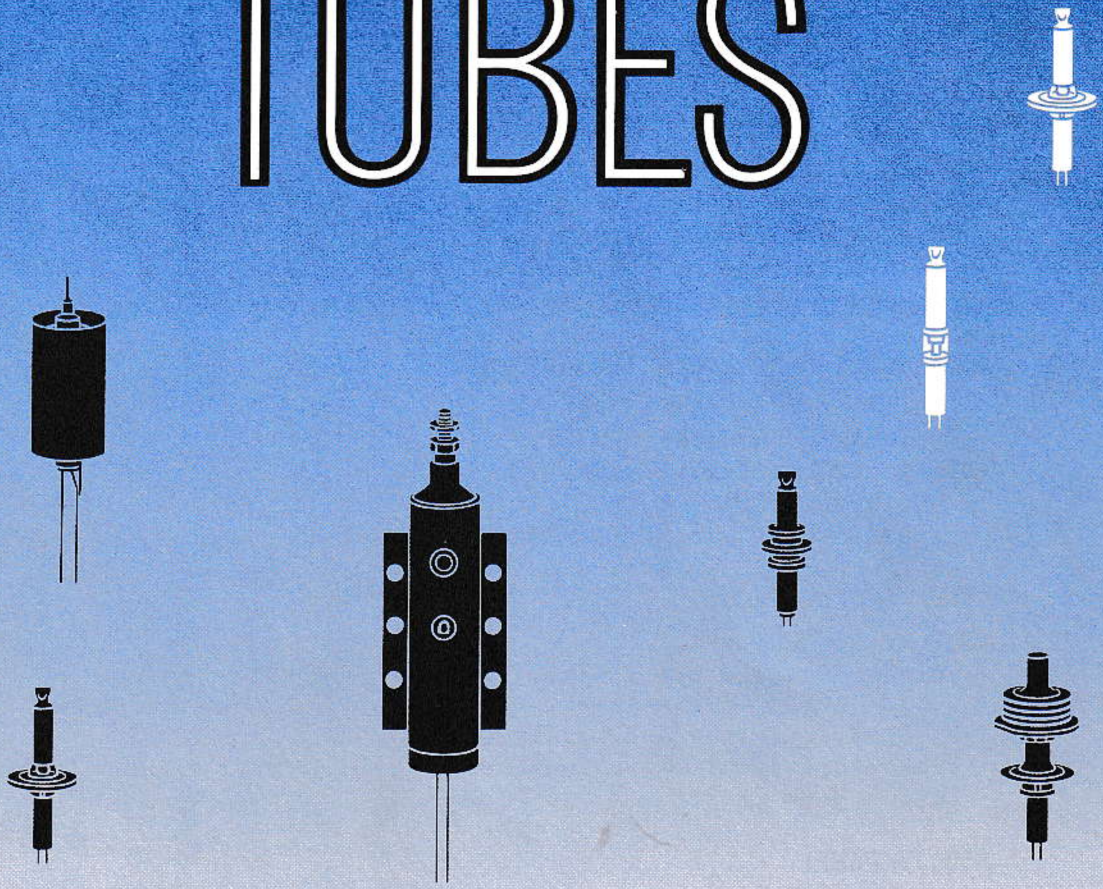
PRICE 50 CENT

RCA PENCIL TUBES



RADIO CORPORATION OF AMERICA
ELECTRON TUBE DIVISION
HARRISON, N. J.

FORM NO. 1CE-2

Foreword: *This publication has been prepared to assist those who work with pencil tubes and circuits. It includes information on the design features of pencil tubes, their application to systems, and electrical and mechanical circuit-design considerations. Tube data for commercially available types are also included.*

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RCA
PENCIL TUBES

Pencil tubes, designed to provide moderate power outputs in ultra-high-frequency applications, bridge the frequency gap between conventional receiving tubes and transit-time devices. The first commercial pencil tube, shown in Fig. 1, was introduced in 1949; since that time, many additional types have been brought out to supply growing industrial and military demands.

