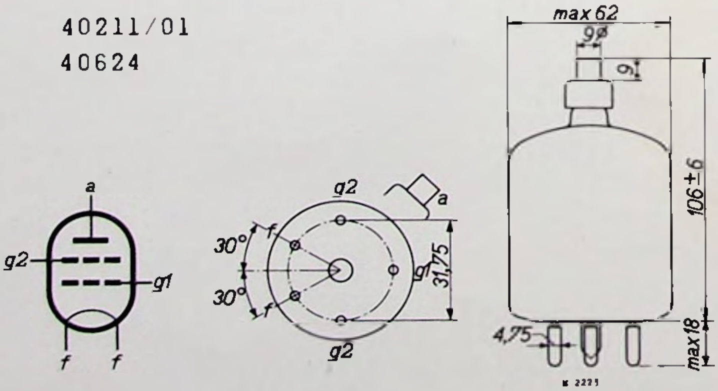


Fig. 56.

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[1] Operating conditions for this purpose are available on request.

MOUNTING POSITION

Vertical with base up or down

MAXIMUM TEMPERATURES

Bulb	:	max.	350 °C
Anode seal	:	max.	220 °C
Pin seals	:	max.	180 °C

NET WEIGHT	120 g
SHIPPING WEIGHT	850 g

H.F. CLASS C TELEGRAPHY

LIMITING VALUES (f = max. 120 Mc/s)

Anode voltage	V_a	=	max.	3000	V
Anode current	I_a	=	max.	225	mA
Anode input power	W_{ia}	=	max.	625	W
Anode dissipation	W_a	=	max.	125	W [1]
Screen-grid voltage	V_{g2}	=	max.	400	V
Screen-grid dissipation	W_{g2}	=	max.	20	W
Control-grid bias	$-V_{g1}$	=	max.	500	V
Control-grid current	I_{g1}	=	max.	15	mA

f = max. 170 Mc/s

Anode voltage	V_a	=	max.	2500	V
Anode input power	W_{ia}	=	max.	560	W

f = max. 200 Mc/s

Anode voltage	V_a	=	max.	2200	V
Anode input power	W_{ia}	=	max.	435	W

OPERATING CONDITIONS (f < 120 Mc/s)

Anode voltage	V_a	= 3000	2500	2000	1500	V
Screen-grid voltage	V_{g2}	= 350	350	350	350	V
Control-grid bias	V_{g1}	= -150	-150	-100	-150	V
Anode current	I_a	= 167	200	200	110	mA
Screen-grid current	I_{g2}	= 30	40	50	56	mA
Control-grid current	I_{g1}	= 6.5	9	9	8	mA
Alternating-grid voltage (peak value)	V_{g1p}	= 300	330	260	225	V
Driving power	W_{ig1}	= 2	3	2.4	1.7	W
Screen-grid dissipation	W_{g2}	= 10.5	14	17.5	5.6	W
Anode input power	W_{ia}	= 500	500	400	165	W
Anode dissipation	W_a	= 125	125	125	55	W
Output power	W_o	= 375	375	275	110	W
Efficiency	η	= 75	75	69	67	%

---

1) Anode red hot, temperature = 850 °C.

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

LIMITING VALUES (f = max. 120 Mc/s)

Anode voltage	V_a	=	max.	2500	V
Anode current	I_a	=	max.	200	mA
Anode input power	W_{ia}	=	max.	415	W
Anode dissipation	W_a	=	max.	83	W
Screen-grid voltage	V_{g2}	=	max.	400	V
Screen-grid dissipation	W_{g2}	=	max.	20	W
Control-grid bias	$-V_{g1}$	=	max.	500	V
Control-grid current	I_{g1}	=	max.	15	mA

f = max. 170 Mc/s

Anode voltage	V_a	=	max.	2100	V
Anode input power	W_{ia}	=	max.	375	W

f = max. 200 Mc/s

Anode voltage	V_a	=	max.	1800	V
Anode current	W_{ia}	=	max.	290	W

OPERATING CONDITIONS (f < 120 Mc/s)

Anode voltage	V_a	=	2500	2000	1500	V
Screen-grid voltage	V_{g2}	=	350	350	300	V
Control-grid bias	V_{g1}	=	-210	-220	-150	V
Anode current	I_a	=	152	150	160	mA
Screen-grid current	I_{g2}	=	30	33	33	mA
Control-grid current	I_{g1}	=	4.5	5	10	mA
Alternating-grid voltage (peak value)	V_{g1p}	=	380	390	250	V
Driving power	W_{ig1}	=	1.7	2	2.5	W
Screen-grid dissipation	W_{g2}	=	10.5	11.5	10	W
Anode input power	W_{ia}	=	380	300	240	W
Anode dissipation	W_a	=	80	75	83	W
Output power	W_o	=	300	225	157	W
Efficiency	η	=	79	75	65	%
Modulation depth 100%						
Alternating screen-grid voltage (peak value)	V_{g2p}	=	300	300	225	V
Modulation power	W_{mod}	=	190	150	120	W

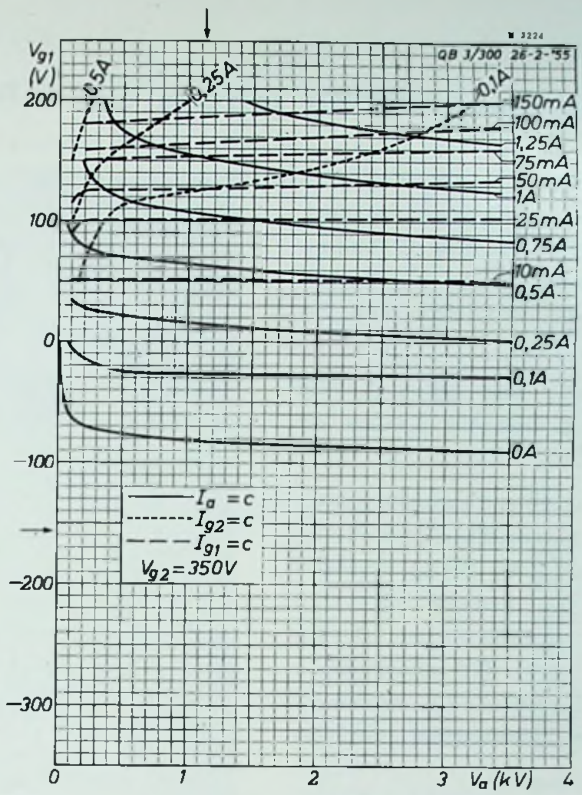

Fig.57. Constant-current characteristics of the QB 3/300.

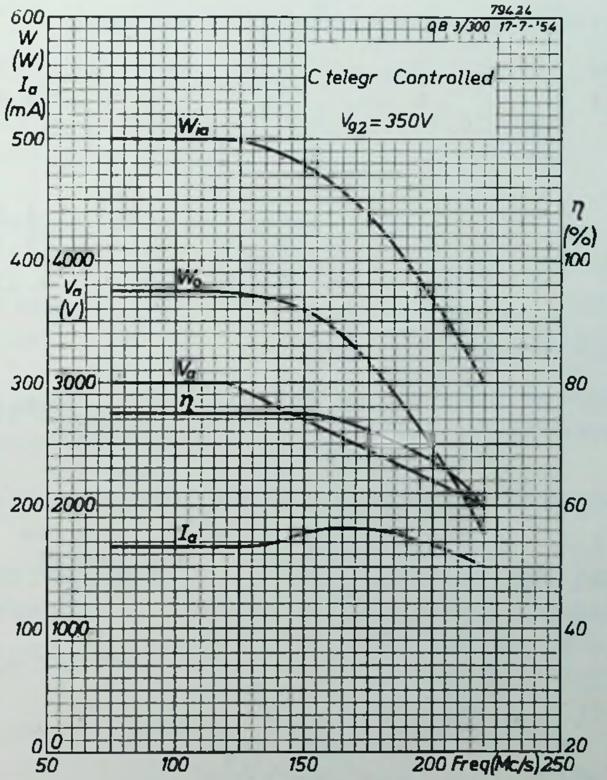

Fig.58. Anode voltage (V_a), anode current (I_a), anode input power (W_{ia}), output power (W_o) and efficiency (η) of the QB 3/300 as a function of frequency under class C telegraphy conditions at a screen-grid voltage of 350 V.

All-glass transmitting tetrode QB 3.5/750

The power amplifying tube QB 3.5/750 is capable of delivering an output power of 1 kW under class C telegraphy conditions at 75 Mc/s. Up to this frequency full ratings may be applied.

Like the QB 3/300, the QB 3.5/750 can be used in the output stage of TV transmitters 1).

In order to keep the temperatures below the maximum permissible values the anode seal and the base should be cooled by a low-velocity air flow. To prevent overheating of the screen-grid pins by RF currents, it is recommended that both screen-grid terminals be connected to the circuitry.
The American type number of the QB 3.5/750 is 6156.

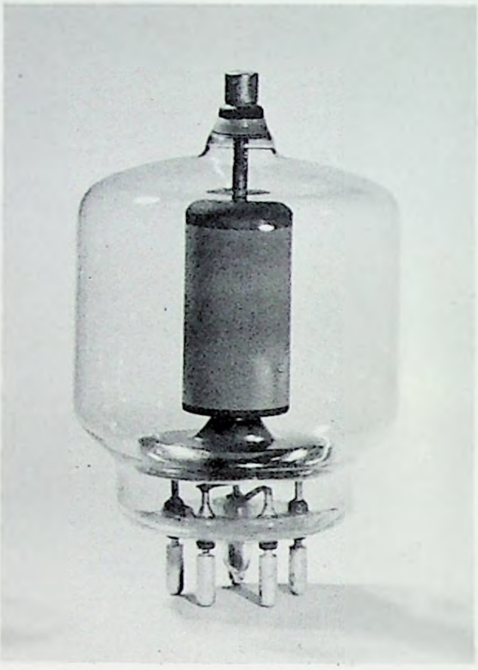

Fig. 59. Photograph of the QB 3.5/750.

TECHNICAL DATA

Filament : thoriated tungsten, directly heated

Filament voltage	V_f	=	5	V
Filament current	I_f	=	14.1	A

CAPACITANCES

C_a	=	4.5	pF
C_{g1}	=	12.7	pF
C_{ag1}	=	0.12	pF

TYPICAL CHARACTERISTICS

Amplification factor between g_2 and g_1	μ_{g2g1}	=	5.1
Mutual conductance (I_a = 100 mA)	S	=	4 mA/V

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS

(in mm)

Socket : 40211/01
Clip : 40624

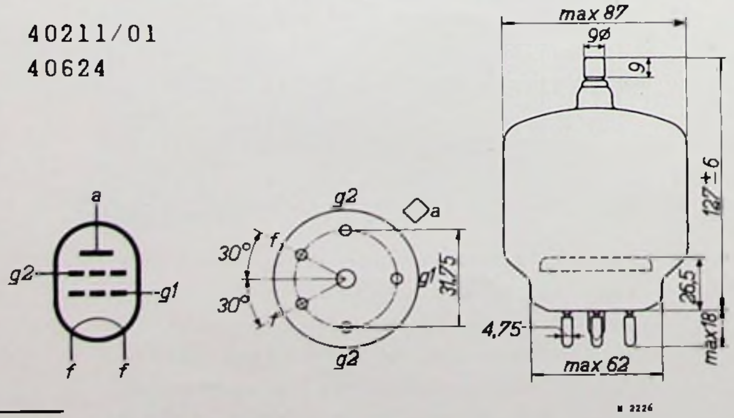

Fig. 60.

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1) See note on page 69.

MOUNTING POSITION

Vertical with base up or down

MAXIMUM TEMPERATURES [2]

Bulb : max. 350 °C
Anode seal: max. 220 °C
Pin seals : max. 180 °C

NET WEIGHT : 185 g

SHIPPING WEIGHT: 910 g

H.F. CLASS C TELEGRAPHY

f = max. 75 Mc/s

Anode voltage	V_a	=	max.	4000	V
Anode input power	W_{ia}	=	max.	1250	W
Anode dissipation	W_a	=	max.	250	W
Anode current	I_a	=	max.	350	mA
Screen-grid voltage	V_{g2}	=	max.	600	V
Screen-grid dissipation	W_{g2}	=	max.	35	W
Control-grid bias	$-V_{g1}$	=	max.	500	V
Control-grid current	I_{g1}	=	max.	20	mA

f = max. 100 Mc/s

Anode voltage	V_a	=	max.	3300	V
Anode input power	W_{ia}	=	max.	1000	W

f = max. 120 Mc/s

Anode voltage	V_a	=	max.	2500	V
Anode input power	W_{ia}	=	max.	750	W

OPERATING CONDITIONS (f = 75 Mc/s)

Anode voltage	V_a	=	4000	3000	2500	V
Screen-grid voltage	V_{g2}	=	500	500	500	V
Control-grid bias	V_{g1}	=	-225	-180	-150	V
Anode current	I_a	=	312	345	300	mA
Screen-grid current	I_{g2}	=	45	60	60	mA
Control-grid current	I_{g1}	=	9	10	9	mA
Alternating-grid voltage (peak value)	V_{g1p}	=	303	265	220	V
Driving power	W_{ig1}	=	2.5	2.4	1.8	W
Screen-grid dissipation	W_{g2}	=	22.5	30	30	W
Anode input power	W_{ia}	=	1248	1035	750	W
Anode dissipation	W_a	=	248	235	175	W
Output power	W_o	=	1000	800	575	W
Efficiency	η	=	80	77	77	%

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[1] Operating conditions for this purpose are available on request.

[2] In order to keep the temperatures below the maximum permitted values a low-velocity air flow must be directed onto the anode seal and the bottom of the envelope.

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

LIMITING VALUES (f = max. 75 Mc/s)

Anode voltage	V_a	=	max.	3200	V
Anode input power	W_{ia}	=	max.	825	W
Anode dissipation	W_a	=	max.	165	W
Anode current	I_a	=	max.	275	mA
Screen-grid voltage	V_{g2}	=	max.	600	V
Screen-grid dissipation	W_{g2}	=	max.	35	W
Control-grid bias	$-V_{g1}$	=	max.	500	V
Control-grid current	I_{g1}	=	max.	20	mA

f = max. 100 Mc/s

Anode voltage	V_a	=	max.	2600	V
Anode input power	W_{ia}	=	max.	660	W

f = max. 120 Mc/s

Anode voltage	V_a	=	max.	2000	V
Anode input power	W_{ia}	=	max.	500	W

OPERATING CONDITIONS (f = 75 Mc/s)

Anode voltage	V_a	=	3000	2500	V
Screen-grid voltage	V_{g2}	=	400	400	V
Control-grid bias	V_{g1}	=	-310	-200	V
Anode current	I_a	=	225	200	mA
Screen-grid current	I_{g2}	=	30	30	mA
Control-grid current	I_{g1}	=	9	9	mA
Alternating-grid voltage (peak value)	V_{g1p}	=	400	280	V
Driving power	W_{ig1}	=	3.3	2.3	W
Screen-grid dissipation	W_{g2}	=	12	12	W
Anode input power	W_{ia}	=	675	500	W
Anode dissipation	W_a	=	165	125	W
Output power	W_o	=	510	375	W
Efficiency	η	=	75.5	75	%
Modulation depth 100%					
Alternating screen-grid voltage (peak value)	V_{g2p}	=	350	350	V
Modulation power	W_{mod}	=	344	256	W

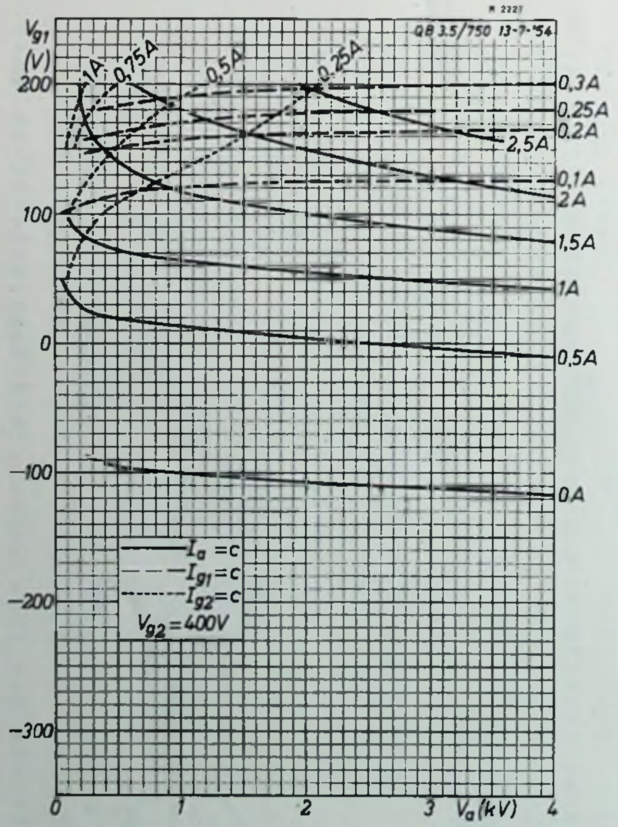

Fig.61. Constant-current characteristics of the QB 3.5/750 at a screen-grid voltage of 400 V.

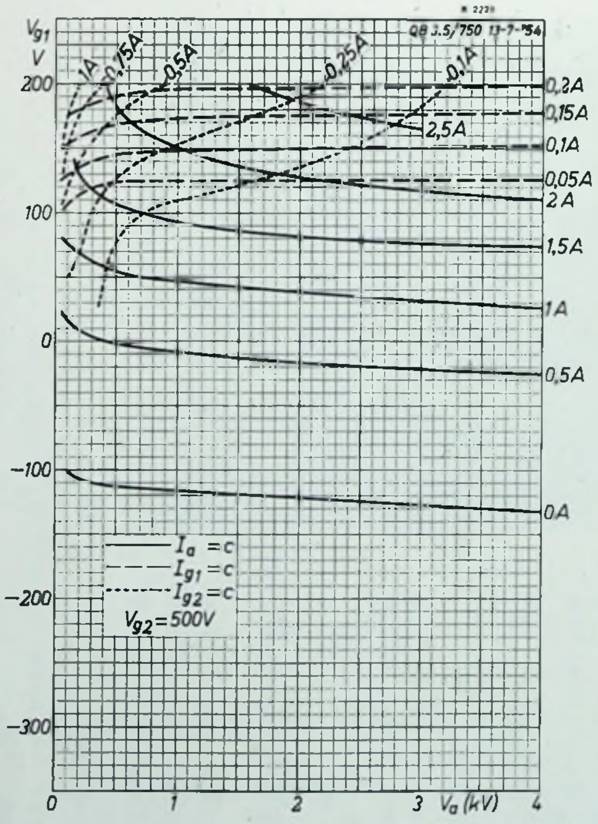

Fig.62. Constant-current characteristics of the QB 3.5/750 at a screen-grid voltage of 500 V.

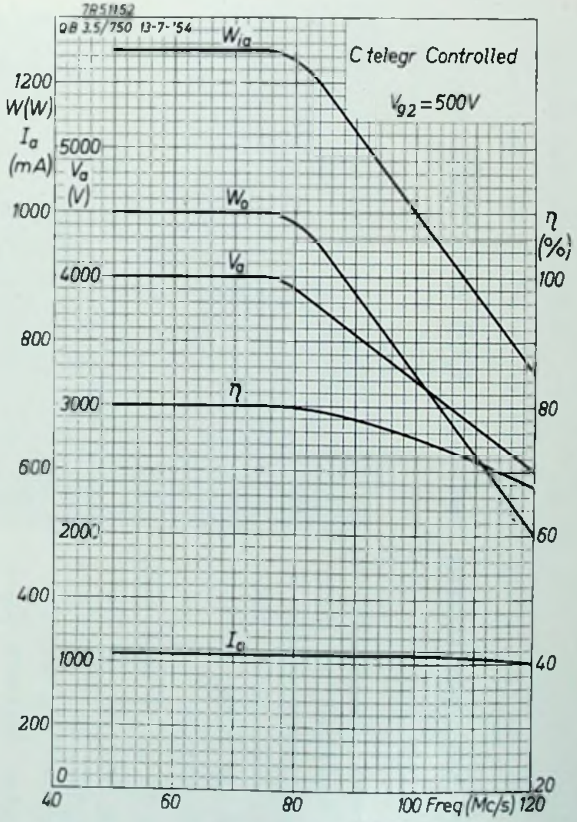

Fig.63. Anode voltage (V_a), anode current (I_a), anode input power (W_{ia}) output power (W_o) and efficiency (η) of the QB 3.5/750 as a function of frequency under class C telegraphy conditions at a screen-grid voltage of 500 V.

All-glass transmitting tetrode QB 5/1750

As a power amplifier at 60 Mc/s the QB 5/1750 can deliver an output power of 1760 W under class C telegraphy conditions. The tube can also be used in the output stage of TV transmitters [1].

To prevent the anode seal and the base from becoming too hot, a low-velocity air flow may be directed towards these parts. To prevent overheating of the screen-grid pins by RF currents, it is recommended to connect both screen-grid terminals to the circuitry.

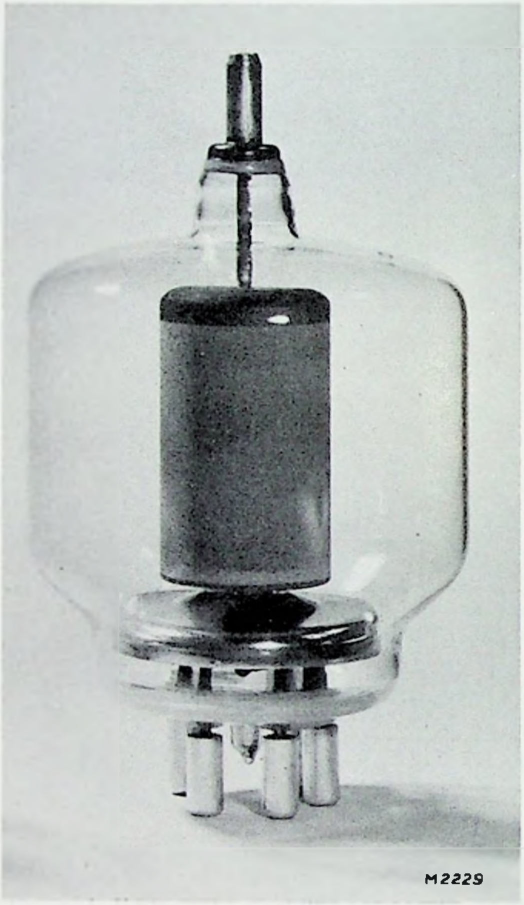

Fig. 64. Photograph of the QB 5/1750.

TECHNICAL DATA

Filament: thoriated tungsten, directly heated

Filament voltage V_f = 10 V

Filament current I_f = 9.9 A

CAPACITANCES

C_a = 8.3 pF

C_{g1} = 24 pF

C_{ag1} = 0.25 pF

TYPICAL CHARACTERISTICS

Amplification factor between g_2 and g_1 (I_a = 120 mA) μ_{g2g1} = 9.5

Mutual conductance (I_a = 120 mA) S = 7 mA/V

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS

(in mm)

Socket : 40216

Clip : 40625

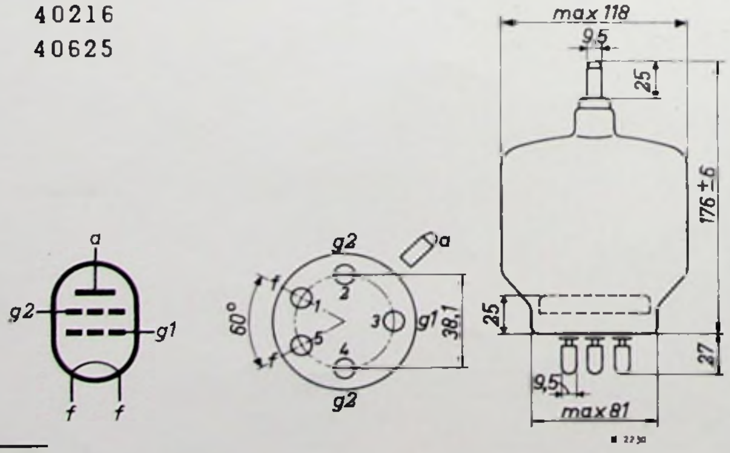

Fig. 65.

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[1] Operating conditions for this purpose are available on request.

MOUNTING POSITION

Vertical with base up or down

MAXIMUM TEMPERATURES

Bulb : max. 250 °C
Anode seal : max. 220 °C
Pin seals : max. 180 °C

NET WEIGHT : 375 g

SHIPPING WEIGHT : 1.35 kg

H.F. CLASS C TELEGRAPHY

LIMITING VALUES (f = max. 75 Mc/s)

Anode voltage	V_a	=	max.	5	kV
Anode input power	W_{ia}	=	max.	2250	W
Anode dissipation	W_a	=	max.	500	W
Anode current	I_a	=	max.	450	mA
Screen-grid voltage	V_{g2}	=	max.	700	V
Screen-grid dissipation	W_{g2}	=	max.	65	W
Control-grid bias	$-V_{g1}$	=	max.	500	V
Control-grid dissipation	W_{g1}	=	max.	25	W

f = max. 110 Mc/s

Anode voltage	V_a	=	max.	4.5	kV
Anode input power	W_{ia}	=	max.	1800	W

OPERATING CONDITIONS

Frequency	f	$\leq$	60	60	60	60	110	Mc/s
Anode voltage	V_a	=	5	5	4	4	4	kV
Screen-grid voltage	V_{g2}	=	600	700	600	700	600	V
Control-grid bias	V_{g1}	=	-200	-200	-200	-200	-200	V
Anode current	I_a	=	440	440	450	450	350	mA
Screen-grid current	I_{g2}	=	80	75	90	85	30	mA
Control-grid current	I_{g1}	=	35	25	39	27	10	mA
Alternating grid voltage (peak value)	V_{g1p}	=	350	340	350	340	-	V
Anode input power	W_{ia}	=	2200	2200	1800	1800	1400	W
Driving power	W_{ig1}	=	12	8	14	8.5	-	W
Screen-grid dissipation	W_{g2}	=	48	52.5	54	59.5	18	W
Anode dissipation	W_a	=	440	440	390	390	500	W
Output power	W_o	=	1760	1760	1410	1410	900	W
Efficiency	η	=	80	80	78	78	64	%

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

(Screen-grid modulation via a choke of 2 H)

LIMITING VALUES (f = max. 75 Mc/s)

Anode voltage	V_a	=	max.	4	kV
Anode input power	W_{ia}	=	max.	1600	W
Anode dissipation	W_a	=	max.	330	W
Anode current	I_a	=	max.	400	mA
Screen-grid voltage	V_{g2}	=	max.	700	V
Screen-grid dissipation	W_{g2}	=	max.	50	W
Control-grid bias	$-V_{g1}$	=	max.	500	V
Control-grid dissipation	W_{g1}	=	max.	25	W

OPERATING CONDITIONS (f $\leq$ 60 Mc/s)

Anode voltage	V_a	=	4	kV
Screen-grid voltage	V_{g2}	=	600	V
Control-grid bias	V_{g1}	=	-240	V
Alternating screen-grid voltage (peak value)	V_{g2p}	=	340	V
Alternating control-grid voltage (peak value)	V_{g1p}	=	415	V
Anode current	I_a	=	380	mA
Screen-grid current	I_{g2}	=	80	mA
Control-grid current	I_{g1}	=	20	mA
Anode input power	W_{ia}	=	1520	W
Driving power	W_{ig1}	=	7.5	W
Screen-grid dissipation	W_{g2}	=	48	W
Anode dissipation	W_a	=	320	W
Output power	W_o	=	1200	W
Efficiency	η	=	79	%
Modulation depth 100%				
Modulation power	W_{mod}	=	760	W

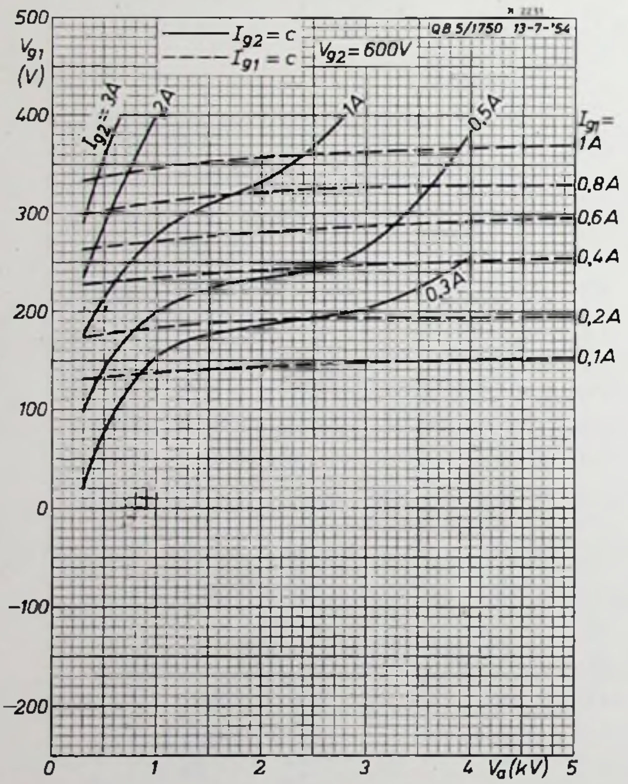

Fig.66. Constant-current characteristics (I_{g1} and I_{g2}) of the QB 5/1750 at a screen-grid voltage of 600 V.

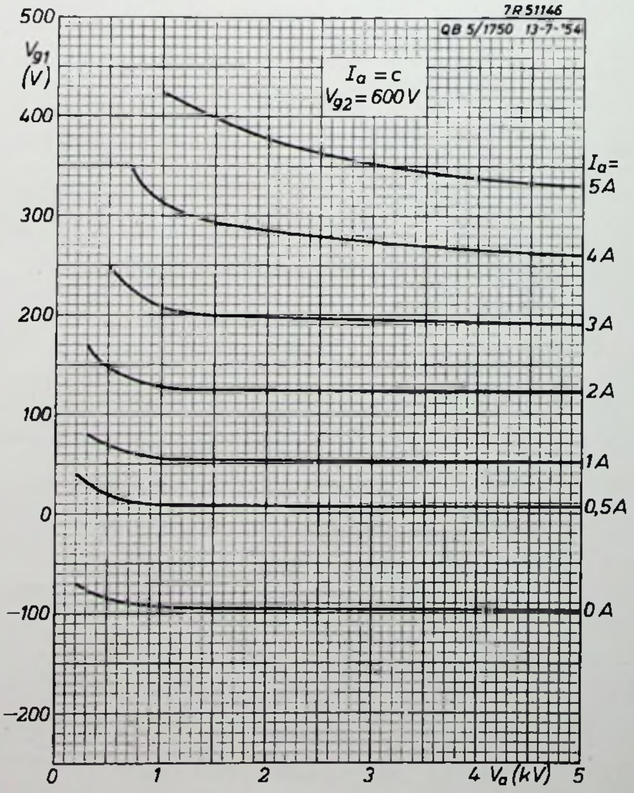

Fig.67. Constant-current characteristics (I_a) of the QB 5/1750 at a screen-grid voltage of 600 V.

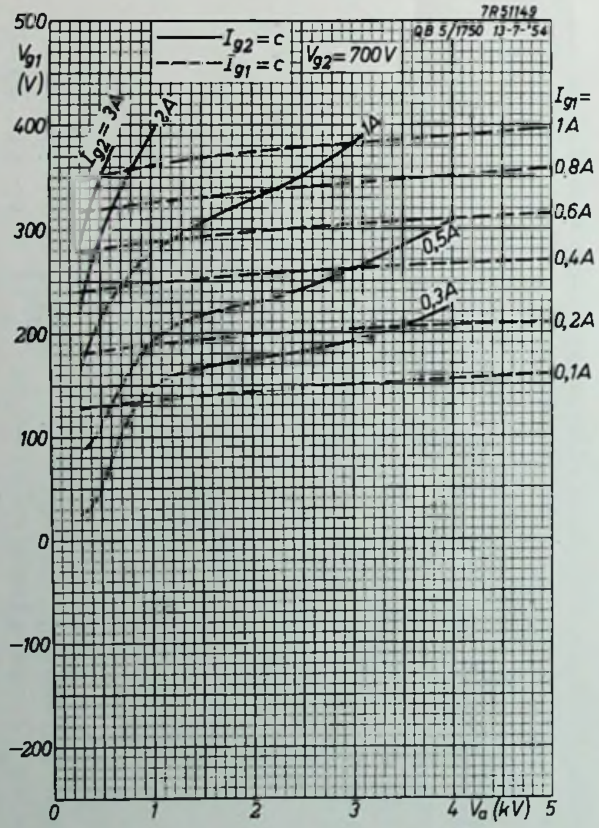

Fig.68. Constant-current characteristics (I_{g1} and I_{g2}) of the QB 5/1750 at a screen-grid voltage of 700 V.

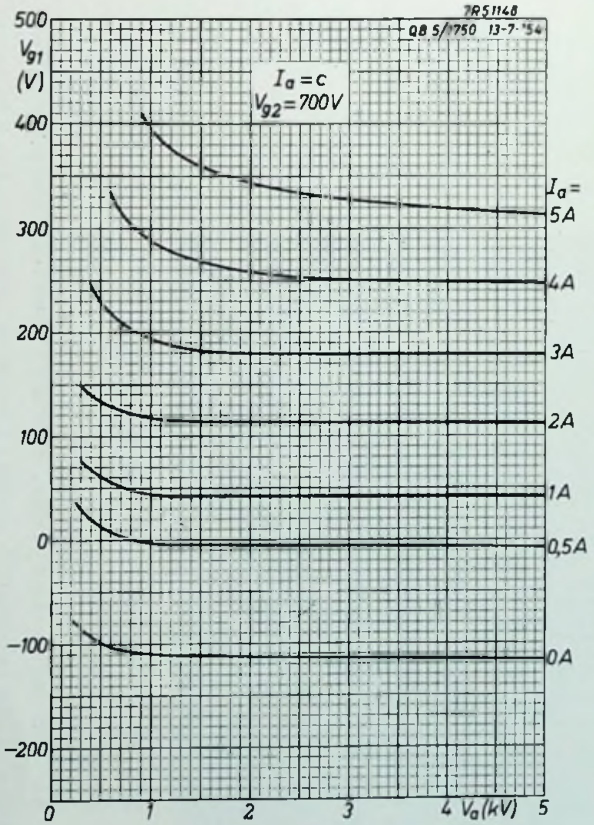

Fig.69. Constant-current characteristics (I_a) of the QB 5/1750 at a screen-grid voltage of 700 V.

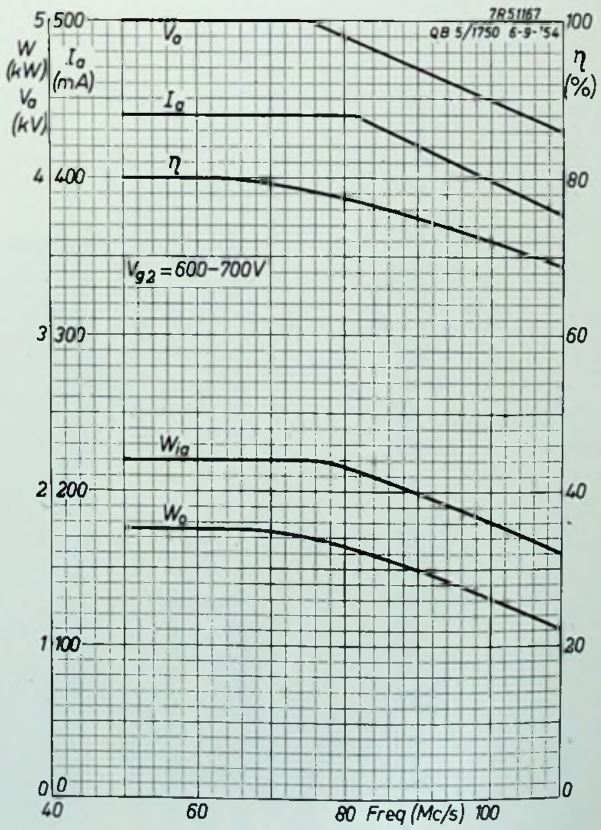

Fig.70. Anode voltage (V_a), anode current (I_a), anode input power (W_{ia}) output power (W_o) and efficiency (η) of the QB 5/1750 as a function of frequency at a screen-grid voltage of 600 - 700 V.

Forced-air cooled transmitting tetrode QEL 1/150

The QEL 1/150 is a forced-air cooled, indirectly heated tetrode for use as oscillator, amplifier or frequency multiplier at frequencies up to 500 Mc/s. The screen-grid connection of this tube is formed by a ring that is coaxial with the (external) anode. The tube has very small dimensions (overall height 62.5 mm.)

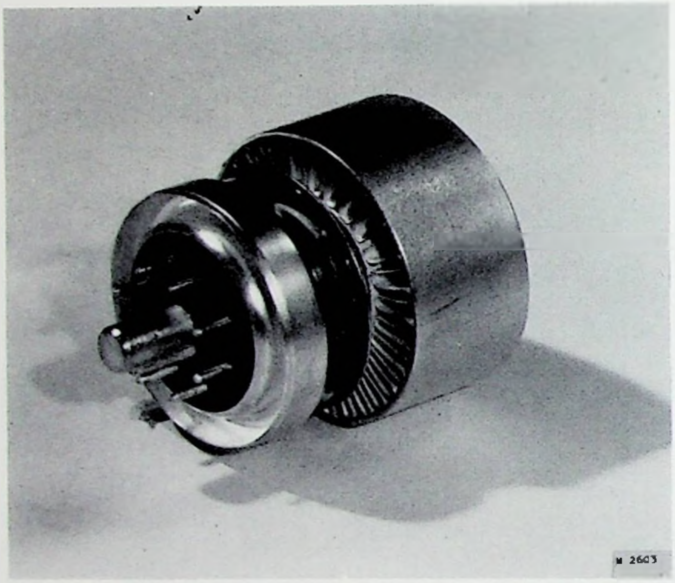

Fig.71. Photograph of the QEL 1/150.

At frequencies up to 165 Mc/s the tube can deliver an output power of 195 W under class C telegraphy conditions at an anode voltage of 1250 V.

The QEL 1/150 is identical to the American tube type 4 X 150 A.

TECHNICAL DATA

Cathode: indirectly heated, oxide coated

Heater voltage V_f = 6.0 V
Heater current I_f = 2.6 A
Heating up time T_h = min. 30 sec

CAPACITANCES

C_a = 4.5 pF
C_{g1} = 15.5 pF
C_{ag1} = 0.03 pF

TYPICAL CHARACTERISTICS

Amplification factor between g_2 and g_1 μ_{g2g1} = 5
Mutual conductance (I_a = 200 mA) S = 12 mA/V

ELECTRODE ARRANGEMENT ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS (in mm)

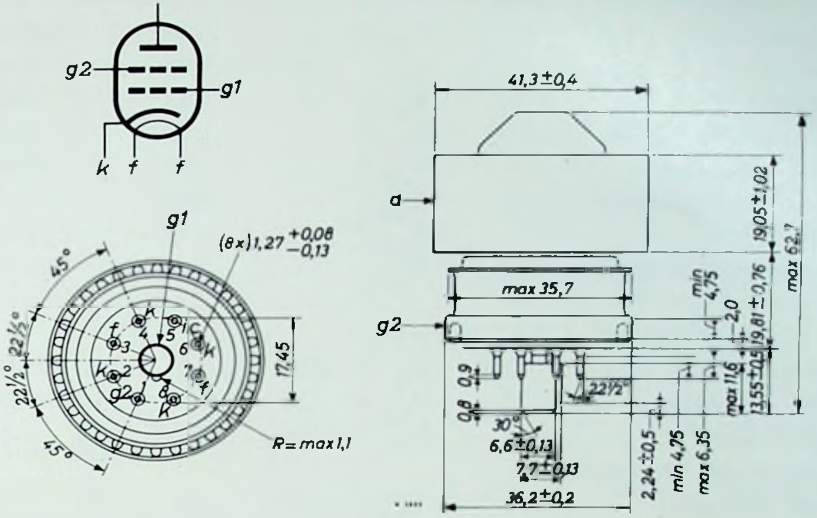

Fig.72.

ACCESSORIES

Base	9 pins-special
Air-system socket	type 40222 (with air-system chimney type 40640 included) [1]
Air-system chimney	type 40640

MOUNTING POSITION any

MAXIMUM SEAL TEMPERATURE 150 °C

WEIGHTS

Net weight	130 g
Shipping weight	300 g

COOLING CHARACTERISTICS

The figures in this table apply to the simultaneous cooling of the radiator and the base, making use of the air-system socket.

anode dissipation (W)	altitude (m)	max. air inlet temp. (°C)	min. air flow (m^3/min)	pressure drop (mm H_2O)
150	0	35	0.220	15
	0	45	0.258	19.8
	1500	35	0.264	18.3
	3000	25	0.278	17.5

---

[1] This type of socket is intended for circuits where the cathode of the tube is at chassis potential.

H.F. CLASS C TELEGRAPHY

LIMITING VALUES (f = max. 500 Mc/s)

Anode voltage	V_a	=	max.	1250	V
Anode current	I_a	=	max.	250	mA
Anode dissipation	W_a	=	max.	150	W
Anode input power	W_{ia}	=	max.	300	V
Screen-grid voltage	V_{g2}	=	max.	300	V
Screen-grid dissipation	W_{g2}	=	max.	12	W
Screen-grid bias	$-V_{g1}$	=	max.	250	V
Control-grid dissipation	W_{g1}	=	max.	2	W

OPERATING CONDITIONS (f = 165 Mc/s)

Anode voltage	V_a =	1250	1000	750	600	V
Screen-grid voltage	V_{g2} =	250	250	250	250	V
Control-grid bias	V_{g1} =	-90	-80	-80	-75	V
Alternating-grid voltage (peak value)	V_{g1p} =	105	95	95	90	V
Anode current	I_a =	200	200	200	200	mA
Screen-grid current	I_{g2} =	20	30	37	37	mA
Control-grid current	I_{g1} =	10	10	10	10	mA
Driving power 1)	W_{ig1} =	0.8	0.7	0.7	0.7	W
Anode input power	W_{ia} =	250	200	150	120	W
Anode dissipation	W_a =	55	50	40	35	W
Screen-grid dissipation	W_{g2} =	5	7.5	9.3	9.3	W
Output power	W_o =	195	150	110	85	W
Efficiency	η =	78	75	73.5	71	%

f = 500 Mc/s 2)

Anode voltage	V_a =	1250	1000	800	600	V
Screen-grid voltage	V_{g2} =	250	250	250	250	V
Control-grid bias	V_{g1} =	-80	-80	-80	-80	V
Anode current	I_a =	200	200	200	200	mA
Screen-grid current	I_{g2} =	7	7	7	7	mA
Control-grid current	I_{g1} =	10	10	10	10	W
Driver output power	W_{dr} =	10	10	10	10	W
Anode input power	W_{ia} =	250	200	160	120	W
Screen-grid dissipation	W_{g2} =	1.8	1.8	1.8	1.8	W
Useful output power in load	W_{ol} =	140	110	90	65	W
Efficiency	η =	56	55	56	54	%

H.F. CLASS C ANODE AND SCREEN GRID MODULATION

LIMITING VALUES

Anode voltage	V_a	=	max.	1000	V
Anode current	I_a	=	max.	200	mA
Anode dissipation	W_a	=	max.	100	W
Anode input power	W_{ia}	=	max.	200	W
Screen-grid voltage	V_{g2}	=	max.	300	W
Screen-grid dissipation	W_{g2}	=	max.	12	W
Control-grid bias	$-V_{g1}$	=	max.	-250	V
Control-grid dissipation	W_{g1}	=	max.	2	W

---

1) Circuit losses not included

2) Single tube, cylindrical cavity

OPERATING CONDITIONS (f = 165 Mc/s)

Anode voltage	V_a	=	1000	800	600	400	V
Screen-grid voltage	V_{g2}	=	250	250	250	250	V
Control-grid bias	V_{g1}	=	-105	-100	-95	-90	V
Alternating grid voltage (peak value)	V_{g1p}	=	125	120	120	110	V
Anode current	I_a	=	200	200	200	200	mA
Screen-grid current	I_{g2}	=	20	25	35	40	mA
Control-grid current	I_{g1}	=	15	10	8	7	mA
Driving power	W_{ig1}	=	2	1.5	1	1	W
Anode input power	W_{ia}	=	200	160	120	80	W
Anode dissipation	W_a	=	60	60	40	25	W
Screen-grid dissipation	W_{g2}	=	5	6.3	8.8	10	W
Output power	W_o	=	140	100	80	55	W
Efficiency	η	=	70	62.5	66.5	69	%

Modulation depth = 100 %

Modulation power	W_{mod}	=	100	80	60	40	W
Alternating screen-grid voltage (peck value)	V_{g2p}	=	170	160	150	140	V

H.F. CLASS B, TV SERVICE, negative modulation, positive synchronisation

LIMITING VALUES (f = max. 220 Mc/s)

Anode voltage	V_a	=	max.	1250	V
Anode current	I_a	=	max.	250	mA
Anode dissipation	W_a	=	max.	150	W
Screen-grid voltage	V_{g2}	=	max.	400	V
Screen-grid dissipation	W_{g2}	=	max.	12	W
Control-grid bias	$-V_{g1}$	=	max.	250	V
Control-grid dissipation	W_{g1}	=	max.	2	W

OPERATING CONDITIONS (f = 216 Mc/s, bandwidth = 5 Mc/s)

Anode voltage		V_a	=	1250	1000	750	V
Screen-grid voltage		V_{g2}	=	300	300	300	V
Control-grid voltage		V_{g1}	=	-70	-65	-60	V
Alternating grid voltage (peak value)	sync	V_{gp}	=	100	95	85	V
	black			75	70	65	V
Anode current	sync	I_a	=	305	330	335	mA
	black			230	240	245	mA
Screen-grid current	sync	I_{g2}	=	45	45	50	mA
	black			10	15	20	mA
Control-grid current	sync	I_{g1}	=	25	20	15	mA
	black			4	4	4	mA
Driving power	sync	W_{ig1}	=	9	8	7	mA
	black			5.5	4.7	4.25	W
Anode input power	black	W_{ia}	=	290	240	185	W
Useful output power	sync	W_o	=	250	200	135	W
	black			140	110	75	W

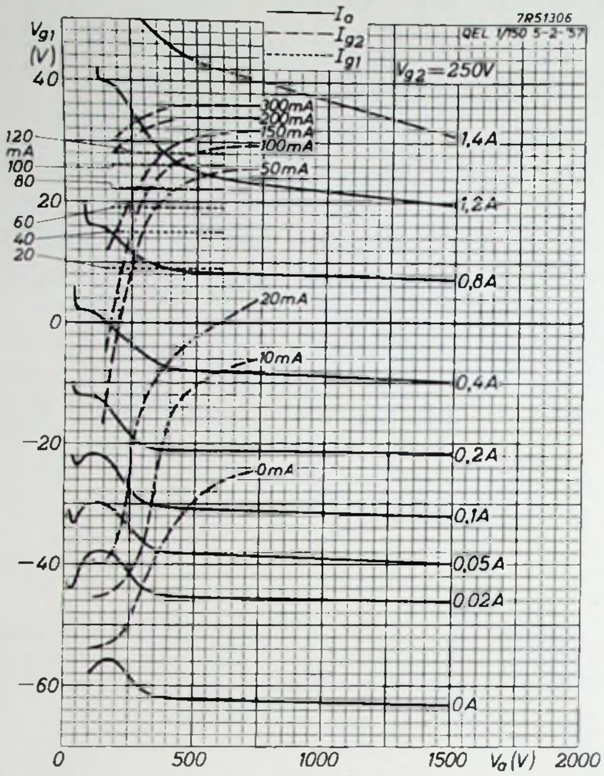

Fig.73. Constant-current characteristics of the QEL 1/150 at a screen-grid voltage of 250 V.

Forced-air cooled transmitting tetrode QBL 4/800

The QBL 4/800 is a tetrode of the external-anode type requiring forced-air cooling. Under class C telegraphy conditions an output power of 930 W at frequencies up to 110 Mc/s can be obtained. Full ratings may be applied up to 120 Mc/s.

The location of the control-grid pin at the centre of the glass base facilitates single-tube operation in coaxial circuits. The tube has a very low anode-to-grid capacitance, so that neutralisation can easily be achieved.

Apart from the necessity of cooling the anode, it is necessary to cool the seals by means of a low-velocity air flow.

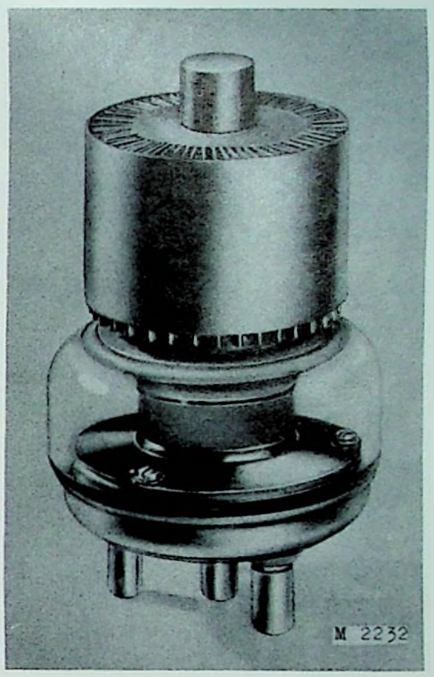

Fig.74. Photograph of the QBL 4/800.

TECHNICAL DATA

Filament: thoriated tungsten, directly heated

Filament voltage	V_f	=	5	V
Filament current	I_f	=	13.5	A

CAPACITANCES

C_a	=	5.6	pF
C_{g1}	=	12.8	pF
C_{ag1}	=	0.05	pF

TYPICAL CHARACTERISTICS

Amplification factor between g_2 and g_1	μ_{g2g1}	=	6.2	
Mutual conductance (I_a = 200 mA)	S	=	5.2	mA/V

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS (in mm)

Socket: 122-102

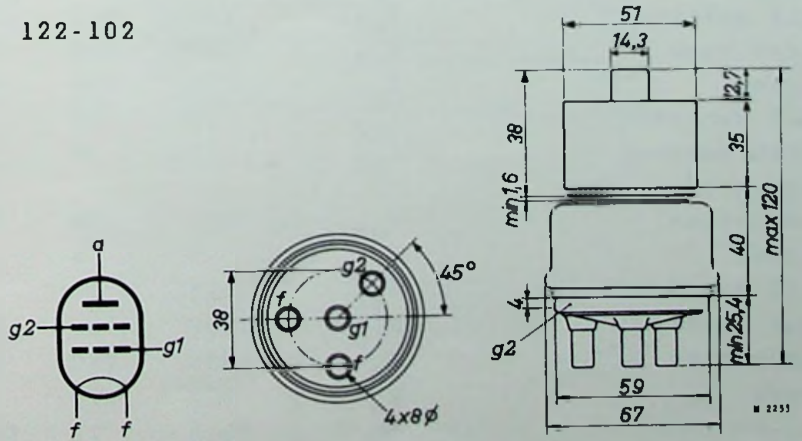

Fig.75.