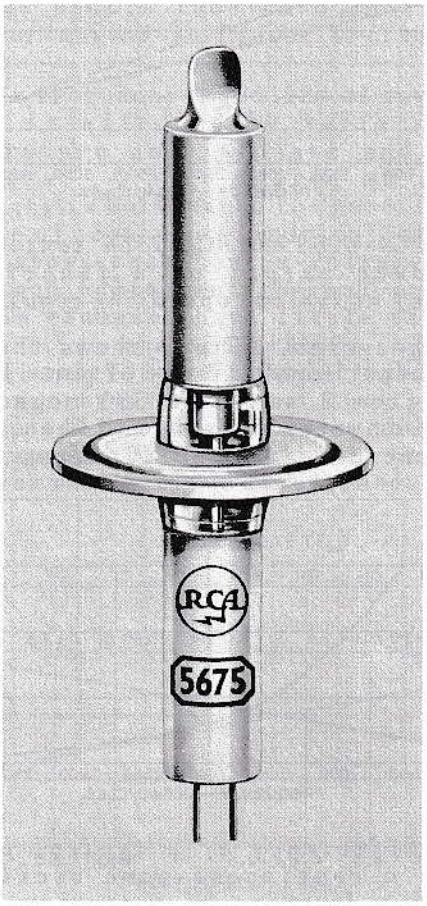


Fig. 1 - Pencil tube RCA-5675 medium-mu triode.

DESIGN FEATURES

A number of unique electrical and mechanical design features make the pencil tube especially suited for efficient and reliable microwave service.

Electrical Design

Pencil tubes are designed to provide the low inductances, low interelectrode capacitances, and close element spacings

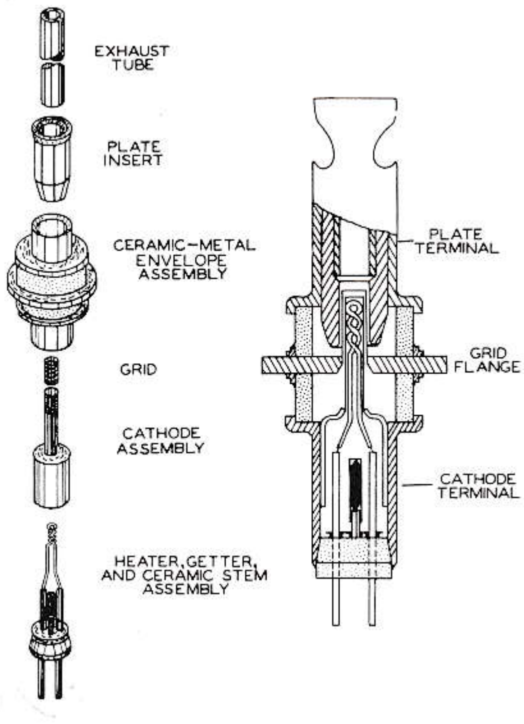


Fig. 2 - Basic construction of the pencil tube.

essential to efficient high-frequency operation. As shown in Fig. 2, the closely spaced coaxial electrodes are integrally connected to terminals which comprise the body of the tube; external connections are made directly to these terminals. The combination of low inductances and low capacitances increases the self-resonant frequencies of the tube and extends its useful frequency range. These low values also permit efficient use of shunt tuning devices and minimize regeneration.

Close spacing of the tube elements reduces transit-time effects at high frequencies. In addition, the cylindrical construction of the pencil tube offers significant improvements in cathode warm-up time and stability over planar designs because the cathode completely encloses the heater. In general, heater power per emissive cathode area is three times more efficient than in planar-cathode tubes. This efficient use of heater power effectively reduces the time required for a tube to reach stable operation after the application of all voltages.