MOUNTING POSITION

Vertical with anode up or down

MAXIMUM TEMPERATURES

Anode	max.	150	°C
Seals	max.	150	°C

NET WEIGHT	530	g

COOLING CHARACTERISTICS

anode dissipation (W)	altitude (m)	max. air inlet temp. (°C)	min. air flow (m^3/min)	pressure drop (mm H_2O)
300	0	35	0.50	9.8
	0	45	0.59	12.9
	1500	35	0.60	12.0
	3000	25	0.63	11.5
400	0	35	0.77	17.5
	0	45	0.90	23.0
	1500	35	0.93	21.3
	3000	25	0.97	20.5
500	0	35	1.13	35.5
	0	45	1.32	46.9
	1500	35	1.36	43.3
	3000	25	1.42	41.5

H.F. CLASS C TELEGRAPHY

LIMITING VALUES (f = max. 120 Mc/s).

Anode voltage	V_a	=	max.	4000	V
Anode current	I_a	=	max.	350	mA
Anode input power	W_{ia}	=	max.	1400	W
Anode dissipation	W_a	=	max.	500	V
Screen-grid voltage	V_{g2}	=	max.	500	V
Screen-grid dissipation	W_{g2}	=	max.	30	W
Control-grid bias	$-V_{g1}$	=	max.	500	V
Control-grid dissipation	W_{g1}	=	max.	10	W

TYPICAL OPERATING CONDITIONS

Frequency	f	=	110	110	110	Mc/s
Anode voltage	V_a	=	4000	3000	2500	V
Screen-grid voltage	V_{g2}	=	500	500	500	V
Control-grid bias	V_{g1}	=	-150	-150	-150	V
Anode current	I_a	=	315	310	310	mA
Screen-grid current	I_{g2}	=	22	24	26	mA
Control-grid current	I_{g1}	=	16	16	15	mA
Alternating grid voltage (peak value)	V_{gp}	=	230	230	230	V
Driving power	W_{ig1}	≈	5	5	5	W
Screen-grid dissipation	W_{g2}	=	11	12	13	W
Anode input power	W_{ia}	=	1260	930	775	W
Anode dissipation	W_a	=	330	260	245	W
Output power	W_o	≈	930	670	530	W
Efficiency	η	=	73.5	72	68.5	%

H.F. CLASS B AMPLIFIER FOR TV SERVICE

negative modulation, positive synchronisation

LIMITING VALUES

Frequency	f	=	max.	220	Mc/s
Anode voltage	V_a	=	max.	3000	V
Screen-grid voltage	V_{g2}	=	max.	500	V
Anode current	I_a	=	max.	350	mA
Anode input power	W_{ia}	=	max.	1050	W
Anode dissipation	W_a	=	max.	500	W
Screen-grid dissipation	W_{g2}	=	max.	30	W
Control-grid dissipation	W_{g1}	=	max.	10	W

TYPICAL OPERATING CONDITIONS (f = 220 Mc/s, B = 6 Mc/s)

Anode voltage		V_a	=	2400	1850	V
Screen-grid voltage		V_{g2}	=	500	500	V
Control-grid bias		V_{g1}	=	-100	-100	V
Alternating grid voltage (peak value)	sync	V_{g1p}	=	185	140	V
Anode current	sync	I_a	=	400	285	mA
	black		=	300	215	mA
Screen-grid current	sync	I_{g2}	=	35	20	mA
	black		=	3	2	mA
Control-grid current	sync	I_{g1}	=	15	10	mA
	black		=	5	2	mA
Driving power	sync	W_{ig1}	=	25	15	W
Anode input power,	sync	W_{ia}	=	960	525	W
	black		=	380	230	W
Output power	sync	W_o	=	600	300	W
	black		=	340	170	W

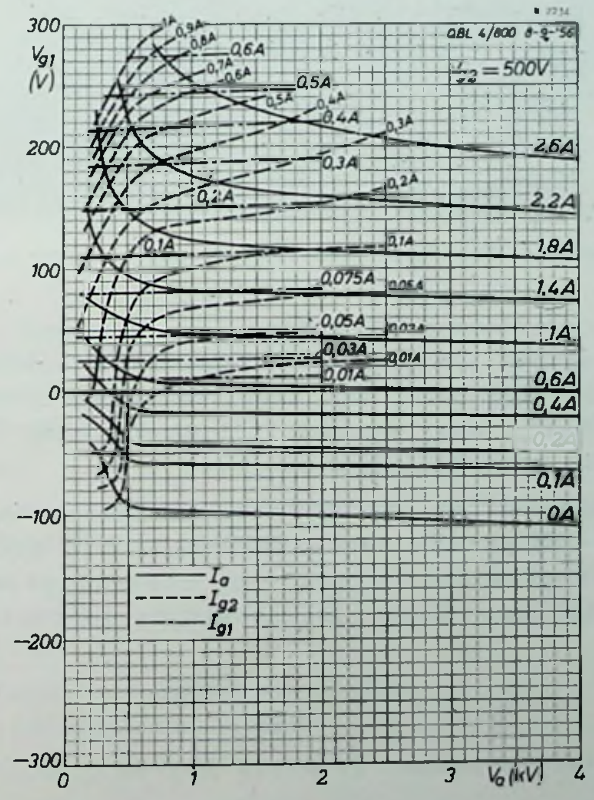

Fig. 76. Constant-current characteristics of the QBL 4/800.

Forced cooled transmitting tetrodes
QBL 5/3500 and QBW 5/3500

From these types the QBL 5/3500 is the air-cooled and the QBW 5/3500 the water-cooled version; the former is provided with a radiator which forms an integral part of the tube.

For both types full ratings may be applied up to 110 Mc/s. At this frequency the QBL 5/3500 and the QBW 5/3500 can deliver an output power of 3.9 kW under class-C telegraphy conditions.

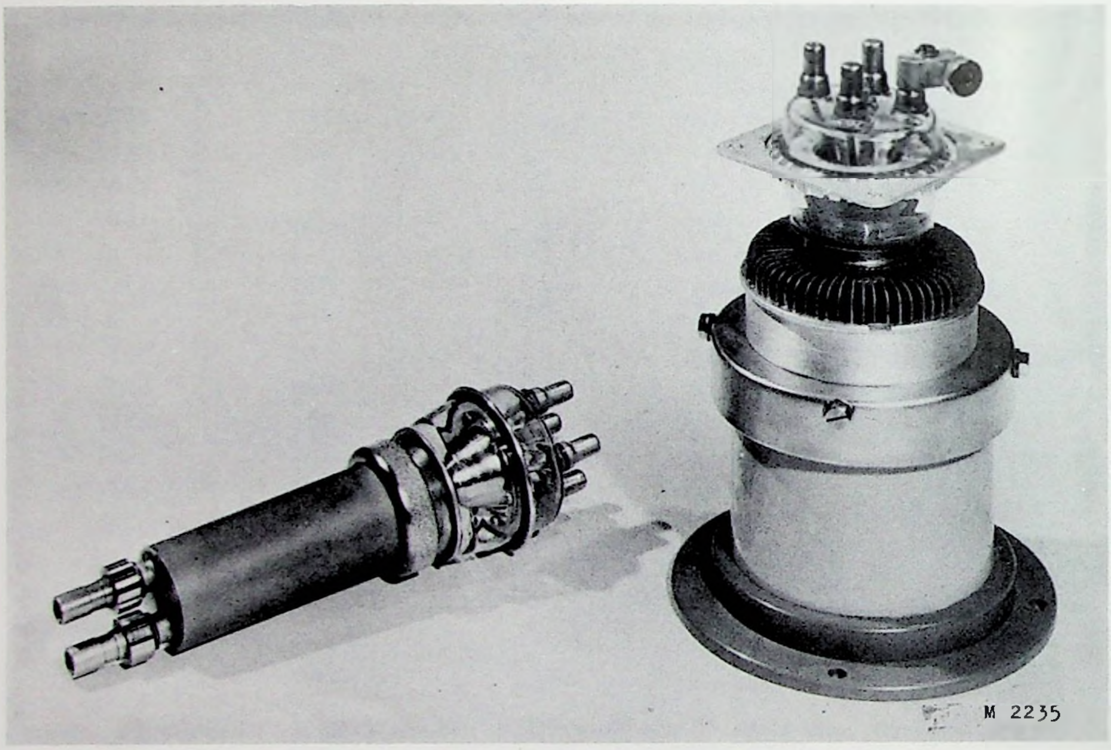

Fig. 77. Photograph of the QBL 5/3500 (right) and the QBW 5/3500 (left).

The tubes are extremely suitable for use as grid-modulated or linear amplifier in the output stage of a TV vision or sound transmitter. When two tubes in push-pull are used, an output power of 8 kW at sync peak (neg. mod., pos. synchr.) in band I and 5 kW under the same conditions in band III is available.

The screen-grid connection of the tube is disc-shaped and can be connected along the entire circumference, thus providing a low-inductance screen-grid connection. The control-grid is connected to two pins at the base; both pins should be connected to the circuit.

TECHNICAL DATA

Filament: thoriated tungsten, directly heated

Filament voltage	V_f	=	6.3	V
Filament current	I_f	=	32.5	A

CAPACITANCES

C_a = 8.4 pF

C_{g1} = 23.5 pF

C_{ag1} = 0.35 pF

TYPICAL CHARACTERISTICS

Amplification factor between g_2 and g_1	μ_{g2g1}	= 8.5
Mutual conductance (I_a = 2 A)	S	= 19 mA/V

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS (in mm)

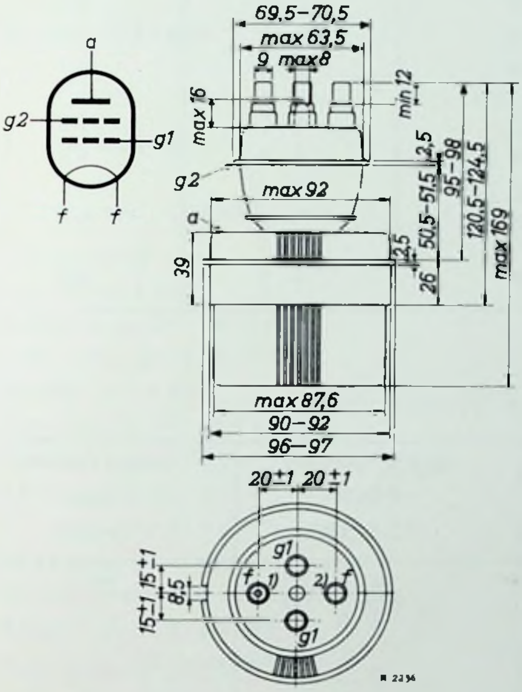

Fig.78. QBL 5/3500.

1) This pin is marked "O".

2) This pin should be used for connecting the anode return lead.

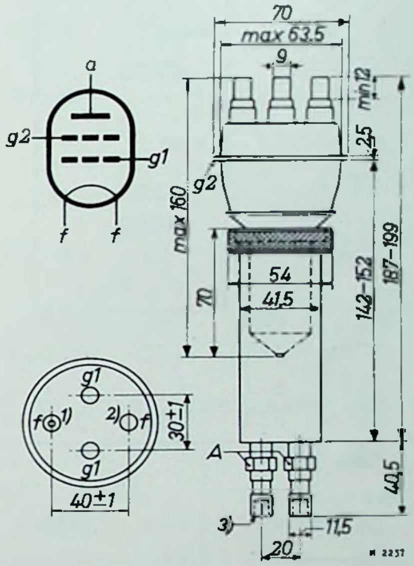

Fig.79. QBW 5/3500.

1) This pin is marked "O"

2) This pin should be used for connecting the anode return lead.

3) 1/8" pipe thread.

ACCESSORIES

QBL 5/3500	
Clips for filament and control grid	40634
Screen-grid connector	40622
Insulating pedestal	40635
QBW 5/3500	
Clips for filament and control grid	40634
Screen-grid connector	40622
Water jacket	K 713

MOUNTING POSITION

QBL 5/3500: vertical, anode up or down

QBW 5/3500: vertical, anode down

MAXIMUM TEMPERATURES

Bulb	max.	250	°C
Seals	max.	180	°C

WEIGHTS

	QBL 5/3500	40635	QBW 5/3500	K 713	
Net weight	2.25	1.6	0.35	0.52	kg
Shipping weight	5.7	2.7	1.1	0.75	kg

COOLING CHARACTERISTICS OF THE QBL 5/3500 [1])

anode dissipation (kW)	altitude (m)	max. air inlet temp. (°C)	min. air flow (m^3/min)	pressure drop (mm H_2O)
1	0	35	1.8	10
	0	45	2.2	15
	1500	35	2.2	13
	3000	25	2.3	13
2.5	0	35	4.5	60
	0	45	5.4	85
	1500	35	5.4	73
	3000	25	5.8	75
3	0	35	5.7	95

COOLING CHARACTERISTICS OF THE QBW 5/3500 [2])

anode dissipation (kW)	inlet temp. (°C)	min. water flow (l/min)	pressure loss (atm)
1	20	2.5	0.073
	50	3.0	0.1
2	20	2.5	0.073
	50	4.8	0.25
3	20	3.0	0.105
	50	6.9	0.55

---

[1]) In order to keep the temperature of the seals below the maximum permissible value, it may be necessary to direct an air flow on the seals.

[2]) To keep the seal temperatures below 180 °C it is necessary to direct an air flow of sufficient velocity on the seals.

H.F. CLASS C TELEGRAPHY

LIMITING VALUES (f = max. 30 Mc/s)

Anode voltage	V_a	=	max.	5.5	kV
Anode input power	W_{ia}	=	max.	5.5	kW
Anode dissipation	W_a	=	max.	3	kW
Anode current	I_a	=	max.	1.1	A
Screen-grid voltage	V_{g2}	=	max.	800	V
Screen-grid dissipation	W_{g2}	=	max.	100	W
Control-grid bias	V_{g1}	=	max.	500	W
Control-grid dissipation	W_{g1}	=	max.	30	W

f = max. 110 Mc/s

Anode voltage	V_a	=	max.	5	kV

f = max. 220 Mc/s

Anode voltage	V_a	=	max.	4	kV

OPERATING CONDITIONS

Frequency	f	=	75	110	75	220	Mc/s
Anode voltage	V_a	=	5	5	4	4	kV
Screen-grid voltage	V_{g2}	=	800	800	800	800	V
Control-grid bias	V_{g1}	=	-250	-250	-250	-250	V
Anode current	I_a	=	1.1	1.1	1.1	1.1	A
Screen-grid current	I_{g2}	=	100	100	120	120	mA
Control-grid current	I_{g1}	=	70	70	80	80	mA
Alternating grid voltage (peak value)	V_{g1p}	=	480	480	500	500	V
Driving power	W_{ig1}	=	30	30	36	36	W
Screen-grid dissipation	W_{g2}	=	80	80	96	96	W
Anode input power	W_{ia}	=	5.5	5.5	4.4	4.4	kW
Anode dissipation	W_a	=	1.4	1.6	1.25	1.5	kW
Output power	W_p	=	4.1	3.9	3.15	2.9	kW
Efficiency	η	=	74.5	71	72	66	%

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

(Screen-grid modulated via a choke of 60 H)

LIMITING VALUES (f = max. 30 Mc/s)

Anode voltage	V_a	=	max.	4.5	kV
Anode input power	W_{ia}	=	max.	3.6	kW
Anode dissipation	W_a	=	max.	2	kW
Anode current	I_a	=	max.	0.9	A
Screen-grid voltage	V_{g2}	=	max.	800	V
Screen grid dissipation	W_{g2}	=	max.	100	W [1]
Control-grid bias	V_{g1}	=	max.	500	V
Control-grid dissipation	W_{g1}	=	max.	30	W

f = max. 110 Mc/s

Anode voltage	V_a	=	max.	4	kV

f = max. 220 Mc/s

Anode voltage	V_a	=	max.	3.2	kV

---

[1] For all other modulation methods W_{g2} = max. 65 W

OPERATING CONDITIONS (f = max. 110 Mc/s)

Anode voltage	V_a	=	4	kV
Screen-grid voltage	V_{g2}	=	800	V
Control-grid bias	V_{g1}	=	-375	V
Alternating-grid voltage (peak value)	V_{g1p}	=	625	V
Anode current	I_a	=	0.9	A
Screen-grid current	I_{g2}	=	120	mA
Control-grid current	I_{g1}	=	85	mA
Anode input power	W_{ia}	=	3.6	kW
Anode dissipation	W_a	=	0.9	kW
Output power	W_o	=	2.7	kW
Screen-grid dissipation	W_{g2}	=	96	W
Driving power	W_{ig1}	=	48	W
Efficiency	η	=	75	%
Modulation depth 100 %				
Modulation power	W_{mod}	=	1.8	kW

GRID MODULARED H.F. CLASS C AMPLIFIER FOR TV SERVICE
(negative modulation, positive synchronization)

LIMITING VALUES (f = max. 110 Mc/s)

Anode voltage	V_a	=	max.	5	kV
Anode current (sync)	I_a	=	max.	1.5	A
Anode input power (sync)	W_{ia}	=	max.	7	kW
Anode dissipation (sync)	W_a	=	max.	3	kW
Screen-grid voltage	V_{g2}	=	max.	800	V
Screen-grid dissipation (sync)	W_{g2}	=	max.	100	W
Control-grid bias	$-V_{g1}$	=	max.	500	V
Control-grid current (sync)	I_{g1}	=	max.	80	mA

f = max. 220 Mc/s

Anode voltage	V_a	=	max.	4	kV
Anode input power (sync)	W_{ia}	=	max.	6	kW

OPERATING CONDITIONS, TWO TUBES IN PUSH-PULL

Frequency		f	=	54-88[1]	170-220[1]	170-220	Mc/s[1]
Bandwidth	(-1.5 dB)	B	=	6.5	6.5	-	Mc/s[2]
	(-3 dB)		=	12	12	7.5	Mc/s[2]
Anode voltage		V_a	=	5	4	4	kV
Screen-grid voltage		V_{g2}	=	800	800	800	V
Control-grid voltage	sync	V_{g1}	=	-175	-150	-150	V
	black			-260	-230	-260	V
	white			-450	-450	-450	V
Alternating grid voltage (peak-to-peak value)		V_{g1g1p}	=	300	850	850	V[3]
Anode current	sync	I_a	=	2.7	2.75	2.75	A
	black			1.75	2.1	1.5	A
Screen-grid current	sync	I_{g2}	=	145	110	250	mA
	black			40	50	65	mA
Control-grid current	sync	I_{g1}	=	82	100	80	mA
	black			35	50	20	mA
Driving power	sync	W_{ig1}	=	200-300	300-400	200-300	W[4]
Output power	sync	W_o	=	8.0	5.0	5.9	kW
	black			4.5	2.8	3.3	kW

---

[1], [2], [3], [4] See page 89.

GRID MODULATED H.F. CLASS C AMPLIFIER FOR TV SERVICE

(positive modulation, negative synchronisation)

LIMITING VALUES (f = max. 110 Mc/s)

Anode voltage		V_a	= max.	5	kV
Screen-grid voltage		V_{g2}	= max.	800	V
Control-grid bias		$-V_{g1}$	= max.	500	V
Anode current	white	I_a	= max.	1.1	A
Anode input power	white	W_{ia}	= max.	5.5	kW
Anode dissipation	white	W_a	= max.	3	kW
Screen-grid dissipation	white	W_{g2}	= max.	100	W
Control-grid current	white	I_{g1}	= max.	80	mA

f = max. 220 Mc/s

Anode voltage	V_a	= max.	4	kV
Anode input power, white	W_{ia}	= max.	4.4	kW

OPERATING CONDITIONS, two tubes in push-pull

Frequency		f	= 170-220[1]	170-220	Mc/s
Bandwidth (-1.5 dB)		B	= 6.5	-	Mc/s [2]
(-3 dB)			= 12	7.5	Mc/s [2]
Anode voltage		V_a	= 4	4	kV
Screen-grid voltage		V_{g2}	= 800	800	V
Control-grid voltage	white	V_{g1}	= -230	-230	V
	black		= -380	-380	V
Alternating-grid voltage (peak to peak value)		V_{g1g1p}	= 850	850	V [3]
Anode current	white	I_a	= 2.1	1.7	A
	black		= 0.6	0.5	A
Screen-grid current	white	I_{g2}	= 50	80	mA
	black		= 10	10	mA
Control-grid current	white	I_{g1}	= 50	25	mA
	black		= 0	0	mA
Driving power		W_{ig1}	= 300-400	200-300	W [4]
Output power	white	W_o	= 2.8[5]	4.0	kW
	black		= 0.25	0.36	kW

---

[1] The operating conditions are given at a frequency slightly below the peak of the resonance curve.

[2] This value of bandwidth is based on measurements on a circuit with a single L-C section.

[3] Measured by the slide back method.

[4] Driving power is accounted for largely by circuit losses. The indicated driving power is required to take care of losses in damping resistors, circuit losses and tube driving power.

[5] In the peak of the resonance curve W_o (white) = 3.3 kW.

GRID MODULATED H.F. CLASS C AMPLIFIER FOR COLOUR TV SERVICE

(negative modulation, positive synchronisation)

LIMITING VALUES (f = max. 110 Mc/s)

Anode voltage	V_a	=	max.	5	kV
Anode current, sync	I_a	=	max.	1.5	A
Anode input power, sync	W_{ia}	=	max.	7	kW
Anode dissipation, sync	W_a	=	max.	3	kW
Screen-grid voltage	V_{g2}	=	max.	800	V
Screen-grid dissipation, sync	W_{g2}	=	max.	100	W
Control-grid bias	$-V_{g1}$	=	max.	500	V
Control-grid current, sync	I_{g1}	=	max.	80	mA

f = max. 220 Mc/s

Anode voltage	V_a	=	max.	4	kV
Anode input power, sync	W_{ia}	=	max.	6	kW

OPERATING CONDITIONS, two tubes in push-pull (f = max. 170-220 Mc/s [1])

Bandwidth (-1.5 dB)		B	=	4 Mc/s [2]
(-3 dB)			=	8.5 Mc/s [2]
Anode voltage		V_a	=	3.5 kV
Screen-grid voltage		V_{g2}	=	700 V
Control-grid voltage,	sync	V_{g1}	=	-120 V
	black		=	-170 V
	white		=	-320 V
Alternating-grid voltage (peak-to-peak value)		V_{g1g1p}	=	640 V [3]
Anode current	sync	I_a	=	2 A
	black		=	1.5 A
Screen-grid current	sync	I_{g2}	=	82 mA
	black		=	38 mA
Control-grid current	sync	I_{g1}	=	100 mA
	black		=	50 mA
Driving power	sync	W_{ig1}	=	100-200 W [4]
Output power	sync	W_o	=	3 kW
	black		=	1.7 kW

H.F. CLASS B AMPLIFIER FOR TV SERVICE

(negative modulation, positive synchronisation)

LIMITING VALUES (f = max. 110 Mc/s)

Anode voltage		V_a	=	max.	5	kV
Screen-grid voltage		V_{g2}	=	max.	800	V
Anode current	sync	I_a	=	max.	1.5	A
Anode input power	sync	W_{ia}	=	max.	7	kW
Anode dissipation	sync	W_a	=	max.	3	kW
Screen-grid dissipation	sync	W_{g2}	=	max.	100	W
Control-grid current	sync	I_{g1}	=	max.	80	mA

f = max. 220 Mc/s

Anode voltage	V_a	=	max.	4	kV
Anode input power, sync	W_{ia}	=	max.	6	kW

---

[1], [2], [3], [4] See page 89.

OPERATING CONDITIONS, two tubes in push-pull

Frequency		f	=	54-88	170-220	Mc/s 1)
Bandwidth (-1.5 dB)		B	=	6.5	6.5	Mc/s 2)
(-3 dB)				12	12	Mc/s 2)
Anode voltage		V_a	=	5	4	kV
Screen-grid voltage		V_{g2}	=	800	800	V
Control-grid bias		V_{g1}	=	-175	-150	V
Alternating-grid voltage (peak-to-peak value),	sync	V_{g1g1p}	=	900	850	V 3)
	black		=	730	700	V 3)
Anode current	sync	I_a	=	2.7	2.75	A
	black		=	1.75	2.1	A
Screen-grid current,	sync	I_{g2}	=	145	110	mA
	black		=	40	50	mA
Control-grid current,	sync	I_{g1}	=	82	100	mA
	black		=	35	50	mA
Driving power,	sync	W_{ig1}	=	200-300	300-400	W 4)
Output power,	sync	W_o	=	8.0	5.0	kW
	black		=	4.5	2.8	kW

H.F. CLASS B AMPLIFIER FOR TV SERVICE

(positive modulation, negative synchronisation)

LIMITING VALUES (f = max. 110 Mc/s)

Anode voltage		V_a	=	max.	5	kV
Screen-grid voltage		V_{g2}	=	max.	800	V
Anode current	white	I_a	=	max.	1.1	A
Anode input power		W_{ia}	=	max.	5.5	kW
Anode dissipation		W_a	=	max.	3	kW
Screen-grid dissipation		W_{g2}	=	max.	100	W
Control-grid current		I_{g1}	=	max.	80	mA

f = max. 220 Mc/s

Anode voltage	V_a	=	max.	4	kV
Anode input power, white	W_{ia}	=	max.	4.4	kW

OPERATING CONDITIONS, two tubes in push-pull (f = 170-220 Mc/s 1))

Bandwidth (-1.5 dB)		B	=	6.5	Mc/s 2)
(-3 dB)			=	12	Mc/s 2)
Anode voltage		V_a	=	4	kV
Screen-grid voltage		V_{g2}	=	800	V
Control-grid bias		V_{g1}	=	-150	V
Alternating-grid voltage (peak-to-peak value),	white	V_{g1g1p}	=	700	V 3)
	black		=	350	V 3)
Anode current,	white	I_a	=	2.1	A
	black		=	0.6	A
Screen-grid current,	white	I_{g2}	=	50	mA
	black		=	10	mA
Control-grid current,	white	I_{g1}	=	50	mA
	black		=	0	mA
Driving power,	white	W_{ig1}	=	200-300	W 4)
Output power	white	W_o	=	2.8	kW 5)
	black		=	0.25	kW

See notes on page 89.

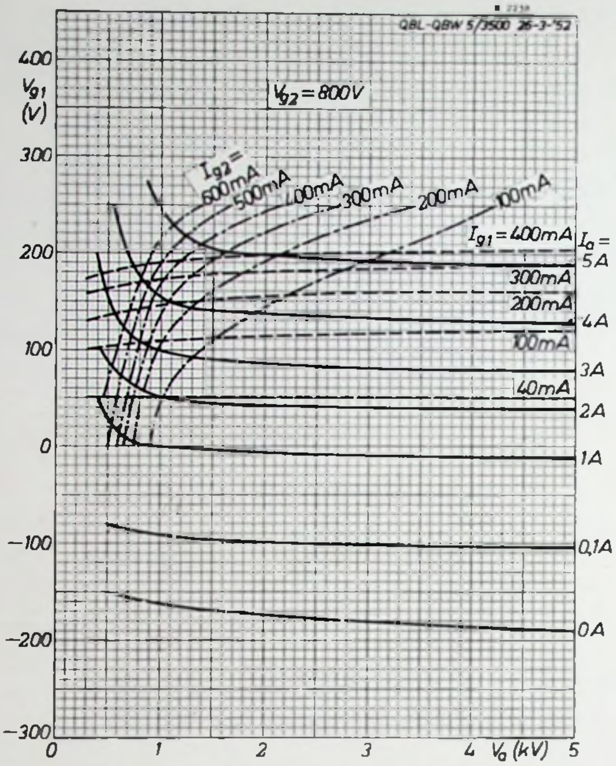

Fig. 80. Constant-current characteristics of the QBL 5/3500 and the QBW 5/3500.

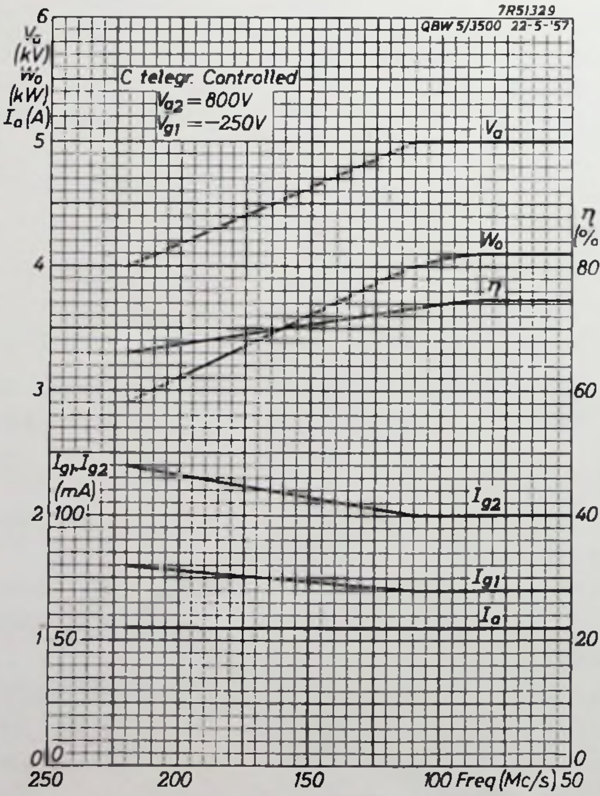

Fig. 81. Anode voltage (V_a), anode current (I_a), screen-grid current (I_{g2}), control-grid current (I_{g1}), output power (W_o) and efficiency (η) of the QBL 5/3500 and QBW 5/3500 at a screen-grid voltage of 800 V.

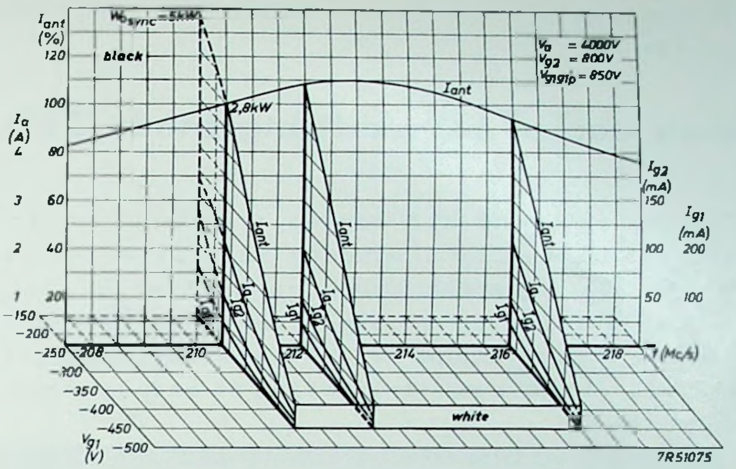

Fig. 82. 3-dimensional diagram of the performance of the QBL 5/3500 and QBW 5/3500 as grid modulated HF class C amplifier for TV service (2 tubes in push-pull, $B_{(-1.5\ dB)}$ = 6.5 Mc/s, $B_{(-3\ dB)}$ = 12 Mc/s).

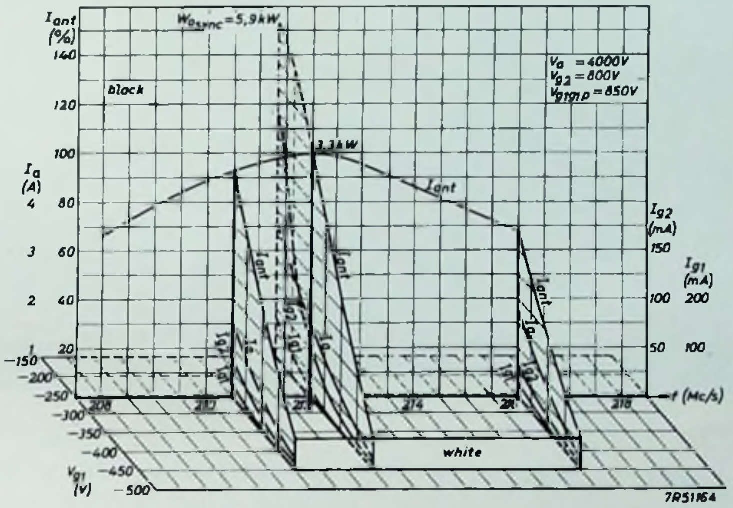

Fig. 83. 3-dimensional diagram of the performance of the QBL 5/3500 and QBW 5/3500 as grid modulated HF class C amplifier for TV service (2 tubes in push-pull, $B_{(-3\ dB)}$ = 7.5 Mc/s).

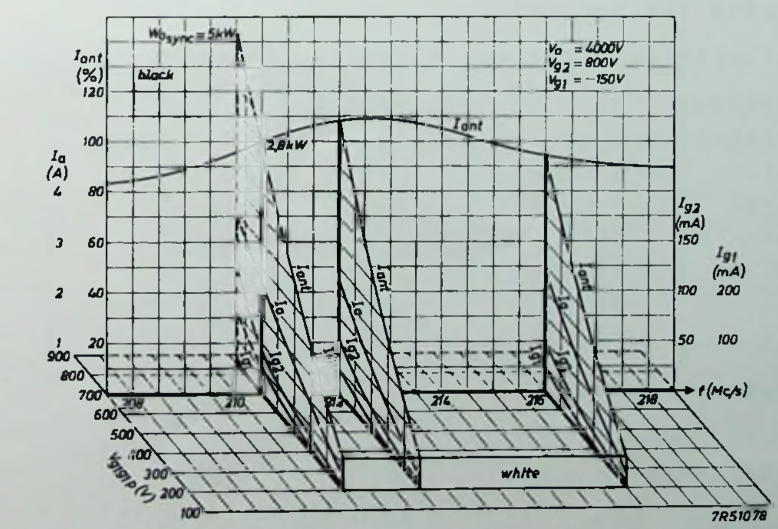

Fig. 84. 3-dimensional diagram of the performance of the QBL 5/3500 and QBW 5/3500 as HF class B amplifier for TV service (2 tubes in push-pull).

Forced-air cooled transmitting triode TBL 2/300

The TBL 2/300 is a forced-air cooled transmitting triode for use as amplifier, oscillator or frequency multiplier at frequencies up to 900 Mc/s. At 175 Mc/s the tube can deliver an output power of 475 W under class-C telegraphy conditions. As grid-modulated class-C amplifier in the output stage of a TV vision transmitter two tubes in push-pull are capable of delivering an output power of 260 W at 900 Mc/s (sync peak).

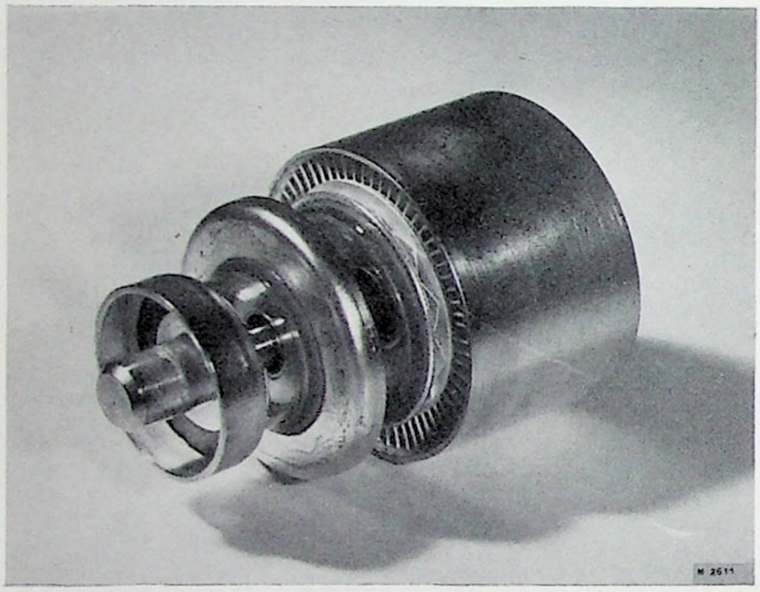

Fig.85. Photograph of the TBL 2/300.

The tube is built coaxially in its entirety, even the filament terminals terminate in coaxial connectors, so that the tube is very suitable for use in coaxial grounded grid circuits or cavity resonators.

TECHNICAL DATA (tentative)

Filament: thoriated tungsten, directly heated

Filament voltage V_f = 3.4 V [1]
Filament current I_f = 19 A

CAPACITANCES

C_a = 0.12 pF
C_g = 9 pF
C_{ag} = 4 pF

TYPICAL CHARACTERISTICS

Amplification factor μ = 32
Mutual conductance S = max. 20 mA/V

---

[1] The filament voltage should be reduced immediately after switching on to 3.3 V for frequencies between 600 and 750 Mc/s and to 3.2 V for frequencies between 750 and 900 Mc/s.

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS (in mm)

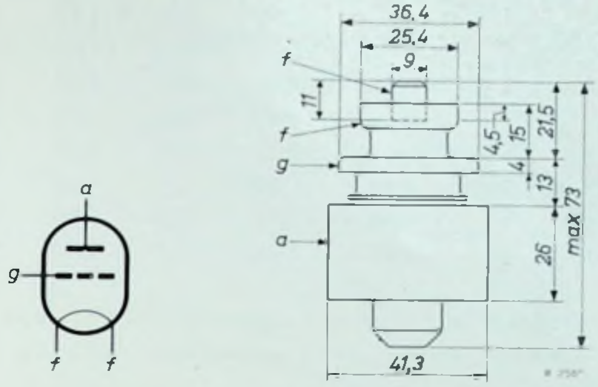

Fig. 86.

MOUNTING POSITION

Vertical with anode up or down

MAXIMUM TEMPERATURE OF THE SEALS: 200 °C

Generally it will be necessary to direct an air flow to the centre filament seal.

WEIGHTS

Net weight	143 g
Shipping weight	225 g

COOLING CHARACTERISTICS

anode dissipation (W)	altitude (m)	max. air inlet temp. (°C)	min. air flow (m^3/min)	pressure drop (mm H_2O)
100	0	35	0.16	2.9
	0	45	0.18	3.9
	1500	35	0.16	3.6
	3000	25	0.20	3.4
200	0	35	0.27	8.7
	0	45	0.31	11.4
	1500	35	0.32	10.5
	3000	25	0.34	10.1
300	0	35	0.39	18.5
	0	45	0.45	24.0
	1500	35	0.46	22.5
	3000	25	0.49	21.5

H.F. CLASS C TELEGRAPHY

LIMITING VALUES

Frequency	f	=	175	300	470	600	900	Mc/s
Anode voltage	V_a	= max.	2500	2000	1750	1600	1300	V
Anode current	I_a	= max.	400	400	400	400	400	mA
Grid bias	$-V_g$	= max.	300	300	300	300	300	V
Grid current	I_g	= max.	120	120	120	120	120	mA
Grid dissipation	W_g	= max.	15	15	15	15	15	W
Anode input power	W_{ia}	= max.	1000	800	700	640	520	W
Anode dissipation	W_a	= max.	300	300	300	300	300	W

OPERATING CONDITIONS (Data for grounded-grid circuit except for the data at 175 Mc/s which refer to a grounded cathode circuit.)

Frequency	f	=	175	300	470	600	900	Mc/s
Anode voltage 1)	V_a	=	2500	2000	1750	1600	1300	V
Anode current	I_a	=	260	335	380	400	350	mA
Grid bias	V_g	=	-200	-120	-105	-90	-60	V
Grid current	I_g	=	100	100	100	100	100	mA
Alternating-grid voltage (peak value)	V_{gp}	=	275	-	-	-	-	V
Driving power	W_{ig}	=	25	-	-	-	-	W
Anode input power	W_{ia}	=	650	670	665	640	455	W
Anode dissipation	W_a	=	175	210	260	290	300	W
Output power	W_o	=	475	460	405	350	155	W
Efficiency	η	=	73	69	61	55	34	%

H.F. CLASS C ANODE MODULATION

LIMITING VALUES

Frequency	f	= max.	175	300	470	600	900	Mc/s
Anode voltage	V_a	= max.	2000	1600	1400	1280	1040	V
Anode current	I_a	= max.	335	335	335	335	335	mA
Grid bias	$-V_g$	= max.	300	300	300	300	300	V
Grid current	I_g	= max.	120	120	120	120	120	mA
Grid dissipation	W_g	= max.	15	15	15	15	15	W
Anode input power	W_{ia}	= max.	670	536	465	429	348	W
Anode dissipation	W_a	= max.	200	200	200	200	200	W

OPERATING CONDITIONS (Data for grounded grid circuit, except for the data at 175 Mc/s which refer to a grounded cathode circuit.)

Frequency	f	=	175	300	470	600	900	Mc/s
Anode voltage 1)	V_a	=	2000	1600	1400	1280	1040	V
Anode current	I_a	=	335	335	332	332	290	mA
Grid bias	V_g	=	-220 2)	-140 2)	-120	-100	-80	V
Grid current	I_g	=	120	120	110	100	80	mA
Alternating-grid voltage (peak value)	V_{gp}	=	275	-	-	-	-	V
Driving power	W_{ig}	=	30	-	-	-	-	W
Anode input power	W_{ia}	=	670	536	465	425	302	W
Anode dissipation	W_a	=	165	166	190	200	200	W
Output power	W_o	=	505	370	275	225	102	W
Efficiency		=	75.5	69	59	53	34	%
Modulation depth = 100%								
Modulation power	W_{mod}	=	335	268	233	213	151	W

---

1) With respect to cathode

2) Partially fixed bias

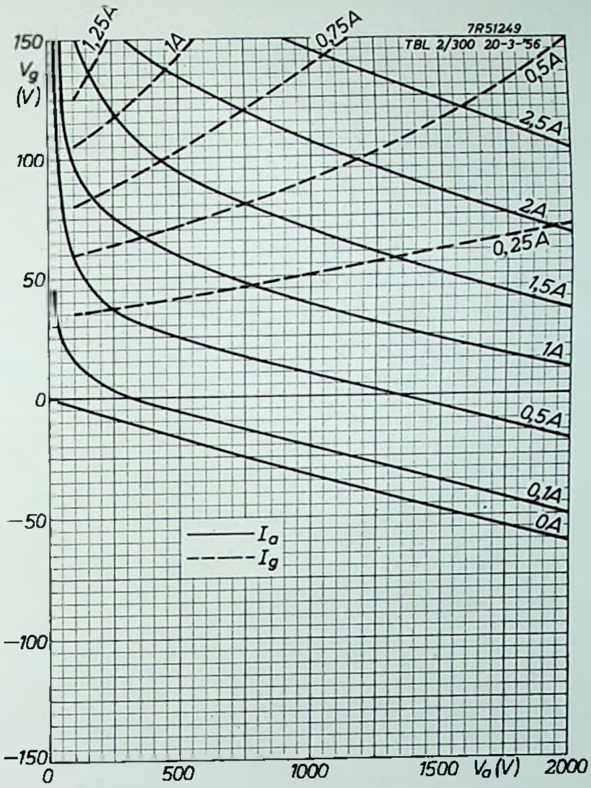

Fig.87. Constant current characteristics of the TBL 2/300.

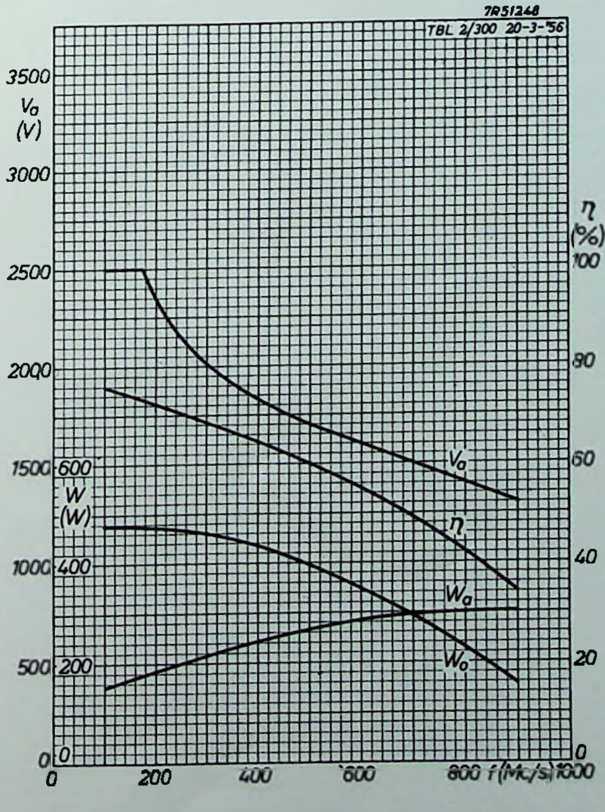

Fig.88. Anode voltage (V_a), anode dissipation (W_a), output power (W_o) and efficiency (η) of the TBL 2/300 as a function of frequency.

Forced cooled transmitting triodes
TBL 6/6000 and TBW 6/6000

The TBL 6/6000 and TBW 6/6000 are the air-cooled and water cooled versions respectively of a triode transmitting tube, which can deliver an output power of approx. 7 kW at 75 Mc/s under class C telegraphy conditions. Full ratings may be applied up to this frequency.

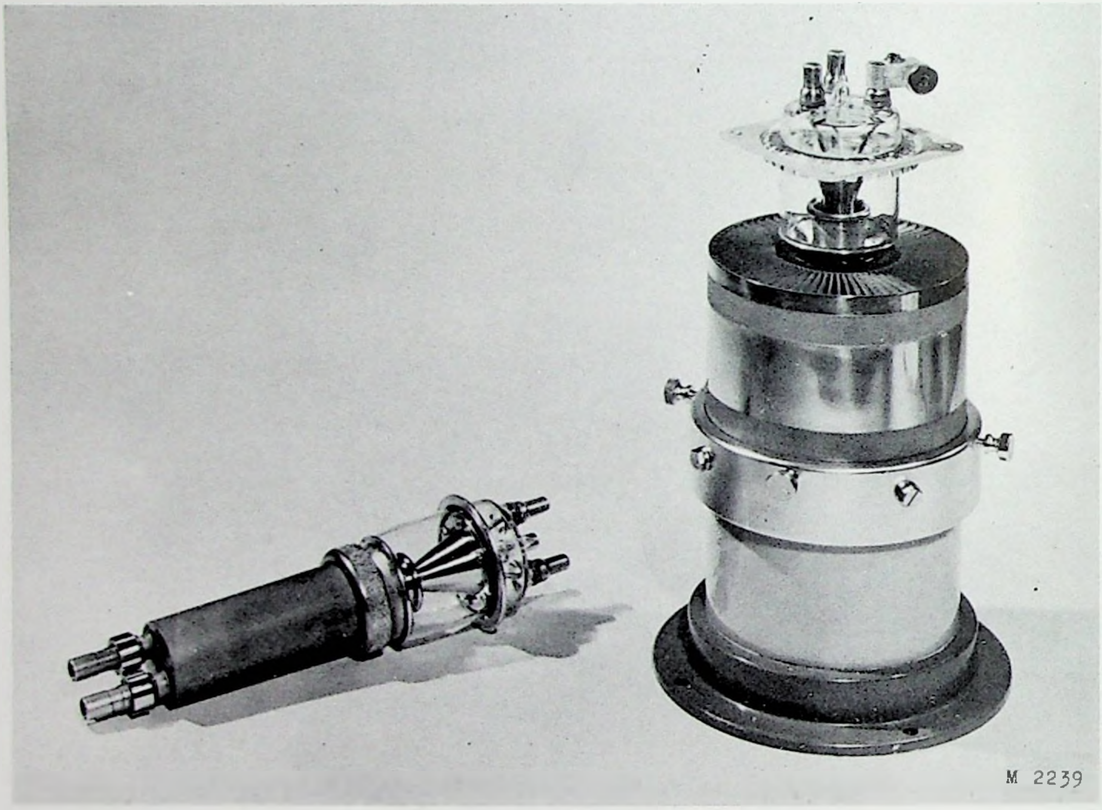

Fig.89. Photograph of the TBL 6/6000 (right) and the TBW 6/6000 (left).

Two tubes in push-pull, used in the output stage of a TV vision transmitter can deliver an output power of 9 kW in band I and 6 kW in band III (sync. peak).

The TBL 6/6000 and TBW 6/6000 are provided with a ring shaped grid terminal to facilitate the use in coaxial resonant circuits or cavity resonators.

TECHNICAL DATA

Filament: thoriated tungsten, directly heated

Filament voltage: V_f = 12.6 V
Filament current: I_f = 33 A

REMARK

The centre tap, marked o, must not be used for filament current supply. The clips, type 40634, must however be used for the cooling of all three filament pins.

CAPACITANCES

C_a = 0.3 pF
C_{gl} = 16 pF
C_{ag} = 11 pF

TYPICAL CHARACTERISTICS

Amplification factor (V_a = 4 kV, I_a = 1 A) μ = 32
Mutual conductance (V_a = 4 kV, I_a = 1 A) S = 17 mA/V

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSION (in mm)

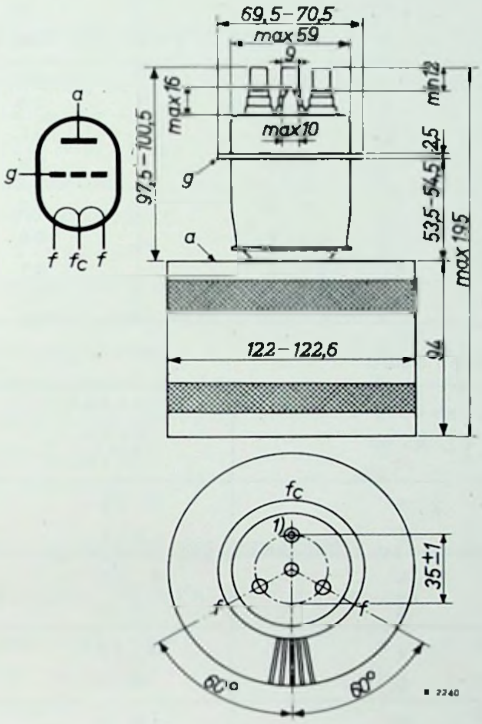

Fig.90. TBL 6/6000.
[1]) This pin is marked "O".

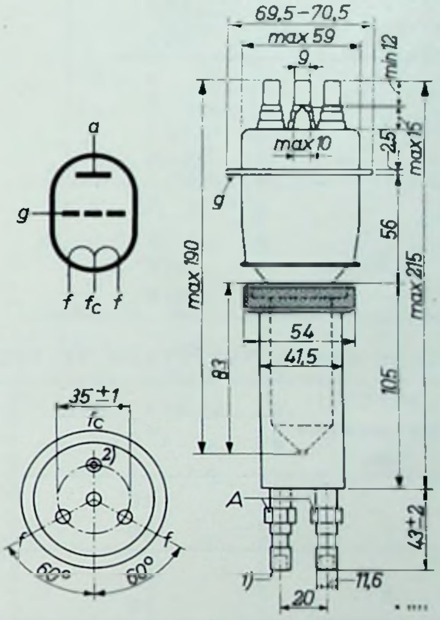

Fig.91. TBW 6/6000.
[1]) 1/8 pipe thread.
[2]) This pin is marked "O".