Mechanical Design

The structure of RCA pencil tubes, capable of withstanding high-impact shocks and high-force vibrations, is inherently rugged. In addition, the effect of thermal variation on electrical characteristics is reduced to a minimum because the longitudinal expansion of the cathode has no effect on electrode spacing. Moreover, the radial expansions of the electrodes are all in the same direction, and thus tend to maintain relative spacing and improve stability with respect to heater-voltage fluctuations.

The size and shape of the pencil tube make it adaptable to most microwave circuitry. Although the cylindrical elements are designed to operate in highly efficient coaxial cavities, they may also be readily used in lumped-constant circuits.

APPLICATION OF PENCIL TUBES TO SYSTEMS

Pencil tubes are recommended for application in any microwave system required to generate or amplify microwave signals at frequencies up to 4000 megacycles and at power levels up to 10 watts cw or 1.5 kilowatts peak. The tubes are particularly useful when size, weight, efficiency, reliability, cost and environmental performance are of importance.

Oscillators

The microwave oscillator is an essential component in all microwave systems. The requirements of such an oscillator may be vastly different from one application to another. For example, in one application a pencil tube may be used in a microwave receiver as a local oscillator to provide high stability and long life at moderate power output. In a widely different application, a pencil tube may be used in a beacon radar or transponder designed for high pulse-power output at short pulse lengths.

CW Oscillator

As a continuous-wave oscillator, the pencil tube is capable of generating microwave power at frequencies up to 4000 megacycles. Fig. 3 shows that the power-output capabilities of pencil tubes extend from 8 watts at 500 megacycles to 100 milliwatts at S-band. When pencil tubes are used as oscillators, their highly efficient operation, shown in Fig. 4, and their inherent stability are important features.

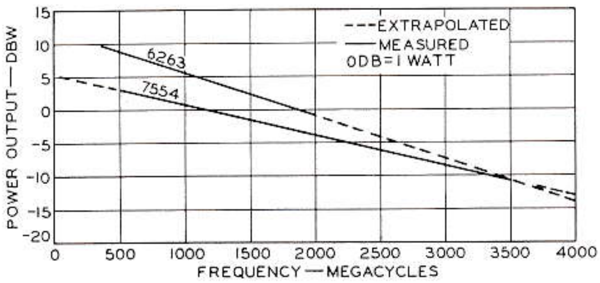


Fig. 3 - RCA-6263 and RCA-7554 continuous-wave power output as a function of frequency at typical operating conditions.

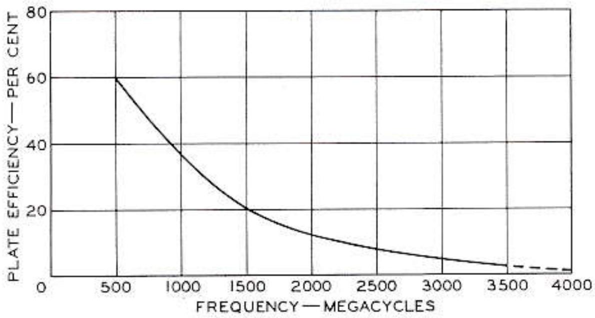


Fig. 4 - Efficiency of a typical pencil tube as a continuous-wave oscillator as a function of frequency.

Pencil tubes are used as oscillators in the following typical applications: local oscillators in microwave receivers, microwave-signal generators, microwavesweep generators, pump oscillators for parametric devices, and radiosonde transmitters.

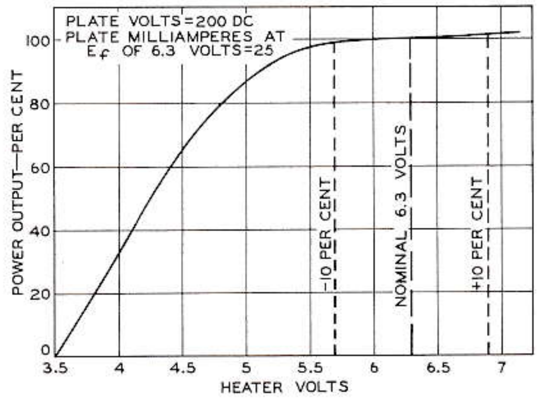


Fig.5 - Oscillator power output of a typical pencil tube as a function of variations in heater voltage.

The frequency stability of any oscillator is affected by variations in temperature and in plate and heater voltages. A high degree of thermal stability is built into the pencil tube by the use of coaxial cylindrical elements. Fig.5 shows that heater-voltage variations and consequent thermal expansion of tube elements have little effect on power-output characteristics. The frequency stability of a pencil tube operating in a typical L-band cavity during warm-up can be illustrated by the following example: At t = 0, heater and plate voltages were applied simultaneously; the

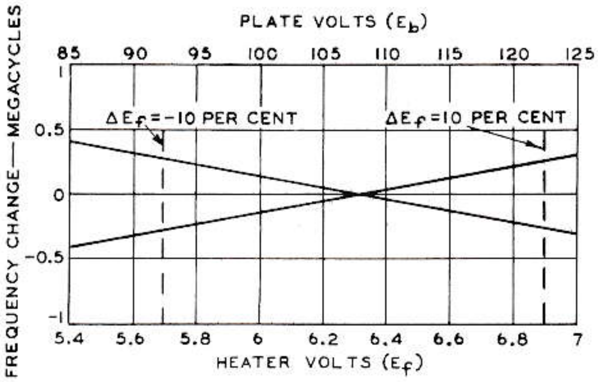


Fig.6 - Change in oscillator frequency of a typical pencil tube as a function of heater voltage and plate voltage; oscillator at L-band.

L-band frequency was then measured at t = 10 seconds and at t = 60 seconds. The total frequency change under these conditions was 70 kilocycles. Long-term stability better than 0.1 per cent may be obtained in properly designed oscillator circuits throughout the useful life of the tube.

The pencil-tube oscillator is much less susceptible to element-voltage changes that produce frequency modulation. Fig.6 shows the frequency shift of a typical pencil tube due to plate-voltage and heater-voltage changes. It is important to recognize, however, that circuit design is a controlling factor of frequency stability with respect to voltage changes.

Pulsed Oscillators

Pencil tubes may be pulsed by the application of positive pulses to the plate. When the tube is biased beyond cutoff, pulse operation is also achieved

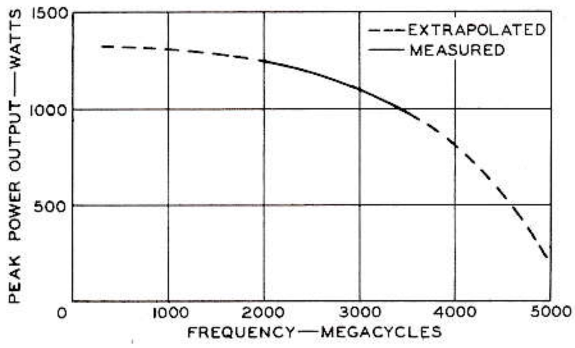


Fig.7 - RCA-5893 peak-power output of plate-pulsed oscillator as a function of frequency at typical operating conditions.

by application of positive pulses to the grid or negative pulses to the cathode. Because the cylindrical cathode has high emission capabilities at low heater powers, high over-all efficiency is obtained during pulse operation. Typical applications in which pencil tubes are used as pulsed oscillators include S-band beacon radars, transponders, and telemetering transmitters. As a plate-pulsed oscillator, the pencil tube is capable of peak power outputs in excess of 1000 watts at S-band frequencies, as shown in Fig.7. The power capabilities of two integral tube-and-cavity units are shown in Fig.8. Both of these units were optimized at a center frequency of 2900 megacycles. Tube-cavity units covering the complete L- and S-band frequency spectrum are also available.