ACCESSORIES

TBL 6/6000

Clips for filament	40634
Grid connector	40622
Insulating pedestal	40630

TBW 6/6000

Clips for filament	40634
Grid connector	40622
Water jacket	K 713

MOUNTING POSITION

TBL 6/6000: vertical, anode up or down
TBW 6/6000: vertical, anode down

MAXIMUM TEMPERATURES

Seals max. 180 °C

WEIGHTS

	TBL 6/6000	40630	TBW 6/6000	K 713
Net weight	4.6	2.1	0.45	0.6 kg
Shipping weight	8.1	3.1	1.2	0.75 kg

COOLING CHARACTERISTICS OF THE TBL 6/6000

anode dissipation (kW)	altitude (m)	max.air inlet temp. (°C)	min.air flow (m^3/min.)	pressure drop (mm H_2O)
1	0	35	3	8
	0	45	3.1	8
	1500	35	3.7	9
	3000	25	4.1	10
3	0	35	5.2	23
	0	45	6.1	29
	1500	35	6.2	26
	3000	25	6.6	26
5	0	35	9.2	68
	0	45	10.7	90
	1500	35	11.2	81
	3000	25	11.6	79

COOLING CHARACTERISTICS OF THE TBW 6/6000

anode dissipation (kW)	inlet temp. (°C)	min.water flow[1] (l/min)	pressure loss (atm.)
1	20	2.5	0.08
	50	3	0.1
2	20	2.5	0.08
	50	5	0.3
4	20	4	0.18
	50	9	0.9
6	20	6	0.4
	50	14	2.5

It is necessary to direct a low-velocity air flow to anode and grid seal at frequencies above 30 Mc/s. Air flow must be started upon or before application of the filament voltage.

---

[1] At temperatures t_i between 20 and 50 °C the required quantity of water can be found by proportional interpolation.

[2] When using the tube above 108 Mc/s, particular attention must be given to a careful design of the installation, otherwise the tube may be damaged.
Therefore, our guarantee for the tubes operating at frequencies above 108 Mc/s can only be given after approval of the installation.

[3] Power transferred from driving stage included.

[4] Pure tube efficiency.

H.F. CLASS C TELEGRAPHY

LIMITING VALUES (f = max. 75 Mc/s)

Anode voltage	V_a	= max.	6	kV
Grid bias	$-V_g$	= max.	1000	V
Anode current	I_a	= max.	1.5	A
Grid current	I_g	= max.	0.35	A
Grid dissipation	W_g	= max.	120	W
Anode input power	W_{ia}	= max.	9	kW
Anode dissipation				
TBL 6/6000	W_a	= max.	5	kW
TBW 6/6000		max.	6	kW

OPERATING CONDITIONS

Wavelength	λ =	4	4	4	m
Frequency	f =	75	75	75	Mc/s
Anode voltage	V_a =	6	5	4	kV
Grid bias	V_g =	-400	-300	-200	V
Anode current	I_a =	1.5	1.5	1.37	A
Grid current	I_g =	0.31	0.33	0.35	A
Alternating-grid voltage (peak value)	V_{gp} =	740	640	500	V
Driving power	W_{ig} =	210	190	160	W
Anode input power	W_{ia} =	9	7.5	5.5	kW
Anode dissipation	W_a =	2.1	1.9	1.5	kW
Output power	W_o =	6.9	5.6	4	kW
Efficiency	π =	76.5	75	73	%

H.F. CLASS C TELEGRAPHY, grounded grid

LIMITING VALUES (f ≤ 75 Mc/s)

Anode voltage	V_a	= max.	6	kV
Grid voltage	$-V_g$	= max.	1000	V
Anode current	I_a	= max.	1.5	A
Grid current	I_g	= max.	0.35	A
Grid dissipation	W_g	= max.	120	W
Anode input power	W_{ia}	= max.	9	kW
Anode dissipation				
TBL 6/6000	W_a	= max.	5	kW
TBW 6/6000		max.	6	kW

OPERATING CONDITIONS. Two tubes in push-pull

Wavelength	λ =	4	$2.7^{1)}$	$2.7^{1)}$	$1.36^{1)}$	m
Frequency	f =	75	110	110	220	Mc/s
Anode voltage	V_a =	6	5	4	4	kV
Grid bias	V_g =	400	300	200	200	V
Anode current	I_a =	2x1.5	2x1.5	2x1.37	2x1.25	A
Grid current	I_g =	2x0.31	2x0.33	2x0.35	2x0.2	A
Alternating-grid voltage (peak value)	V_{gp} =	740	640	500	450	V
Driving power	W_{ig} =	2x1120	2x920	2x675	2x380	W
Anode input power	W_{ia} =	2x9	2x7.5	2x5.5	2x5	kW
Anode dissipation	W_a =	2x2.1	2x2.2	2x1.7	2x2.5	kW
Output power$^{2)}$	W_o =	13.8+1.82	10.6+1.46	7.6+1.03	5+0.6	kW
Efficiency$^{3)}$	=	76.5	71	69	50	%

See notes on opposite page.

H.F. CLASS C ANODE MODULATION

LIMITING VALUES (f $\leq$ 75 Mc/s)

Anode voltage	V_a	= max.	5	kV
Grid bias	$-V_g$	= max.	1000	V
Anode current	I_a	= max.	1.3	A
Grid current	I_g	= max.	0.35	A
Grid dissipation	W_g	= max.	120	W
Anode input power	W_{ia}	= max.	6.5	kW
Anode dissipation				
TBL 6/6000	W_a	= max.	3.4	kW
TBW 6/6000		= max.	4	kW

OPERATING CONDITIONS

Wavelength	λ =	4	4	4	4	4	m
Frequency	f =	75	75	75	75	75	Mc/s
Anode voltage	V_a =	5	4.5	4	3.5	3	kV
Grid bias [1]	V_g =	-400	-350	-300	-300	-250	V
Anode current	I_a =	1.2	1.2	1.2	1.2	1	A
Grid current	I_g =	0.3	0.3	0.3	0.3	0.3	A
Alternating-grid voltage (peak value)	V_{gp} =	690	650	600	600	510	V
Driving power	W_{ig} =	190	180	165	165	140	W
Anode input power	W_{ia} =	6	5.4	4.8	4.2	3	kW
Anode dissipation	W_a =	1.3	1.3	1.3	1.2	0.8	kW
Output power	W_o =	4.7	4.1	3.5	3	2.2	kW
Efficiency	η =	78	76	73	71.5	73	%

Modulation depth = 100 %

Modulation power	W_{mod} =	3	2.7	2.4	2.1	1.5	kW

GRID MODULATED H.F. CLASS C AMPLIFIER FOR TV SERVICE

(negative modulation, positive synchronisation)

LIMITING VALUES (f = max. 75 Mc/s)

Anode voltage	V_a	= max.	5	kV
Anode input power, sync	W_{ia}	= max.	9.5	kW
Anode dissipation, sync	W_a	= max.	5	kW
Anode current, sync	I_a	= max.	1.9	A
Grid dissipation, sync	W_g	= max.	120	W
Grid voltage	$-V_g$	= max.	1000	V

f = max. 220 Mc/s

Anode voltage	V_a	= max.	4	kV
Anode input power, sync	W_{ia}	= max.	6.5	kW
Anode dissipation, sync	W_a	= max.	4	kW
Anode current, sync	I_a	= max.	1.6	A
Grid dissipation, sync	W_g	= max.	120	W
Grid voltage	$-V_g$	= max.	1000	V

---

1) Grid bias partially obtained by the grid resistor.

OPERATING CONDITIONS, two tubes in push-pull

Frequency		f	=	48-75	170-220 1)	Mc/s
Bandwidth (-1.5 dB)		B	=	5.25	6.5	Mc/s 2)
(-3 dB)				8	10	Mc/s 2)
Anode voltage		V_a	=	5	4	kV
Grid voltage,	sync	V_g	=	-200	-150	V
	black			-300	-225	V
	white			-550	-500	V
Alternating-grid voltage (peak-to-peak value),	sync	V_{ggp}	=	1000	1000	V 3)
Anode current	sync	I_a	=	3.8	3.2	A
	black		=	2.6	2.6	A
Grid current	sync	I_g	=	0.5	0.4	A
	black		=	0.35	0.22	A
Driving power	sync	W_{ig}	=	250	350-450	W 4)
Output power	sync	W_o	=	9	6	kW
	black		=	5.35	3.37	kW

GRID MODULATED H.F. CLASS C AMPLIFIER FOR TV SERVICE

(positive modulation, negative synchronisation)

LIMITING VALUES (f = max. 75 Mc/s)

Anode voltage	V_a	= max.	5	kV
Grid voltage	$-V_g$	= max.	1000	V
Anode current, white	I_a	= max.	1.9	A
Anode input power, white	W_{ia}	= max.	9.5	kW
Anode dissipation, white				
TBL 6/6000	W_a	= max.	5	kW
TBW 6/6000		= max.	6	kW
Grid dissipation, white	W_g	= max.	120	W

OPERATING CONDITIONS, two tubes in push-pull

Frequency		f	=	48-75	Mc/s
Bandwidth (I_{ant} = 85 %)		B	=	5.25	Mc/s
(I_{ant} = 70 %)				8	Mc/s
Anode voltage		V_a	=	5	kV
Grid voltage,	white	V_g	=	-200	V
	black		=	-460	V
	sync		=	-580	V
Alternating-grid voltage (peak-to-peak value),	white	V_{ggp}	=	1000	V
Anode current,	white	I_a	=	3.8	A
	black		=	0.8	A
Grid current,	white	I_g	=	0.5	A
	black		=	0	A
Driving power,	white	W_{ig}	=	250	W
Output power,	white	W_o	=	9	kW
	black		=	0.6	kW

---

1) See footnote 2) on page 100.

2) This value of bandwidth is based on measurements on a circuit with a single LC section.

3) Measured by the slide back method.

4) Driving power is accounted for largely by circuit losses. The indicated driving power is required to take care of losses in damping resistors, circuit losses and tube driving power.

H.F. CLASS B AMPLIFIER FOR TV SERVICE

(negative modulation, positive synchronisation)

LIMITING VALUES (f = max. 75 Mc/s)

Anode voltage	V_a	= max.	5 kV
Anode input power, sync	W_{ia}	= max.	9.5 kW
Anode dissipation, sync	W_a	= max.	5 kW
Anode current, sync	I_a	= max.	1.9 A
Grid dissipation, sync	W_g	= max.	120 W

f = max. 75 Mc/s

Anode voltage	V_a	= max.	4 kV
Anode input power, sync	W_{ia}	= max.	6.5 kW
Anode dissipation, sync	W_a	= max.	4 kW
Anode current, sync	I_a	= max.	1.6 A
Grid dissipation, sync	W_g	= max.	120 W

OPERATING CONDITIONS, two tubes in push-pull

Frequency	f	=	48-75	170-220[1]	Mc/s
Bandwidth (-1.5 dB)	B	=	5.25	6.5	Mc/s[2]
(-3 dB)		=	8	10	Mc/s[2]
Anode voltage	V_a	=	5	4	kV
Grid bias	V_g	=	-200	-150	V
Alternating-grid voltage (peak-to-peak value), sync	V_{ggp}	=	1000	1000	V[3]
black		=	800	750	V[3]
white		=	0	200	V[3]
Anode current, sync	I_a	=	3.8	3.2	A
black		=	3	2.6	A
white		=	0.2	-	A
Grid current, sync	I_g	=	0.5	0.4	A
black		=	0.22	0.22	A
white		=	0	-	A
Driving power, sync	W_{ig}	=	250	350-450	W[4]
Output power, sync	W_o	=	9	6	kW
black		=	5.35	3.37	kW

---

[1] When using the tube above 108 Mc/s, particular attention must be given to a careful design of the installation, otherwise the tube may be damaged.
Therefore, our guarantee for the tubes operating at frequencies above 108 Mc/s can only be given after approval of the installation.

[2] This value of bandwidth is based on measurements on a circuit with a single LC section.

[3] Measured by the slide back method.

[4] Driving power is accounted for largely by circuit losses.
The indicated driving power is required to take care of losses in damping resistors, circuit losses and tube driving power.

H.F. CLASS B AMPLIFIER FOR TV SERVICE

(positive modulation, negative synchronisation)

LIMITING VALUES (f = max. 75 Mc/s)

Anode voltage V_a = max. 5 kV
Anode input power, white W_{ia} = max. 9.5 kW
Anode dissipation, white W_a = max. 5 kW
Anode current, white I_a = max. 1.9 A
Grid dissipation, white W_g = max. 120 W

OPERATING CONDITIONS (two tubes in push-pull, f = 48-75 Mc/s)

Bandwidth (-1.5 dB) B = 5.25 Mc/s
(- 3 dB) 8 Mc/s
Anode voltage V_a = 5 kV
Grid bias V_g = -200 V
Alternating grid voltage
(peak-to-peak value), white V_{ggp} = 1000 V
black 400 V
Anode current, white I_a = 3.8 A
black 0.8 A
Grid current, white I_g = 0.5 A
black 0 A
Driving power, white W_{ig} = 250 W
Output power, white, W_o = 9 kW
black 0.6 kW

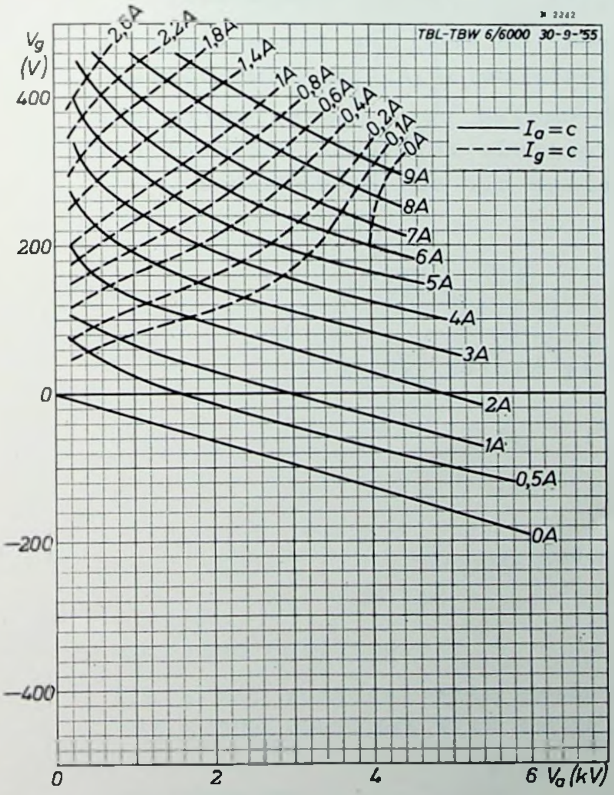

Fig.92. Constant-current characteristics of the TBL 6/6000 and the TBW 6/6000.

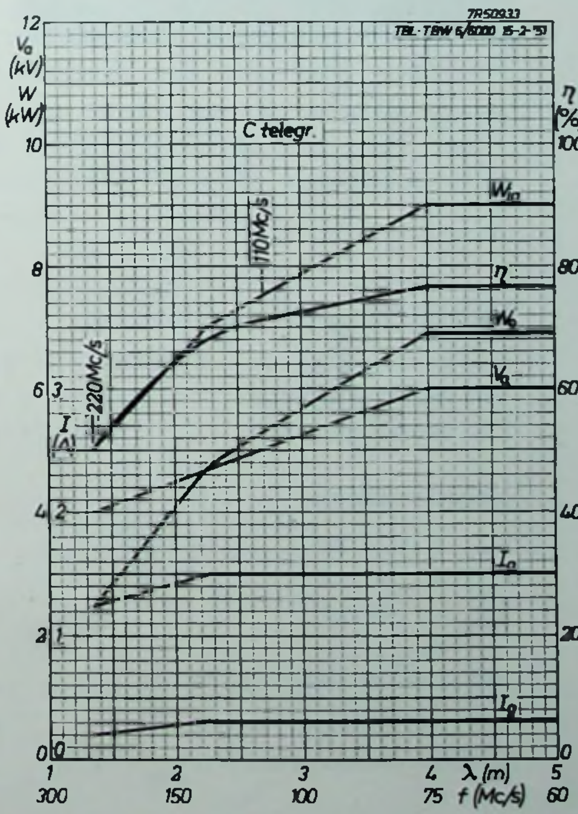

Fig.93. Anode voltage (V_a), anode current (I_a), anode input power (W_{ia}), grid current (I_g), output power (W_o) and efficiency (η) of the TBL 6/6000 and the TBW 6/6000 as a function of frequency.

Forced cooled transmitting triodes
TBL 6/20 and TBW 6/20

Fig. 94. Photograph of the TBL 6/20

The TBL 6/20 and TBW 6/20 are forced cooled transmitting triodes, specially designed for high-power, high frequency operation as e.g. in the output stage of TV or FM transmitters. Under class C telegraphy conditions the tubes can deliver an output power of 17 kW at 110 Mc/s.

When the TBL 6/20 or TBW 6/20 is used in the output stage of a TV vision transmitter the tube can deliver an output power of 17 kW in Band I and 10.5 kW in Band III (CCIR system) in grounded-grid circuit.

The tubes are built-up coaxially in their entirety, similar to the TBL (W) 2/300, so that they are very suitable for use in coaxial line circuits and cavity resonators.

In order to keep the temperature of the seals below the maximum permissible values, these parts should be cooled by a low-velocity air flow. For this purpose most of the electrode terminals are provided with apertures through which the cooling air can be directed.

TECHNICAL DATA (tentative)

Filament: thoriated tungsten, directly heated

Filament voltage:	V_f = 6.3 V
Filament current:	I_f = 154 A [1])

CAPACITANCES

C_a = 0.6 pF
C_g = 65 pF
C_{ag} = 29 pF

TYPICAL CHARACTERISTICS

Amplification factor	μ = 60
Mutual conductance (I_a = 1 A)	S = 60 mA/V

---

[1]) The filament current must never exceed a peak value of 500 A instantaneously at any time during the energizing schedule (corresponding to an r.m.s. value of 355 A.

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS (in mm)

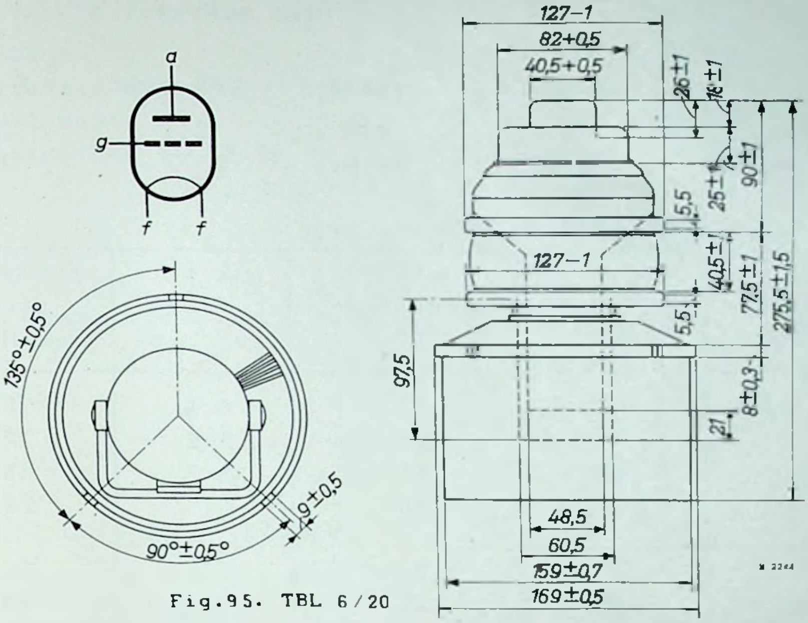

Fig.95. TBL 6/20

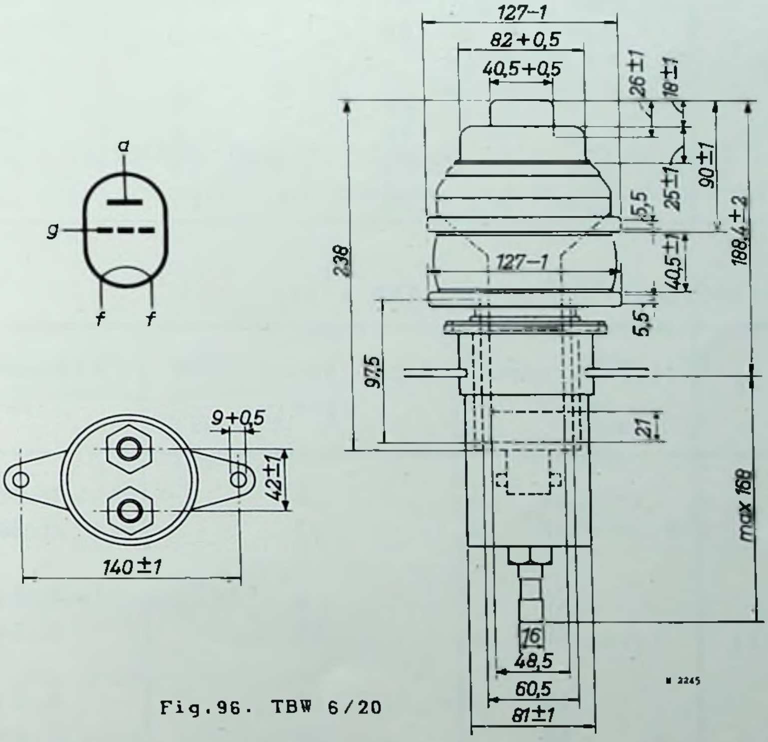

Fig.96. TBW 6/20

MOUNTING POSITION

TBL 6/20: vertical with anode up or down
TBW 6/20: vertical with anode down

ACCESSORIES

	TBL 6/20	TBW 6/20
Grid and anode connector	40651	40651
Inner filament connector	40652	40652
Outer filament connector	40653	40653
Insulating pedestal	40654	
Water jacket		K 718

MAXIMUM TEMPERATURES

Seals max. 180 °C

WEIGHTS

	TBL 6/20	40654	TBW 6/20	K 718	
Net weight	9.7	4.2	2.2	2.6	kg
Shipping weight	42.7	10.6	35.2	3.3	kg

COOLING CHARACTERISTICS OF THE TBL 6/20

anode dissipation (kW)	altitude (m)	max. air inlet temp. (°C)	min. air flow (m^3/min)	pressure drop (mm H_2O)
5	0	35	5.0	16
	0	45	5.6	19
	1500	35	5.9	18
	3000	25	5.7	16
7	0	35	7.3	32
	0	45	8.4	42
	1500	35	8.6	36
	3000	25	8.5	32
9	0	35	11	65
	0	45	12.8	85
	1500	35	13	75
	3000	25	13	66

COOLING CHARACTERISTICS OF THE TBW 6/20

anode dissipation (kW)	inlet temp. (°C)	min. water flow (l/min)	pressure loss (atm.)
6	20	6	0.08
	50	12	0.30
8	20	8	0.13
	50	16	0.54
10	20	10	0.21
	50	20	0.84
12	20	12	0.30
	50	24	1.20

---

[1] Power transferred from driving stage included.

[2] Pure tube efficiency.

[3] All voltages with respect to cathode.

H.F. CLASS C TELEGRAPHY

(grounded grid, f = max. 110 Mc/s)

LIMITING VALUES (advance data)

Anode voltage	V_a	= max. 5.5 kV
Anode current	I_a	= max. 6 A
Anode input power	W_{ia}	= max. 30 kW
Anode dissipation TBL 6/20	W_a	= max. 9 kW
TBW 6/20	W_a	= max. 12 kW
Grid bias	$-V_g$	= max. 500 V
Grid current	I_g	= max. 1.5 A

OPERATING CONDITIONS (advance data)

Frequency	f	= 110 Mc/s
Anode voltage	V_a	= 5 kV
Grid bias	V_g	= -300 V
Anode current	I_a	= 4.8 A
Grid current	I_g	= 1.2 A
Alternating grid voltage(peck value)	V_{gp}	= 520 V
Driving power	W_{ig}	= 2560 W
Anode input power	W_{ig}	= 24 kW
Anode dissipation	W_a	= 9 kW
Output power [1]	W_o	= 15 + 2 kW
Efficiency [2]	η	= 62.5 %

H.F. CLASS B TELEPHONY FOR TV SERVICE

(grounded grid, negative modulation, positive synchronisation)

LIMITING VALUES

Frequency	f	= max.	75	220 Mc/s
Anode voltage	V_a	= max.	5.5	4.5 kV
Anode input power, sync	W_{ia}	= max.	25	22 kW
Anode dissipation, sync TBL 6/20	W_a	= max.	10	10 kW
TBL 6/20		= max.	12	12 kW
Anode current, sync	I_a	= max.	6	6 A
Grid current, sync	I_g	= max.	1.5	1.5 A

OPERATING CONDITIONS [3]

Frequency	f	=	48-75	170-220 Mc/s
(-1.5 dB)		=		7 Mc/s
Bandwidth	B			
(-3 dB)		=	6	12 Mc/s
Anode voltage	V_a	=	5	4 kV
Grid bias	V_g	=	-90	-75 V
Alternating-grid voltage (peak value), sync	V_{gp}	=	270	430 V
black		=	200	275 V
Anode current, sync	I_a	=	4.8	5.1 A
black		=	3.6	3.9 A
Grid current, sync	I_g	=	1.0	1.35 A
black		=	0.35	0.55 A
Driving power, sync	W_{ig}	=	1.4	1.4 kW
Output power, sync	W_o	=	17	10.5 kW
black		=	9.6	6 kW

See notes on opposite page

H.F. CLASS B TELEPHONY FOR TV SERVICE

(grounded grid positive modulation, negative synchronisation)

LIMITING VALUES (f = max. 220 Mc/s)

Anode voltage		V_a	= max.	4.5	kV
Anode input power, white		W_{ia}	= max.	22	kW
Anode dissipation, white					
	TBL 6/20	W_a	= max.	9	kW
	TBW 6/20		max.	12	kW
Anode current, white		I_a	= max.	6	A
Grid current, white		I_g	= max.	1.2	A

OPERATING CONDITIONS [1]

Frequency		f	= =	170-220	Mc/s
Bandwidth (-3 dB)		B	=	12	Mc/s
Anode voltage		V_a	=	4	kV
Grid bias		V_g	=	-70	V
Alternating-grid voltage					
(peak value),	white	V_{gp}	=	250	V
	black		=	110	V
Anode current,	white	I_a	=	5	A
	black		=	1.6	A
Grid current,	white	I_g	=	1	A
	black		=	0.2	A
Driving power,	white	W_{ig}	=	1.3	W
Output power,	white	W_o	=	12	kW
	black		=	1.2	kW

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[1] All voltages with respect to cathode.