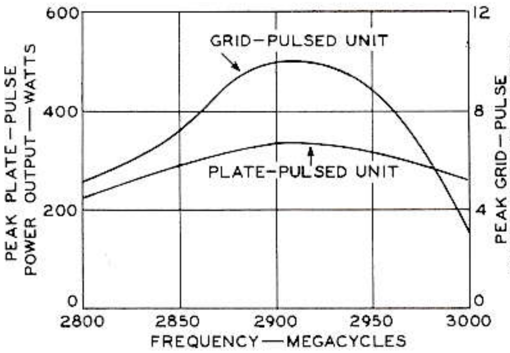


Fig.8 - Tuning range of plate-pulsed and grid-pulsed S-band integral tube-and-cavity units; power output optimized at 2900 megacycles.

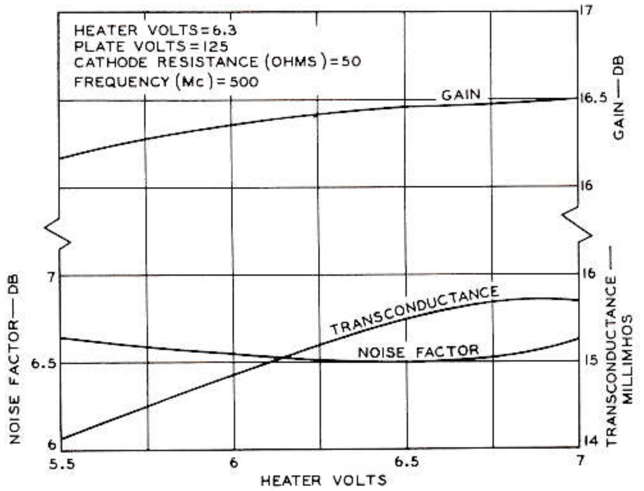


Fig.9 - RCA-7552 gain, noise factor, and transconductance as functions of heater voltage.

Amplifiers

Certain design features of the pencil tube make it an efficient amplifier of both large and small signals in the microwave frequency spectrum above 200 megacycles. Cylindrical terminals allow the pencil tube to be used in high-efficiency cavity and transmission-line circuits. In grounded-grid circuits, the coaxial symmetry of the grid with respect to the plate and cathode provides a high degree of shielding between the input and output stages. This coaxial symmetry also allows the grid to act as an effective shield which reduces the plate-to-cathode capacitance to a very low value and thus greatly reduces any tendency towards regeneration. The lower values of lead inductance and interelectrode capacitance raise the resonant frequency of the input, output, and feedback circuits.

Small-Signal Class A Amplifiers

Small-signal amplifiers are used primarily for microwave receivers in which the signal level to be amplified is in the vicinity of -60 dbm. It is important that the amplifying device have low internal noise, high usable power gain, high-gain-bandwidth characteristics, mechanical and thermal stability, and reliable performance. The high-performance capabilities of a representative pencil tube are shown in Figs.9 through 12.

Large-Signal Class B and Class C Power Amplifiers

Large-signal amplifiers are used in microwave transmitters either as driver amplifiers or as output tubes. In power

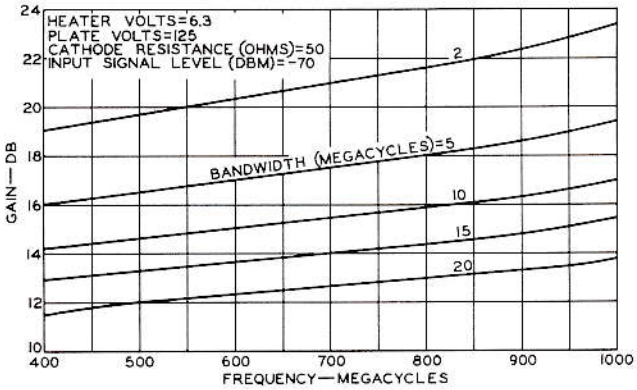


Fig.10 - RCA-7552 gain as a function of frequency at various bandwidths.