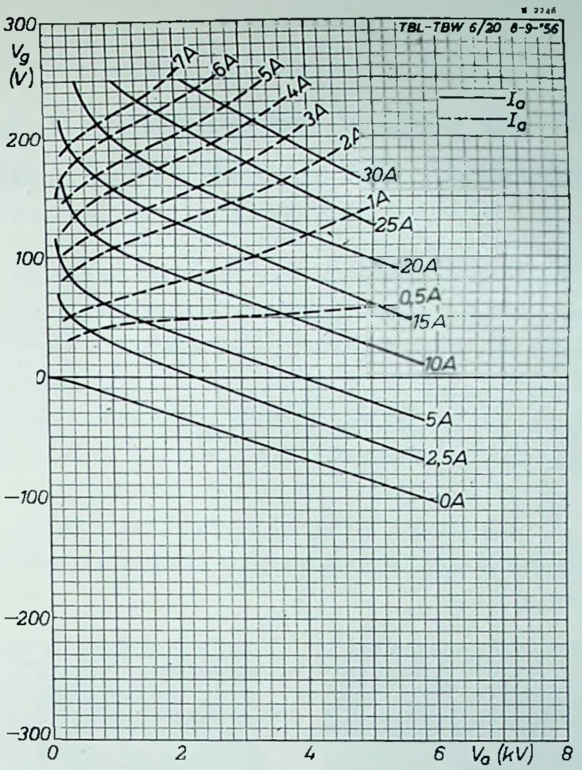


Fig.97. Constant-current characteristics of the TBL 6/20 and the TBW 6/20.

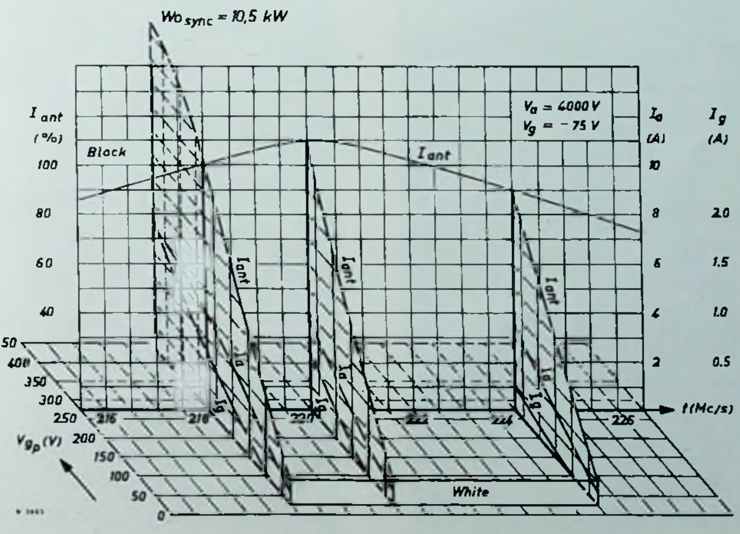


Fig.98. 3-dimensional diagram of the performance of the TBL 6/20 and TBW 6/20 as HF class B amplifier for TV service.

Forced cooled transmitting triodes
TBL 12/100 and TBW 12/100

The TBL 12/100 and TBW 12/100 are the forced-air cooled and the water cooled versions respectively of a high-power transmitting tube, delivering an output power of 108 kW at 15 Mc/s under class C telegraphy conditions.

As a linear amplifier in a TV vision transmitter two tubes in push-pull grounded-grid can deliver an output power of 100 kW (sync. peak) in band I.

The TBL 12/100 is provided with a multifin radiator system, which allows for a relatively large anode dissipation, inherent in the high power involved.

Fig. 99. Photograph of the TBL 12/100.

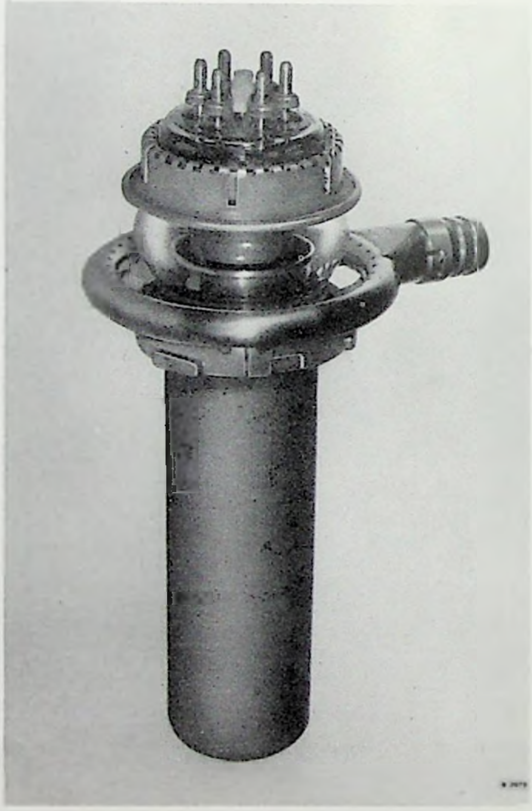


Fig. 100. Photograph of the TBW 12/100.

For the same purpose the TBL 12/100 has a special water jacket ("Grip-o-matic"). To cool the seals of this tube additional air-cooling is required.

For a detailed description of the TBL 12/100 and the TBW 12/100 reference is made to the publication: "TBL 12/100 and TBW 12/100 Transmitting Tubes").

Since both tubes operate at rather high voltages, anti-corona rings are provided to prevent sparking between the grid and the anode connections.

TECHNICAL DATA

Filament: thoriated tungsten, directly heated

Filament voltage:	V_f = 17.5 V
Filament current:	I_f = 196 A

The filament current must never exceed a peak value of 420 A at any time during initial energising schedule.

CAPACITANCES

C_a = 3.4 pF C_g = 116 pF C_{ag} = 86 pF

TYPICAL CHARACTERISTICS

Amplification factor	(V_a = 10 kV, I_a = 5 A)	μ	= 27
Mutual conductance		S	= 50 mA/V
	(V_a = 3 kV, I_a = 50 A)	S_{max}	= 92 mA/V

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS (in mm)

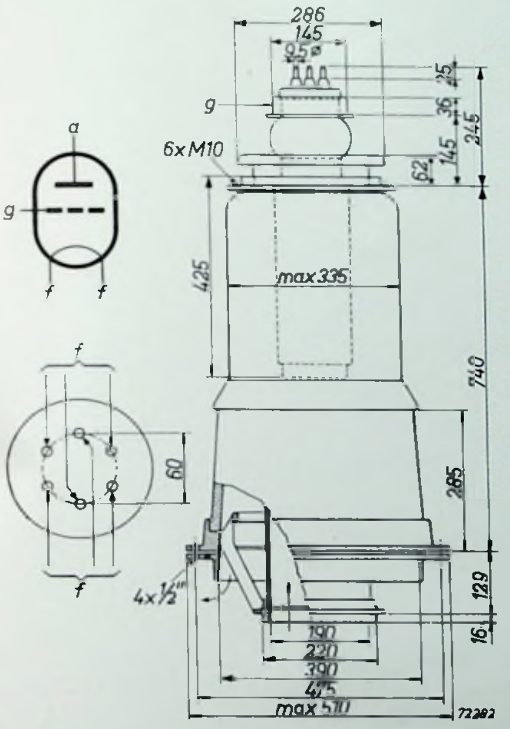


Fig. 101. TBL 12/100. When connecting the filament the three pins of each group must be joined.

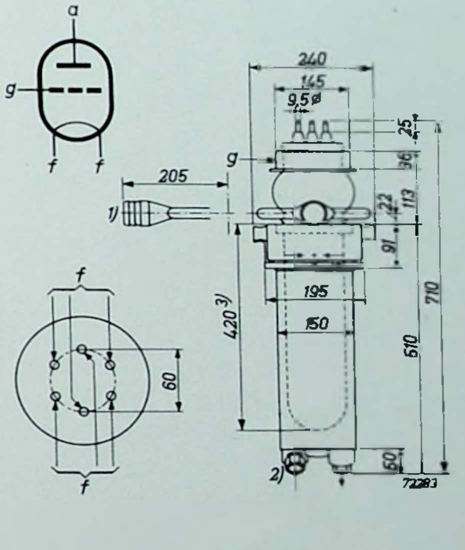


Fig. 102. TBW 12/100.

1) Use connecting hose with an inner diameter of $1^3/4''$.

2) Coupling for metal tubing with an outer diameter of 28 mm.

3) For removing the tube from its water jacket the free height above the tube must be at least 420 mm.

ACCESSORIES

TBL 12/100

Clips for filament	40628
Cooler housing	K 506

TBW 12/100

Clips for filament	40628
Water jacket	K 714

MOUNTING POSITION

TBL 12/100: vertical with anode down
TBW 12/100: vertical with anode down

MAXIMUM TEMPERATURES:

Seals: max. 180 °C 1)

WEIGHTS

	TBL 12/100	K 506	TBW 12/100	K 714
Net weight	28.5	72	14	20.5 kg
Shipping weight	97	105	82	39 kg

COOLING CHARACTERISTICS OF THE TBL 12/100 1) 2)

anode dissipation (kW)	altitude (m)	max. air inlet temp. (°C)	min. air flow (m^3/min)	pressure drop (mm H_2O)
30	0	35	35	114
	0	45	40	143
	1500	35	42	136
	3000	25	44	132
45	0	35	54	275
	0	45	62.5	335
	1500	35	64.5	322
	3000	25	68	319

COOLING CHARACTERISTICS OF THE TBW 12/100 2)3)

anode dissipation (kW)	inlet temp.4) (°C)	min water flow5) (l/min.)	pressure loss (atm.)
30	20	25	0.15
	50	45	0.45
50	20	32	0.25
	50	65	0.85
100	20	55	0.6
	50	120	3

---

1) When the tube is used at frequencies above 6 Mc/s, special attention must be given to the anode- and grid seal temperatures. Cooling of these seals is effected by air flowing through the slots provided at the top of the cooler housing. In certain cases, e.g. at low anode dissipation and with cooling by the minimum quantity of air, the air flow to the seals will not be sufficient to maintain the seal temperatures below the maximum permissible value at frequencies above 6 Mc/s.
Consequently, in these cases, a larger quantity of air must be supplied.

2) When using the special filament connectors type no. 40628, together with the connecting leads of adequate cross-section, additional air cooling of the filament terminals is, as a rule, not necessary.
Care should be taken to ensure firm contact of the filament terminals in order to obtain equal distribution of current over these terminals.

3), 4) and 5) See page 115.

H.F. CLASS B AMPLIFIER FOR TV SERVICE

(negative modulation, positive synchronisation)

LIMITING VALUES (f = max. 68 Mc/s)

Anode voltage	V_a	= max.	6.5 kV
Anode current, sync	I_a	= max.	16 A
Anode input power, sync	W_{ia}	= max.	100 kW
Anode dissipation, sync	W_a	= max.	50 kW
Grid current, sync	I_g	= max.	2 A

OPERATING CONDITIONS, two tubes in push-pull

Frequency		f	=	48-68 Mc/s[6]
Bandwidth (-1.5 dB)		B	=	5.5 Mc/s[7]
(-3 dB)				7.5 Mc/s[7]
Anode voltage		V_a	=	6.5 kV
Grid bias		V_g	=	-250 V
Alternating-grid voltage (peak-to-peak value),	sync	V_{ggp}	=	1740 V[8]
	black			1300 V[8]
Anode current,	sync	I_a	=	32 A
	black			24 A
Grid current,	sync	I_g	=	3.4 A
	black			2.2 A
Driving power,	sync	W_{ig}	=	22.4 kW[9]
Output power,	sync	W_o	=	80+20 kW[10]
	black			45+11 kW[10]

---

[3] To keep the seal temperatures below 180 °C it will often be necessary to direct an air flow of sufficient velocity to the seals. This air flow must be started upon or before application of the filament voltage. Anode- and grid seals can be cooled by connecting a blower of suitable size to the air inlet of the anti-corona ring, attached to the tube. At frequencies below 6 Mc/s, air cooling will, as a rule, not be necessary. Above 6 Mc/s air cooling must be used in order to prevent overheating of anode- and grid seals. At maximum frequency (30 Mc/s) and the published operating conditions at least 2.5 m^3 (95 cub. feet) per minute is required with a pressure loss of about 500 mm (20 inch) water column.

[4] Maximum inlet temperature of cooling water is 50 °C.

[5] At inlet temperatures of the cooling water between 20 and 50 °C the required quantity of water can be found by proportional interpolation.

[6] In the frequency range of 60-68 Mc/s a special version of the tube is necessary.

[7] This value of bandwidth is based on measurements on a circuit with a single LC section.

[8] Measured by the slide back method.

[9] Driving power is accounted for largely by circuit losses. The indicated driving power is required to take care of losses in damping resistors, circuit losses and tube driving power.

[10] Power transferred from driving stage included.

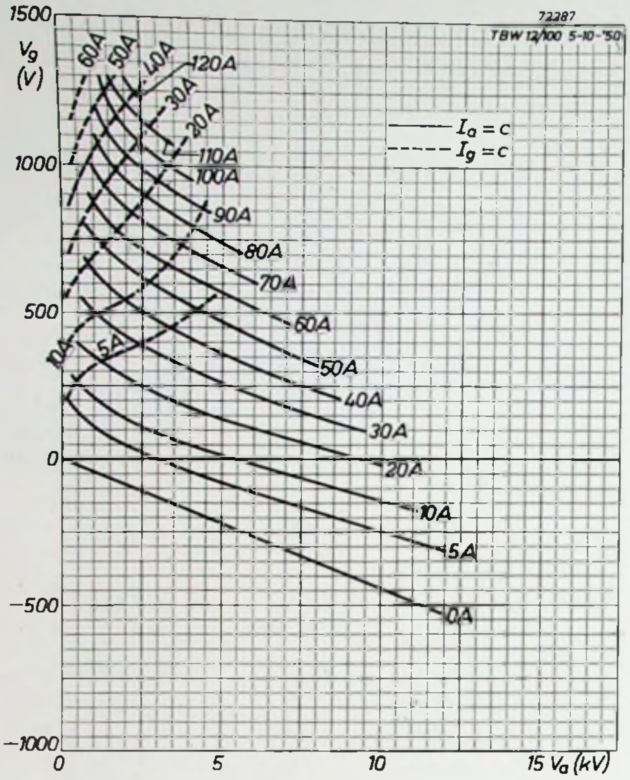


Fig. 103. Constant current characteristics of the TBL 12/100 and TBW 12/100.

DESCRIPTIONS OF RECTIFYING TUBES

The rectifying tubes, described below, can be divided into two groups, viz. mercury vapour and xenon filled tubes. The DCG 4/1000 G, DCG 5/5000 GS, DCG 6/18, DCG 7/100, DCG 7/100 B, DCG 9/20 and DCG 12/30 are mercury vapour tubes, whereas the DCX 4/1000 and DCX 4/5000 are xenon filled.

The mercury vapour tubes may only be used vertically, whereas the xenon filled tubes may be mounted in any position.

The technical data of the rectifying tubes described include a table with 7 different operating conditions, denoted by the figures *a* to *g* that refer to the rectifying circuits, the diagrams of which are given below (see Fig. 104).

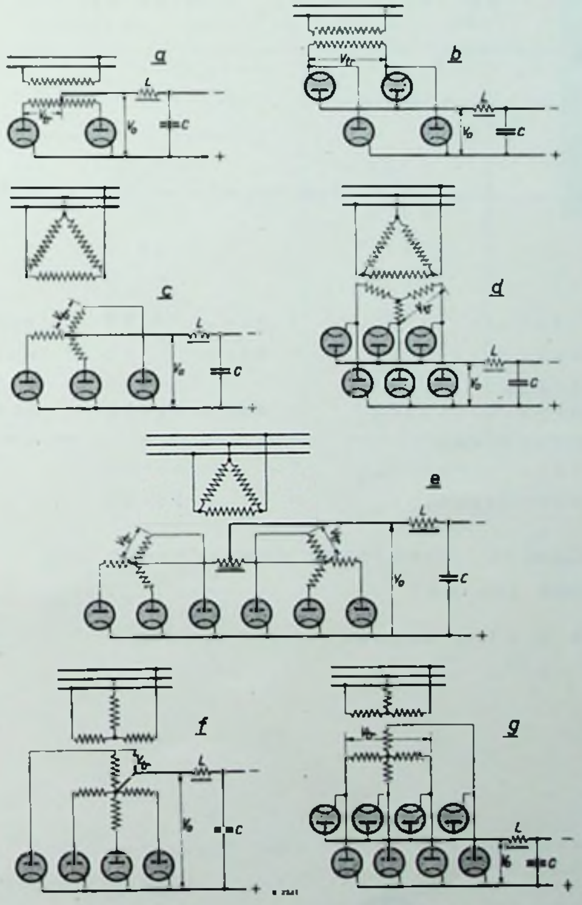
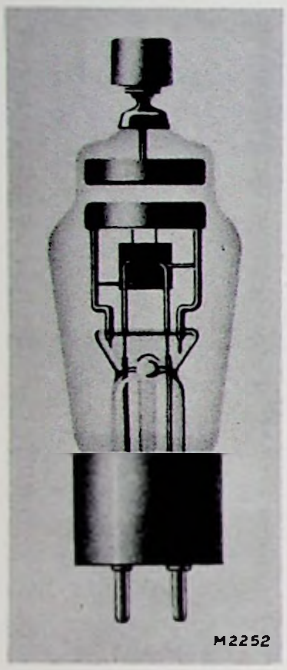


Fig. 104. Circuits of rectifying tubes.

Single-anode mercury vapour rectifying tube DCG 4/1000 G



The DCG 4/1000 G is a directly heated rectifying tube with a maximum inverse peak voltage of 10 kV. The maximum d.c. output current is 0.25 A.

Technical data

Filament: oxide coated
Heating: direct
Heater voltage........ V_f = 2.5 V [1])
Heater current........ I_f = 4.8 A
Waiting time.......... T_w = min. 30 s [2])

TYPICAL CHARACTERISTICS

Arc voltage (I_o = 0.25 A)........ V_{arc} = 12 V

Fig.105. Photograph of the DCG 4/1000 G.

LIMITING VALUES

Direct current...........	I_o	= max.	0.25	max.	0.5 A
Anode peak current.......	I_{ap}	= max.	1	max.	2 A
Inverse peak voltage (max. 150 c/s)........	$V_{inv\,p}$	= max.	10	max.	2 kV
Temperature of condensed mercury [3])............	t_{Hg}	=	25-60		25-70 °C
Ambient temperature [4])....	t_{amb}	=	15-40		15-50 °C

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS (in mm)

Base: medium 4 p with bayonet
Socket: 40218 - 03 [5])
Cap: 40619

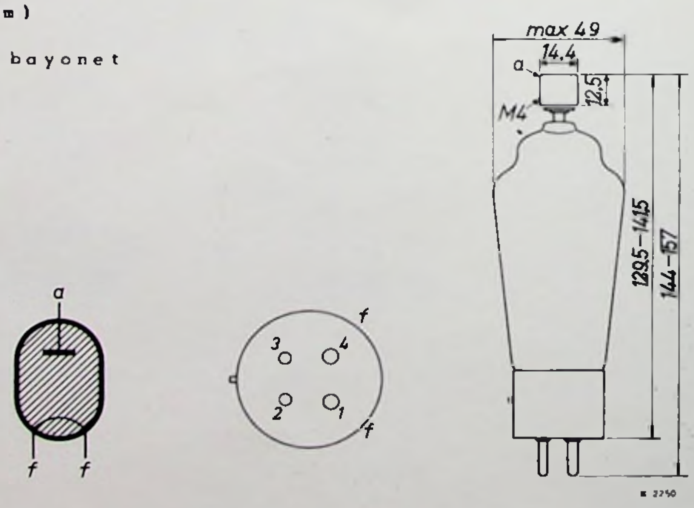


Fig.106. Electrode arrangement, electrode connections and maximum dimensions in mm of the DCG 4/1000 G.

For footnotes see next page.

MOUNTING POSITION:

Vertical with base down

NET WEIGHT: 80 g

SHIPPING WEIGHT: 125 g

OPERATING CONDITIONS [6]

Inverse peak voltage = 10 kV

Circuit (see Fig.104)	Secondary transformer voltage (without load) (kV_{rms})	Direct voltage (kV)	Direct current KA)	Output power (kW)
a	3.5	3.2	0.5	1.59
b	7.1	6.4	0.5	3.18
c	4.1	4.8	0.75	3.60
d	7.1	9.6	0.75	7.20
e	3.5	4.1	1.5	6.20
f	3.5	4.5	1	4.50
g	7.1	9.0	1	9.00

Inverse peak voltage = 2 kV

Circuit (see Fig.104)	Secondary transformer voltage (without load) (kV_{rms})	Direct voltage (kV)	Direct current (A)	Output power (kW)
a	0.71	0.63	1	0.63
b	1.41	1.27	1	1.27
c	0.82	0.96	1.5	1.43
d	1.41	1.91	1.5	2.87
e	0.71	0.83	3	2.48
f	0.71	0.90	2	1.80
g	1.41	1.80	2	3.60

---

[1] Phase shift of 90° ± 30° between V_a and V_f and use of a centre-tapped filament transformer is recommended.

[2] Waiting time after transport at least 30 minutes.

[3] When the equipment is started max. twice a day it is permitted to apply the high tension at a condensed mercury temperature of 20 °C.

[4] With convection cooling only.

[5] At voltages above 2 kV the socket must be insulated from the chassis.

[6] Transformer regulation and voltage drops in the tubes are neglected.

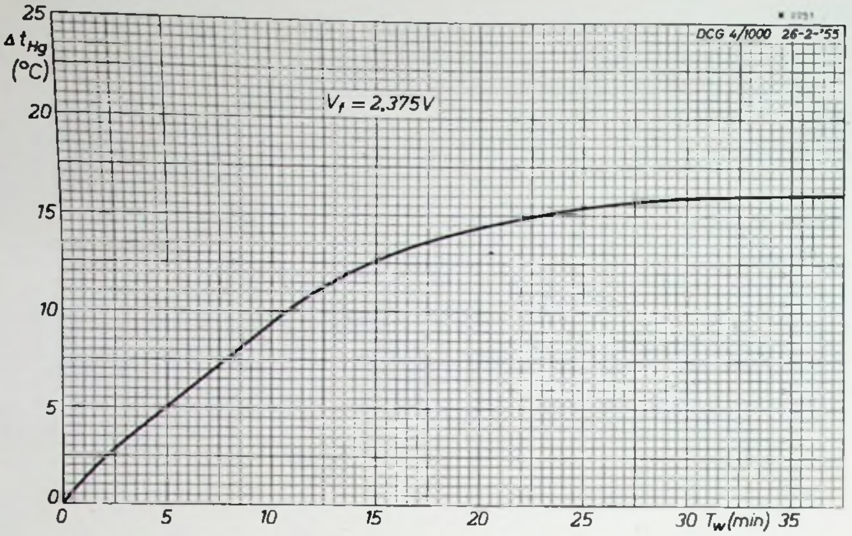


Fig.107. Rate of rise of condensed mercury temperature of the DCG 4/1000 G.

Single-anode xenon-filled rectifying tube DCX 4/1000

Fig.108.

The DCX 4/1000 is a xenon-filled rectifying tube with a maximum inverse peak voltage of 10 kV at a maximum d.c. output current of 0.25 A. Although the DCX 4/1000 differs physically from the DCG 4/1000 G, the electrical data of both tubes are roughly identical.

Technical data

Filament: oxide coated

Heating: direct

Heater voltage:....... V_f = 2.5 V 1)

Heater current:....... I_f = 5 A

Waiting time:......... T_w = min.10 sec.

TYPICAL CHARACTERISTICS

Arc voltage (I_o = 0.5 A)... V_{arc} = 12 V

LIMITING VALUES

Direct current..........	I_o	= max. 0.25 2)	max. 0.5 A 2)
Anode peak current......	I_{ap}	= max. 1	max. 2 A
Inverse peak voltage....	$V_{inv\,p}$	= max. 10	max. 5 kV
Frequency...............	f	= max. 150	max. 500 c/s
Ambient temperature.....	t_{amb}	= max.-55/+75	max.-55/+75 °C
Surge current...........	I_{surge}	= max. 20 3)	max. 20 A 3)

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS (in mm)

Base: medium 4 p with bayonet

Socket: 40218 - 03 4)

Top cap: medium

Cap: 40619

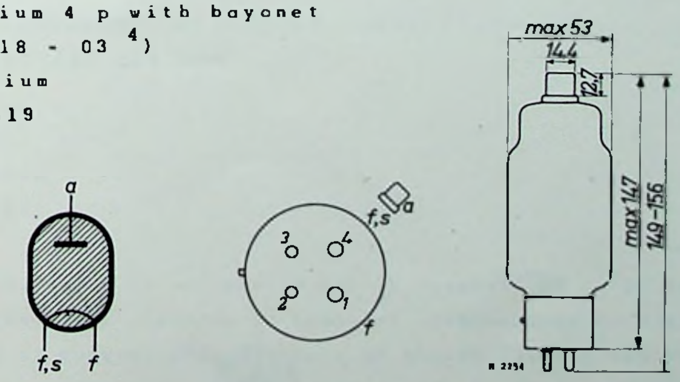


Fig.109.Electrode arrangement, electrode connections and maximum dimensions in mm of the DCX 4/1000.

For footnotes see next page.

MOUNTING POSITION: arbitrary

NET WEIGHT: 100 g

SHIPPING WEIGHT: 165 g

OPERATING CONDITIONS [5]

Inverse peak voltage = 10 kV

Circuit (see Fig.104)	Secondary transformer voltage (without load) (kV_{rms})	Direct voltage (kV)	Direct current (A)	Output power (kW)
a	3.5	3.2	0.5	1.6
b	7.1	6.4	0.5	3.2
c	4.1	4.8	0.75	3.6
d	7.1	9.6	0.75	7.2
e	3.5	4.1	1.5	6.2
f	3.5	4.5	1.0	4.5
g	7.1	9.0	1.0	9.0

Inverse peak voltage = 5 kV

Circuit (see Fig.104)	Secondary transformer voltage (without load (kV_{rms})	Direct voltage (kV)	Direct current (A)	Output power (kW)
a	1.8	1.6	1.0	1.6
b	3.5	3.2	1.0	3.2
c	2.0	2.4	1.5	3.6
d	3.5	4.8	1.5	7.2
e	1.8	2.1	3.0	6.2
f	1.8	2.2	2.0	4.5
g	3.5	4.5	2.0	9.0

---

[1] Phase shift of 90° ± 30° between V_a and V_f and use of a centre-tapped filament transformer is recommended. In order to obtain a low ignition voltage, the voltage of pin 4 (f,s) should be positive with respect to pin 1 at the moment of ignition.

[2] Averaging time = max. 15 sec.

[3] Max. duration 0.1 sec.

[4] At voltages above 2 kV the socket must be insulated from the chassis.

[5] Transformer regulation and voltage drops in the tubes are neglected.

Single-anode xenon-filled rectifying tube DCX 4/5000

The DCX 4/5000 is a xenon filled rectifying tube with a maximum inverse peak voltage of 10 kV and a maximum d.c. output current of 1.25 A.

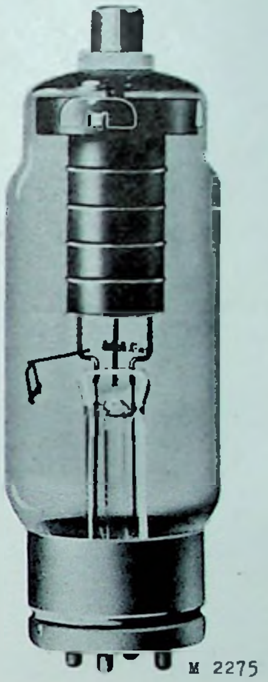


Fig.110.Photograph of the DCX 4/5000.

Technical data

Filament: oxide coated

Heating: direct

Heater voltage......... V_f = 5 V [1]

Heater current......... I_f = 7.1 A

Waiting time........... T_w = min. 30 sec

TYPICAL CHARACTERISTICS

Arc voltage (I_o = 1.25 A).... V_{arc} = 12 V

LIMITING VALUES

Direct current............................ I_o = max. 1.25 A [2]

Anode peak current........................ $I_{a\,p}$ = max. 5 A

Inverse peak voltage...................... $V_{inv\,p}$ = max. 10 kV

Frequency................................. f = max. 150 c/s

Ambient temperature....................... t_{amb} = -55/+70 °C

Surge current............................. I_{surge} = max. 50 A [3]

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS (in mm)

Base: Jumbo 4 p

Socket: 40408

Top cap: Medium

Cap: 40619

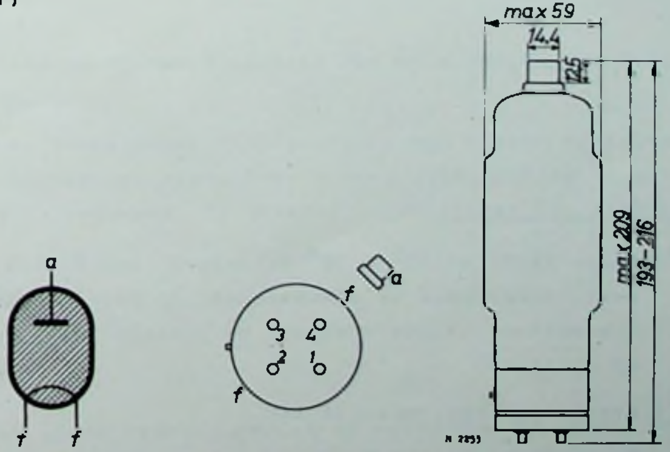


Fig.111.Electrode arrangement, electrode connections and maximum dimensions in mm of the DCX 4/5000.

For footnotes see next page.

MOUNTING POSITION: arbitrary

NET WEIGHT: 190 g

SHIPPING WEIGHT: 950 g

OPERATING CONDITIONS: 4)

Inverse peak voltage = 10 kV

Circuit (see Fig.104)	Secondary transformer voltage (without load) ($\mathrm{kV_{rms}}$)	Direct voltage (kV)	Direct current (A)	Output power (kW)
a	3.5	3.2	2.5	8
b	7.1	6.4	2.5	16
c	4.1	4.8	3.75	18
d	7.1	9.6	3.75	36
e	3.5	4.1	7.5	31
f	3.5	4.5	5.0	22.5
g	7.1	9.0	5.0	45

---

1) Phase shift of 90° ± 30° between V_a and V_f and use of a centre-tapped filament transformer is recommended. In order to obtain a low ignition voltage the voltage of pin 4 should be positive with respect to pin 2 at the moment of ignition.

2) Averaging time: max. 15 sec.

3) Maximum duration 0.1 sec.

4) Transformer regulation and voltage drops in the tubes are neglected.

Single-anode mercury vapour rectifying tube
DCG 5/5000 GS

The DCG 5/5000 GS is a mercury vapour filled rectifying tube with a maximum inverse peak voltage of 13 kV at a maximum d.c. output current of 1.5 A.

Fig.112. Photograph of the DCG 5/5000 GS.

Technical data

Filament: oxide coated

Heating: direct

Heater voltage.......... V_f = 5 V 1)

Heater current.......... I_f = 7 A

Waiting time............ T_w = min. 30 sec. 2)

TYPICAL CHARACTERISTICS

Arc voltage (I_o = 1.5 A)........ V_{arc} = 12 V

LIMITING VALUES

Inverse peak voltage 3)......	$V_{inv\,p}$	= max.	13	10	5	kV
Direct current 4)...........	I_o	= max.	1.5	1.5	1.75	A
Anode peak current..........	I_{ap}	= max.	6	6	7	A
Surge current 5)............	I_{surge}	= max.	40	40	40	A
Temperature of condensed mercury 6)...............	t_{Hg}	=	25-55	25-60	25-70	°C
Ambient temperature 7).......	t_{amb}	=	15-40	15-45	15-55	°C

---

1) Phase shift of 90° ± 30° between V_a and V_f and/or use of a tapped filament transformer are recommended.

2) For average conditions, i.e. temperature within limits and proper distribution of mercury. After transport and also after a long interruption of service a longer waiting time is required. In general, a period of 30 minutes will be sufficient.

3) f = max. 150 c/s.

4) Averaging time is max. 10 sec.

5) During max. 0.1 sec.

6) If the equipment is started up to twice a day it is permitted to apply the high tension at a condensed mercury temperature of 20 °C.

7) With natural cooling; average values.

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS (in mm) OF THE DCG 5/5000 GS

Base: Super Jumbo with bayonet

Socket: DCG 5/5000 GB: 40408, DCG 5/5000 GS: 40403
Cap: - 40619, - 40619

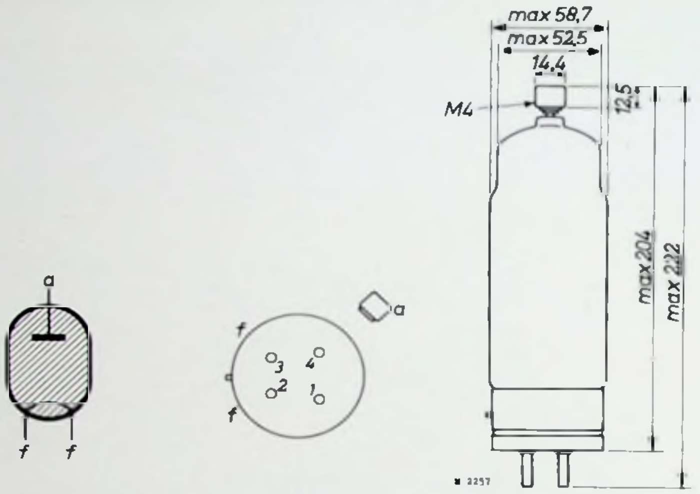


Fig.113.Electrode arrangement, electrode connections and maximum dimensions in mm of the DCG 5/500 GS.

MOUNTING POSITION:

vertical with base down

NET WEIGHT: 225 g

SHIPPING WEIGHT: 370 g

OPERATING CONDITIONS *)

Inverse peak voltage = 13 kV

Circuit (see Fig.104)	Secondary transformer voltage (without load) (kV_{rms})	Direct voltage (kV)	Direct current (A)	Output power (kV)
a	4.6	4.1	3	12.4
b	9.2	8.3	3	24.8
c	5.3	6.2	4.5	27.8
d	9.2	12.4	4.5	55.5
e	4.6	5.4	9	48.4
f	4.6	5.8	6	34.8
g	9.2	11.6	6	69.7

---

*) Transformer regulation and voltage drops in the tubes are neglected.

Inverse peak voltage = 5 kV

Circuit (see Fig.41)	Secondary transformer voltage (without load) (kV_{rms})	Direct voltage (kV)	Direct current (A)	Output power (kV)
a	1.75	1.6	3.5	5.6
b	3.5	3.2	3.5	11.1
c	2.0	2.4	5.25	12.6
d	3.5	4.8	5.25	25.1
e	1.75	2.1	10.5	21.7
f	1.75	2.25	7	15.7
g	3.5	4.5	7	31.5

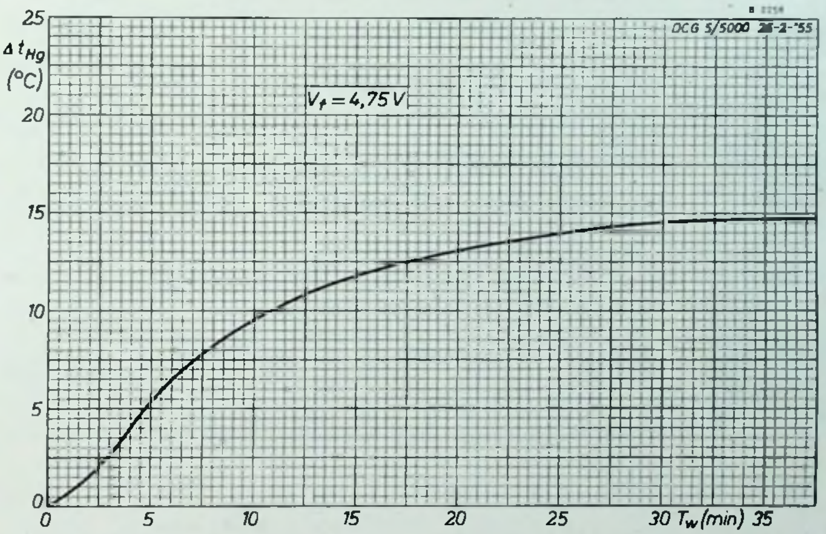
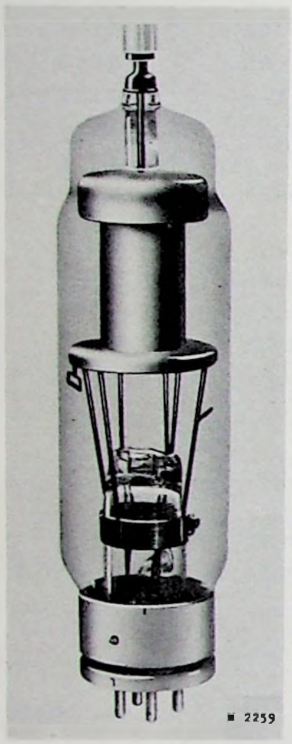


Fig.114.Rate of rise of condensed mercury temperature of the DCG 5/5000 GS.

Single-anode mercury vapour rectifying tube DCG 6/18



The mercury vapour rectifying tube DCG 6/18 has a maximum inverse peak voltage of 15 kV: at a maximum d.c. output current of 3 A.

Technical data

Filament: oxide coated

Heating: direct

Heater voltage......... V_f = 5 V [1]

Heater current......... I_f = 11.5 A

Waiting time........... T_w = min. 60 sec. [2]

TYPICAL CHARACTERISTICS

Arc voltage (I_o = 3 A)............ V_{arc} = 12 V

Equilibrium condensed mercury temperature rise over ambient.......
- no load: 19 °C
- full load: 21 °C

Fig.115. Photograph of the DCG 6/18.

LIMITING VALUES

Frequency..................	f	= max. 150 c/s		
Inverse peak voltage........	$V_{inv\,p}$	= max. 15	2.5	kV
Direct current [3]...........	I_o	= max. 3	5	A
Anode peak current..........	I_{ap}	= max. 12	20	A
Surge current [4]............	I_{surge}	= max. 120	200	A

Inverse peak voltage..............	$V_{inv\,p}$	= 15	10	2.5	kV
Temperature of condensed mercury [5]	t_{Hg}	= 25-55	25-60	25-75	°C
Ambient temperature [6]............	t_{amb}	= 15-35	15-40	15-55	°C

---

[1] A phase shift of 90° ± 30° between V_a and V_f and the use of a centre tapped filament transformer are recommended.

[2] For average conditions, i.e. temperature within limits and proper distribution of mercury. After transport and also after a long interruption of service a longer waiting time is required. In general, a period of 30 minutes will be sufficient.

[3] Averaging time is max. 10 sec.

[4] Duration max. 0.1 sec.

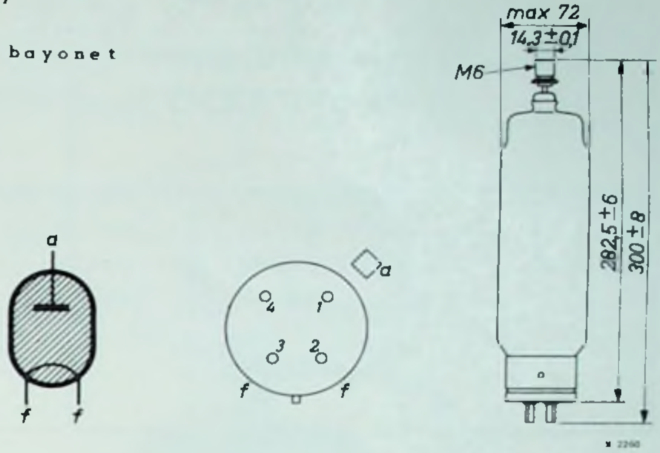
[5] If the equipment is started not more than twice a day, it is permitted to apply high tension at a condensed mercury temperature of 20 °C.

[6] With natural cooling; approximate values.

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS (in mm)

Base: super Jumbo with bayonet
Socket: 40403
Cap: medium

Fig.116. Electrode arrangement, electrode connections and maximum dimensions in mm of the DCG 6/18.



MOUNTING POSITION

vertical with base down

NET WEIGHT: 450 g

SHIPPING WEMGHT: 1650 g

MAXIMUM OPERATING CONDITIONS [1]

Inverse peak voltage = 15 kV

Circuit (see Fig.104)	Secondary transformer voltage (without load) (kV$_{rms}$)	Direct voltage (kV)	Direct current (A)	Output power (kW)
a	5.3	4.8	6	28.8
b	10.6	9.6	6	57.6
c	6.1	7.2	9	64.8
d	10.6	14.4	9	130
e	5.3	6.2	18	112
f	5.3	6.7	12	80.4
g	10.6	13.5	12	162

Inverse peak voltage = 2.5 kV

Circuit (see Fig.104)	Secondary transformer voltage (without load) (kV$_{rms}$)	Direct voltage (kV)	Direct current (A)	Output power (kW)
a	0.88	0.79	10	7.9
b	1.76	1.58	10	15.8
c	1.02	1.19	15	17.9
d	1.76	2.38	15	35.8
e	0.88	1.03	30	30.9
f	0.88	1.13	20	22.6
g	1.76	2.26	20	45.2

---

[1] Transformer regulation and voltage drops in the tubes are neglected.

TYPICAL OPERATING CONDITIONS

Inverse peak voltage = max. 15 kV [1])

Circuit (see Fig.41)	Secondary transformer voltage (without load) (kV_{rms})	Direct voltage[2]) (kV)	Direct current (A)	Output power (kW)
a	4.8	4.0	6	24
b	9.6	8.0	6	48
c	5.55	6.0	9	54
d	9.6	12.0	9	108
e	4.8	5.15	18	93
f	4.8	5.6	12	67
g	9.6	11.2	12	134

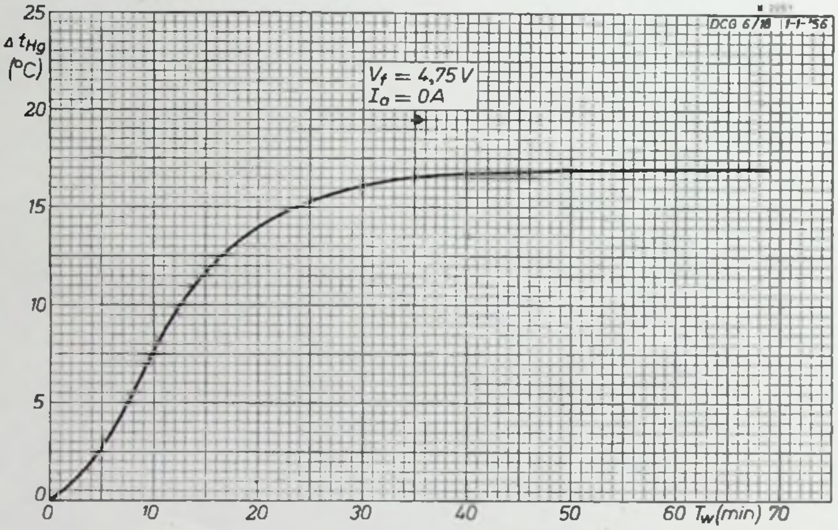


Fig.117. Rate of rise of condensed mercury temperature of the tube DCG 6/18.

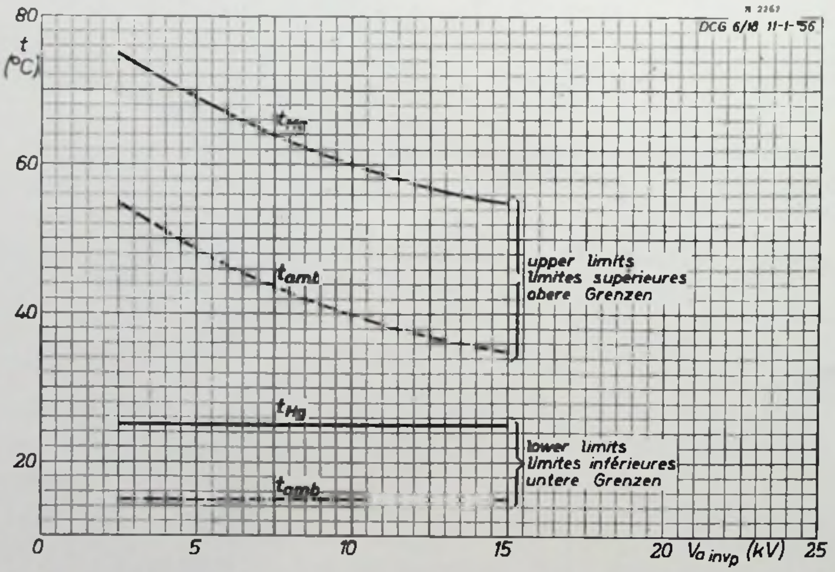


Fig.118. Temperature limits of the DCG 6/18 as functions of the inverse peak voltage.

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[1]) This value corresponds to a nominal peak inverse anode voltage of 13.6 kV, allowing a mains voltage voltage fluctuation of ± 10%.

[2]) Tube voltage drop and losses in transformer, filter etc., amounting to 8% of the output voltage across the load, have already been deducted.

Grid-controlled mercury vapour rectifying tubes
DCG 7/100 and DCG 7/100 B

The DCG 7/100 and DCG 7/100 B are grid controlled rectifying tubes with a maximum inverse peak voltage of 15 kV at average current of 10 A (continuous operation). When the tubes are used for intermittent operation, the direct current may be rise to 15 A.

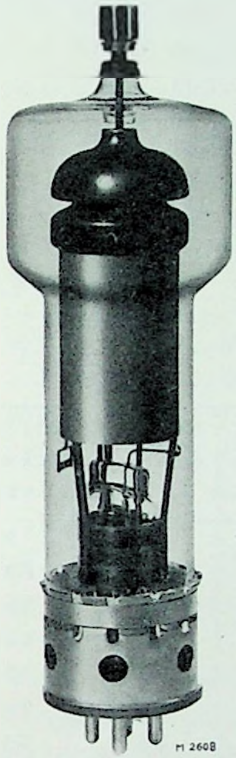

Fig. 119. Photograph of the DCG 7/100.

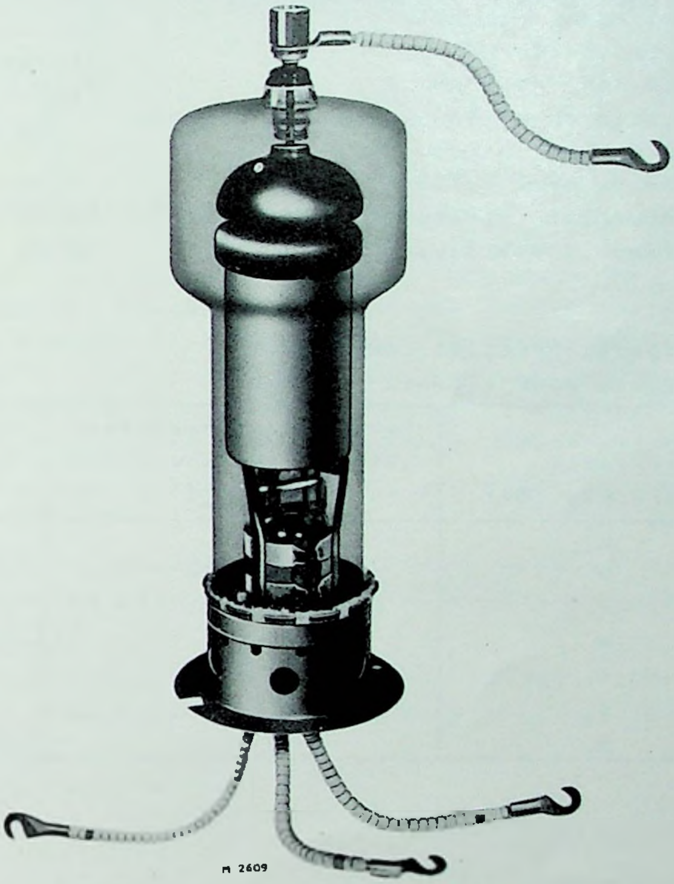

Fig. 120. Photograph of the DCG 7/100 B.

Both tubes have the same electrical and mechanical data except for the base connections, the DCG 7/100 being provided with pins whereas the DCG 7/100 B has flying lead base connections.

Owing to the possibility of control by means of the grid voltage, the tubes are very suitable for use in stabilized power supplies whilst they can also be used for protection purposes [1]).

TECHNICAL DATA

Cathode: oxide coated

Heating: indirect, k connected to f

Heater voltage	V_f = 5 V
Heater current	I_f = max. 20 A
Waiting time	T_w = min. 10 min. [2])

See notes on page 133.