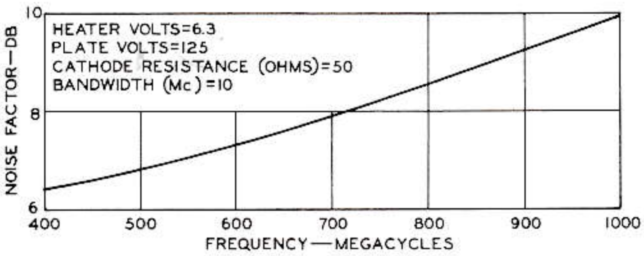


Fig.11 - RCA-7552 noise factor over the 400- to 1000-megacycle range.

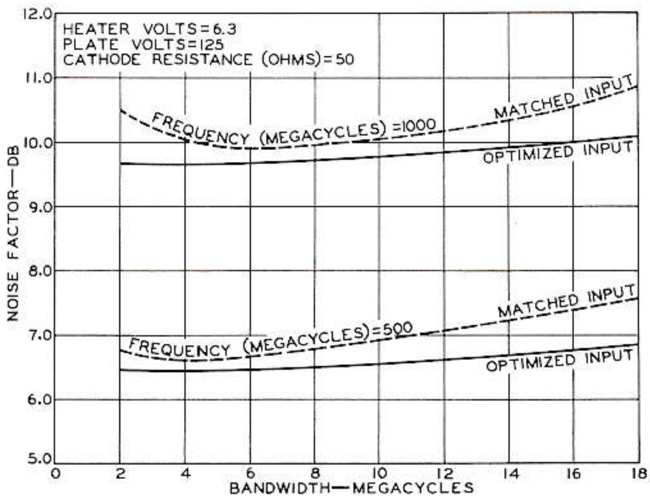


Fig. 12 - RCA-7552 matched and optimum noise-factor curves at 500 and 1000 megacycles as a function of bandwidth.

amplifiers, it is desirable to have both high power gain and high efficiency. Pencil tubes are suitable for use in driver-amplifier chains and in power-output stages supplying up to 10 watts of output, as shown in Fig. 13. The pencil-tube amplifier can be modulated by any of the conventional methods; i.e., plate modulation, grid modulation, or cathode modulation. With grounded-grid amplifiers it is necessary to modulate the driver stage to obtain 100-per cent modulation.

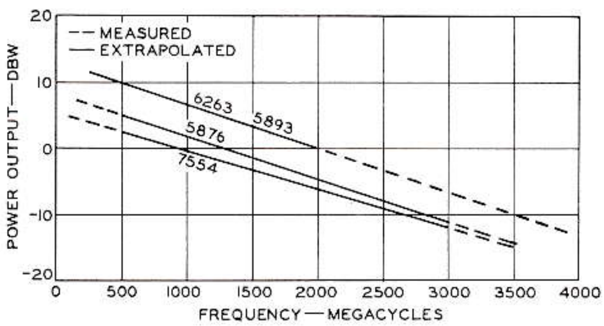


Fig. 13 - RCA-6263, -5893, -5876, and -7554 as class C power amplifiers at typical operating conditions.

Frequency Multipliers and Harmonic Generators

In many microwave receiver and transmitter designs, it is desirable to obtain microwave power from a low-frequency, low-power source. Pencil tubes are well suited to this application because the major requirements are the same as for the class C power amplifier. A frequency multiplier essentially distorts the incoming signal to generate harmonics of the signal frequency and then filters and amplifies the desired harmonic. Fig. 14 shows the effect of frequency multiplication on power output.

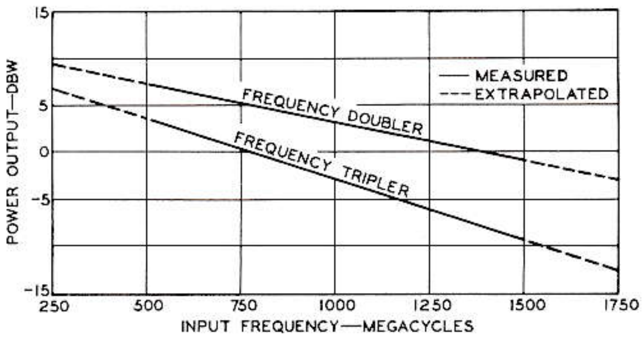


Fig. 14 - Operation of a pencil tube as a frequency multiplier under typical operating conditions.