TYPICAL CHARACTERISTICS

Arc voltage (I_b = 15 A)		V_{arc} = 12 V
Equilibrium condensed mercury temperature rise over ambient	no load	27°C
	full load	30°C

LIMITING VALUES

Inverse peak voltage 3)	V_a	= max. 15 kV
Forward peak voltage	$V_{a\ fwd}$	= max. 15 kV
Direct current	I_o	= max. 10 A
(averaging time max. 10 sec)	I_o	= max. 15 A 4)
Anode peak current	I_{ap}	= max. 45 A
Surge current	I_{surge}	= max. 600 A 5)
Grid peak voltage	V_{gp}	= max. 600 V
Resistance between grid and cathode	R_g	= max. 20 kΩ

- -

Inverse peak voltage	15	10 kV
Temperature of condensed mercury 6)	25-60	25-65 °C
Ambient temperature 7)	10-30	10-35 °C

MAXIMUM OPERATING CONDITIONS 8)

Inverse peak voltage = 15 kV

Circuit (see Fig.104)	Secondary transformer voltage (without load) (kV_{rms})	Direct voltage (kV)	Direct current (A)	Output power (kW)
a	5.3	4.8	20	96
b	10.6	9.6	20	192
c	6.1	7.2	30	216
d	10.6	14.4	30	432
e	5.3	6.2	60	372
f	5.3	6.7	40	268
g	10.6	13.5	40	540

TYPICAL OPERATING CONDITIONS

Inverse peak voltage = max. 15 kV 9)

Circuit (see Fig.104)	Secondary transformer voltage (without load) (kV_{rms})	Direct voltage (kV) 10)	Direct current (A)	Output power (kW)
a	4.8	4	20	80
b	9.6	8	20	160
c	5.55	6	30	180
d	9.6	12	30	360
e	4.8	5.15	60	309
f	4.8	5.6	40	224
g	9.6	11.2	40	448

See notes on opposite page

NOTES

1) See: Control device for H.T. supply units of transmitters.

2) For average conditions, i.e. temperatures within limits and proper distribution of mercury.
After transport and also after a long interruption of service a longer waiting time is required before anode voltage is applied to ensure proper distribution of the mercury. In general, a time of 45 minutes will be sufficient. Moreover, 10 minutes after having switched on the heater voltage, preheating of the anode must be started by connecting the anode to a supply voltage V_b=max.500 V via a resistor limiting the current I_o to 6 A.

3) f = max. 150 c/s.

4) For intermittent operation.

5) Maximum duration 0.1 sec.

6) If the equipment is started not more than twice daily, it is permitted to apply high tension at a condensed-mercury temperature of 20 °C.

7) Approximate values; with natural cooling. The tube can be operated at higher ambient temperatures than the stated maxima, when the difference between the ambient and the condensed mercury temperature (30 °C with natural cooling) is reduced by an air flow directed at the bulb just above the base. A reduction to less than 10 °C can easily be obtained with a simple airjet.

8) Transformer regulation and voltage drops in the tubes are neglected.

9) This value corresponds to a nominal peak inverse anode voltage of 13.6 kV,allowance being made for a mains voltage fluctuation of ± 10 %.

10) Tube voltage drop and losses in transformer, filter, etc. , amounting to 8 % of the output voltage across the load, have already been deducted.

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS (in mm)

Socket: 40409
Cap: 40620

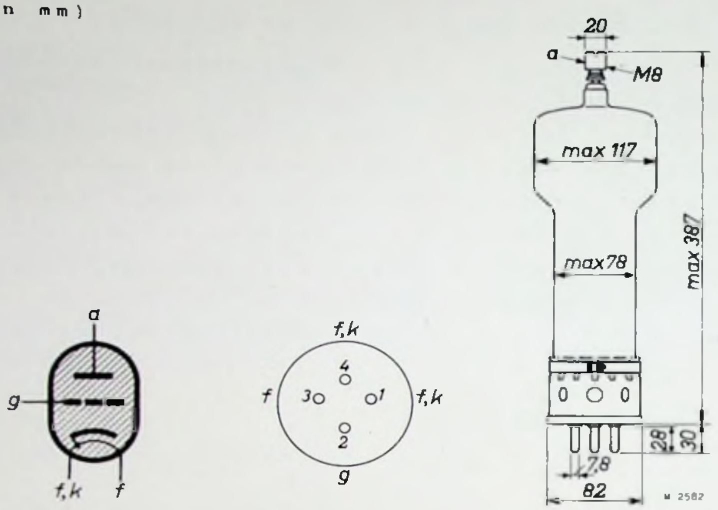

Fig.121a. DCG 7/100.

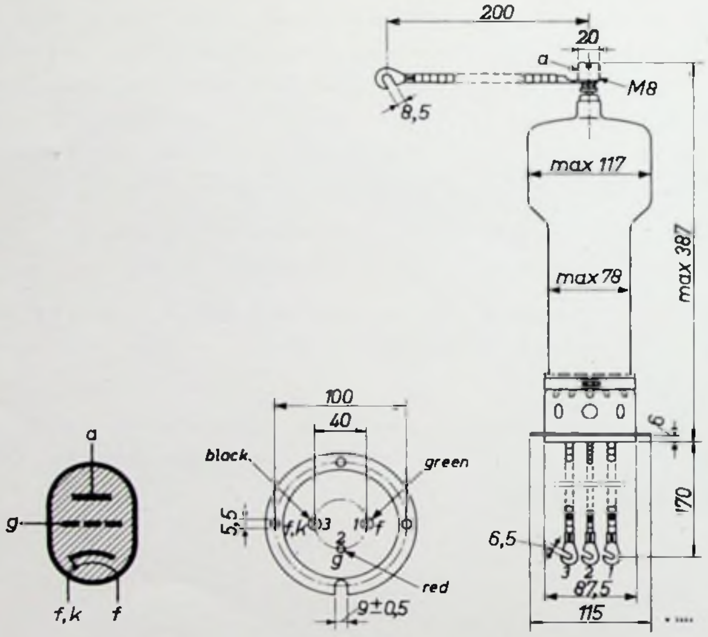

Fig.121b. DCG 7/100 B.

MOUNTING POSITION

vertical with anode terminal up

NET WEIGHT: 1200 g

SHIPPING WEIGHT: 3760 g

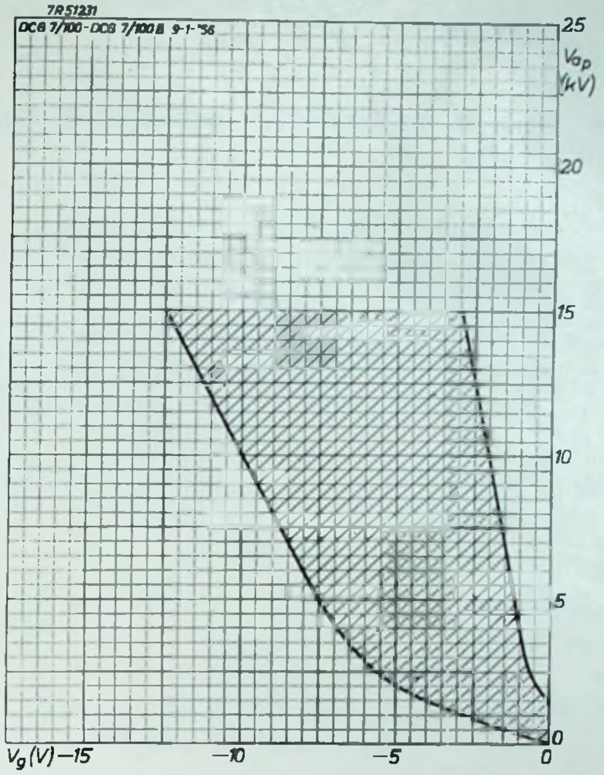

Fig. 122. Control characteristics of the DCG 7/100 and DCG 7/100 B.

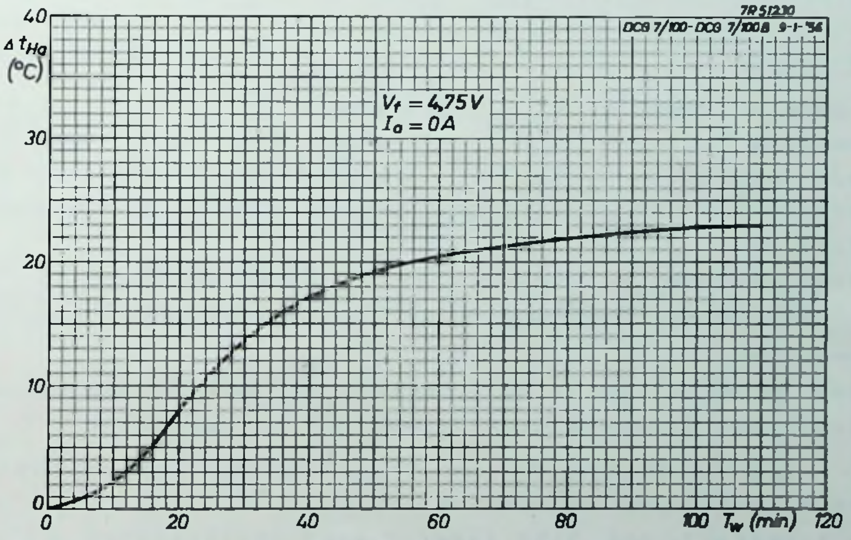

Fig. 123. Rate of rise of condensed-mercury temperature of the DCG 7/100 and DCG 7/100 B.

Single-anode mercury vapour rectifying tube DCG 9/20

The DCG 9/20 is a mercury vapour rectifying tube with a maximum inverse peak voltage of 21 kV at a direct current of maximum 2.5 A.

The DCG 9/20 is provided with an external cap, attached to the anode terminal for causing the mercury vapour to condense in the lower part of the tube.

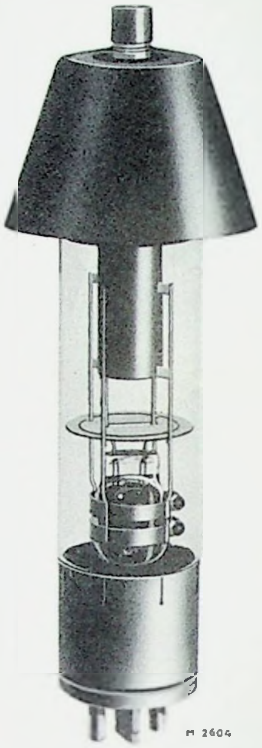

Fig.124. Photograph of the DCG 9/20.

TECHNICAL DATA

Filament: oxide coated
Heating: direct

Heater voltage	V_f =	5 V 1)
Heater current	I_f =	12.5 A
Waiting time	T_w =	min. 90 sec 2)

TYPICAL CHARACTERISTICS

De - ionization time	T_{dion} <	500 μsec
Ionization time	T_{ion} <	10 μsec
Arc voltage (I_o = 2.5 A)	V_{arc} =	12 V

LIMITING VALUES

Inverse peak voltage 3)	$V_{a\ inv\ p}$	= max.	21	15	10	kV
Direct current 4)	I_o	= max.	2.5	2.5	2.5	A
Anode peak current	I_{ap}	= max.	10	10	10	A
Surge current 5)	I_{surge}	= max.	100	100	100	A
Temperature of condensed mercury 6)	t_{Hg}	=	25-45	25-50	25-60	°C
Ambient temperature 7)	$t_{amb.}$	=	15-30	15-35	15-45	°C

---

1) A phase shift of 90° ± 30° between V_a and V_f and/or use of a centre-tapped filament transformer are recommended.

2) For average conditions, i.e. temperature within limits and proper distribution of mercury.
After transport and also after a long interruption of service a longer waiting time is required before anode voltage is applied to ensure proper distribution of the mercury. In general, a time of 60 minutes will be sufficient.

3) f = max. 150 c/s.

4) Averaging time = max. 30 sec.

5) Maximum duration: 0.1 sec.

6) If the equipment is started not more than twice daily it is permitted to apply high tension at a condensed-mercury temperature of 20 °C.

7) With natural cooling, approximate values.

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS (in mm)

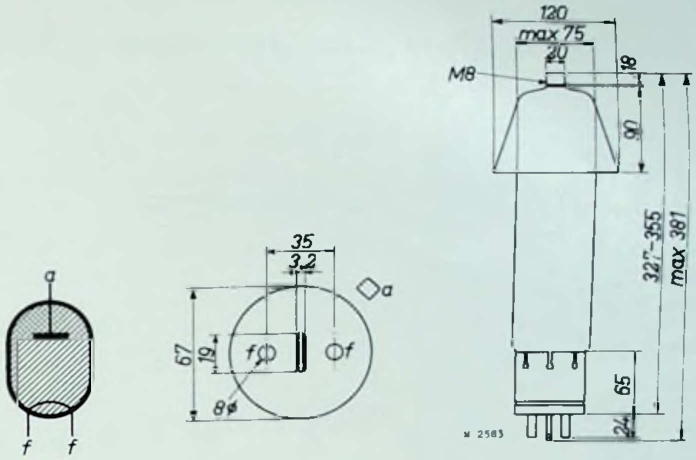

Fig.125.

Socket	40209
Top cap	40620
Anode cap	40616

This cap must always be mounted on the tube, consequently also during preheating.

MOUNTING POSITION

vertical with base down

NET WEIGHT: 0.75 kg

SHIPPING WEIGHT: 2.3 kg

OPERATING CONDITIONS [1]

Inverse peak voltage = 21 kV

Circuit (see Fig.104)	Secondary transformer voltage (without load) (kV_{rms})	Direct voltage (kV)	Direct current (A)	Output power (kW)
a	7.4	6.7	5	33.5
b	14.8	13.4	5	67
c	8.6	10	7.5	75
d	14.8	20	7.5	150
e	7.4	8.7	15	130
f	7.4	9.5	10	95
g	14.8	19	10	190

---

[1] Transformer regulation and voltage drops in the tubes are neglected.

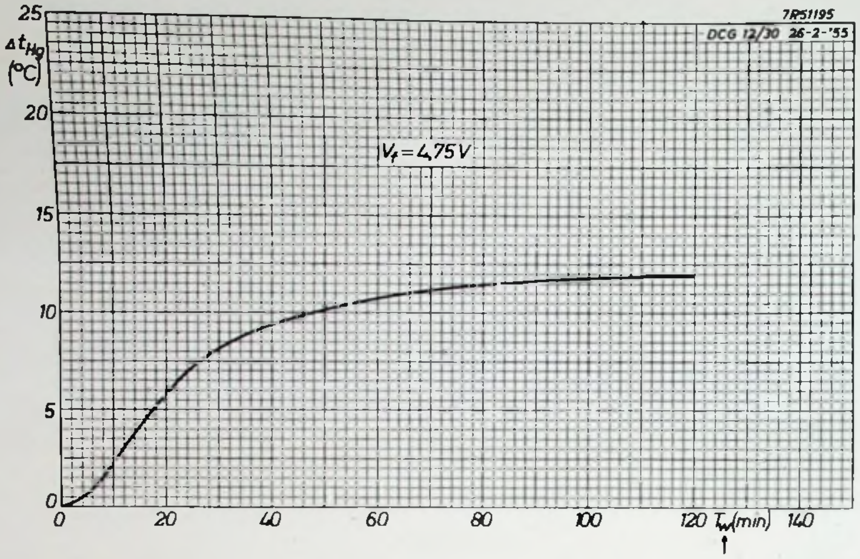

Fig.126. Rate of rise of condensed-mercury temperature of the DCG 9/20.

Grid-controlled mercury vapour rectifying tube DCG 12/30

The DCG 12/30 is a grid-controlled mercury vapour rectifying tube with a maximum inverse peak voltage of 27 kV at a direct current of 2.5 A.

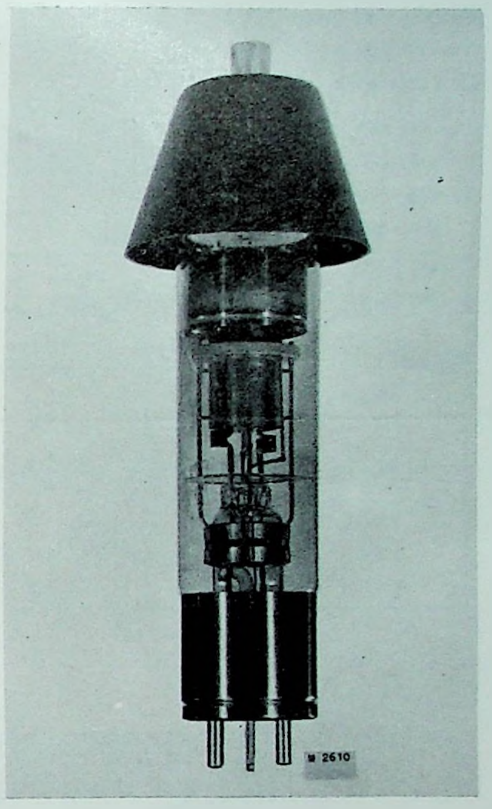

Fig. 127. Photograph of the DCG 12/30.

TECHNICAL DATA

Filament: oxide coated
Heating: direct

Heater voltage	V_f = 5 V [1]
Heater current	I_f = 13.5 A
Waiting time	T_w = min. 90 sec [2]

CAPACITANCES

C_{ag} = 4 pF
C_g = 13 pF

TYPICAL CHARACTERISTICS

De-ionization time	T_{dion}	< 500 μsec
Ionization time	T_{ion}	< 10 μsec
Arc voltage (I_o = 2.5 A)	V_{arc}	= 12 V

---

[1] A phase shift of 90° ± 30° between V_a and V_f and/or use of a centre-tapped filament transformer are recommended.

[2] For average conditions i.e. temperature within limits and proper distribution of mercury (see Fig. 129).
After transport and also after a long interruption of service a longer waiting time is required before anode voltage is applied to ensure proper distribution of the mercury. In general, a time of 60 minutes will be sufficient.

LIMITING VALUES

Inverse peak voltage	$V_{a\ inv\ p}$	= max.	27 kV [1]
Anode peak voltage	V_{ap}	= max.	27 kV
Direct current	I_o	= max.	2.5 A [2]
Anode peak current	I_{ap}	= max.	10 A
Surge current	I_{surge}	= max.	100 A [3]
Grid voltage	$-V_g$	= max.	300 V [4]
Average grid current	I_g	= max.	25 mA [2]
Grid peak current	I_{gp}	= max.	125 mA

Inverse peak voltage	$V_{a\ inv\ p}$	=	27	21	15	13	10 kV
Temperature of condensed mercury[5]	t_{Hg}	=	30-40	30-45	25-50	25-55	25-60 °C
Ambient temperature [6]	$t_{amb.}$	=	20-25	20-30	15-35	15-40	15-45 °C

When the anode voltage V_a is negative, the grid voltage must never be positive.

ELECTRODE ARRANGEMENT, ELECTRODE CONNECTIONS AND MAXIMUM DIMENSIONS (in mm)

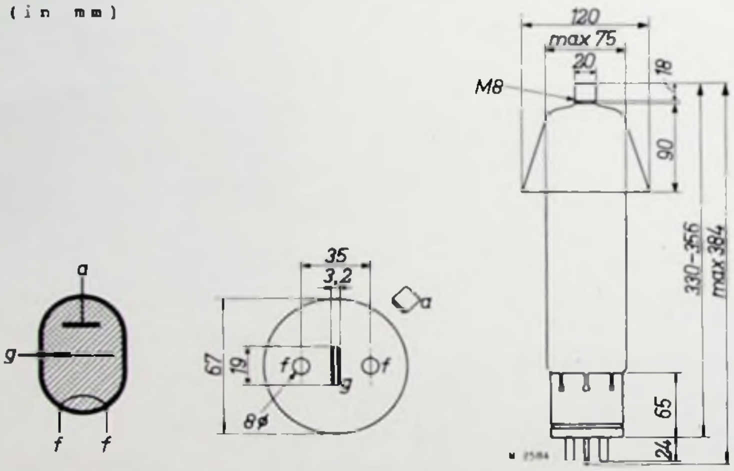

Fig.128.

Socket	40209
Top cap	40620
Anode cap	40616

This cap must always be mounted on the tube, consequently also during preheating.

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[1] f = max. 150 c/s.

[2] Averaging time = max. 30 sec.

[3] Max. duration: 0.1 sec.

[4] Direct voltage; before conduction.

[5] If the equipment is started not more than twice daily it is permitted to apply high tension at a condensed mercury temperature which is 5 °C less than the values mentioned in the table.

[6] With natural cooling; approximate values.

MOUNTING POSITION

vertical with base down

NET WEIGHT: 0.75 kg

SHIPPING WEIGHT: 2.3 kg

OPERATING CONDITIONS [1]

Grid voltage ($V_{a\ inv\ p}$ = 27 kV) V_g = -100 V
($V_{a\ inv\ p}$ = 10 kV) V_g = -50 V
Grid current I_g = 2 mA

Inverse peak voltage = 27 kV

Circuit (see Fig.104)	Secondary transformer voltage (kV_{eff})	Direct voltage (kV)	Direct current (A)	Output power (kW)
a	9.5	8.6	5	43
b	19.1	17.2	5	86
c	11	12.9	7.5	97
d	19.1	25.8	7.5	194
e	9.5	11.2	15	168
f	9.5	12.1	10	121
g	19.1	24.3	10	243

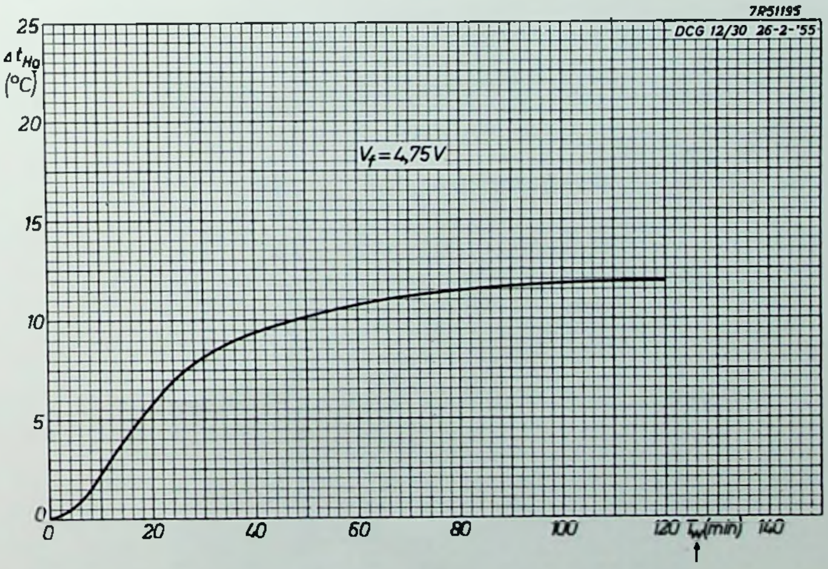

Fig.129. Rate of rise of condensed-mercury temperature of the DCG 12/30.

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[1] Transformer regulation and voltage drops in the tubes are neglected.

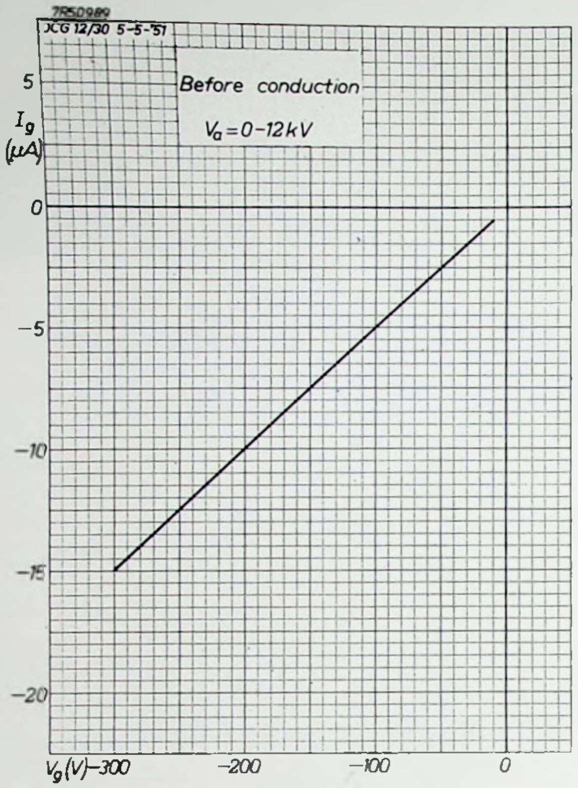

Fig.130. Grid current of the DCG 12/30 as a function of the grid voltage before conduction.

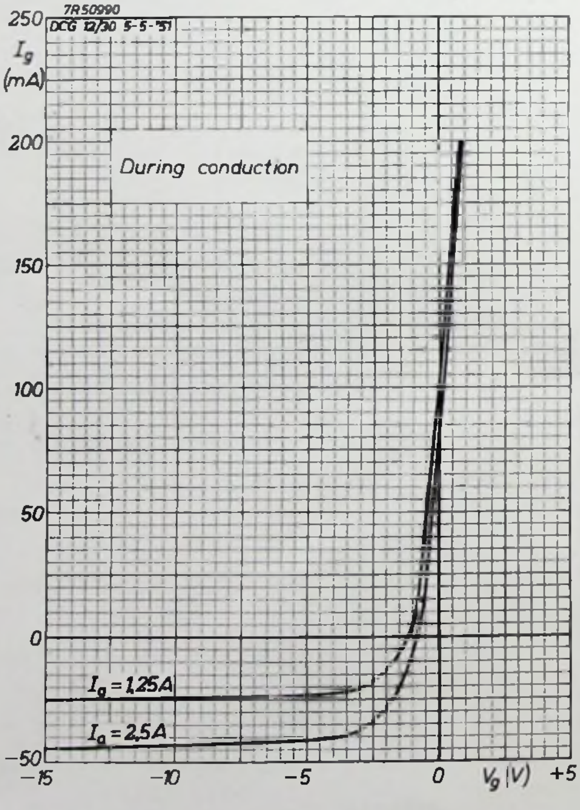

Fig.131. Grid current of the DCG 12/30 as a function of the grid voltage during conduction.