Typical applications of the pencil tube as a frequency multiplier include: stable local oscillator in microwave receivers employing a crystal-controlled oscillator in the frequency-multiplier chain; low-power frequency-multiplier and driver-amplifier chain for microwave-transmitting equipment; harmonic generator for microwave-measurement equipment.

Table I and Fig. 15 summarize the performance characteristics of the RCA-7554, a ceramic pencil tube designed for class C service.

Mixers

The frequencies of incoming microwave signals are often converted to lower intermediate frequencies at which amplification and selectivity are more easily obtained. At frequencies above 100 megacycles, this conversion or mixing is most commonly performed by triode and diode tube mixers and crystal rectifiers. Each of these devices has both advantages and limitations.

The pencil-tube triode mixer has considerable merit as a mixer because of the conversion gain it provides. In addition, when preceded by one or more low-noise rf amplifier stages, the triode mixer provides a lower system noise figure than conventional crystal rectifiers at frequencies above approximately

SERVICE	DRIVE POWER (Watts)	POWER OUTPUT (Watts)	OUTPUT FREQUENCY (Megacycles)	PLATE EFFICIENCY (Per cent)	TOTAL EFFICIENCY* (Per cent)
Class C Amplifier	0.2	1.8	500	60	41
	0.2	1.4	1000	35	24
Frequency Doubler	0.2	0.90	500	30	20
	0.2	0.50	1000	17	11
Frequency Tripler	0.2	0.4	500	15	10
	0.2	0.15	1000	8	5

* Total Efficiency = Plate Input plus Heater Power.

Table I - Performance characteristics of the RCA-7554.

1000 megacycles. Other advantages of the pencil-tube triode mixer are:

1. It is capable of withstanding overload without burn-out.
2. It is less dependent upon input matching.
3. It provides greater reliability and is less susceptible to damage.

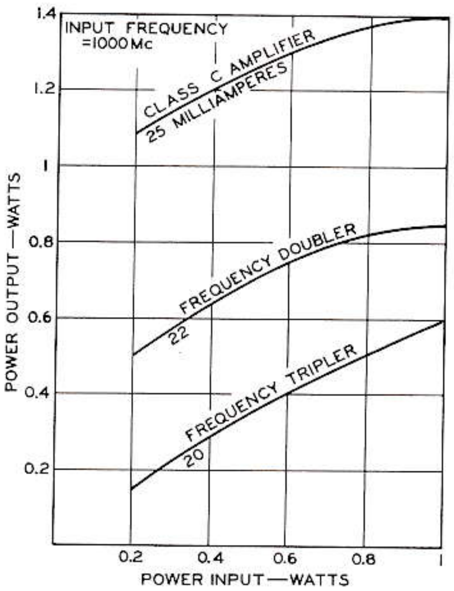
The pencil-tube diode mixer is used for high-power-level mixer applications and in applications requiring high input impedance. As in the case of the triode mixer, the diode mixer offers overload protection.

Detectors

The RCA-6173 pencil-tube diode is designed for use as a peak-power detector at microwave frequencies. It is particularly useful for detector applications at high power levels. Its rugged construction and high-peak-current capabilities make it desirable for applications in which crystal detectors would be subject to burn-out or damage. Like the other pencil tubes, the 6173 is ideal for coaxial circuits. In satellite applications, pencil-tube diode mixers improve reliability because of their ability to withstand radiation.

ELECTRICAL CIRCUIT DESIGN CONSIDERATIONS

In the design of uhf circuits for use with pencil tubes, careful consideration should be given to the selection



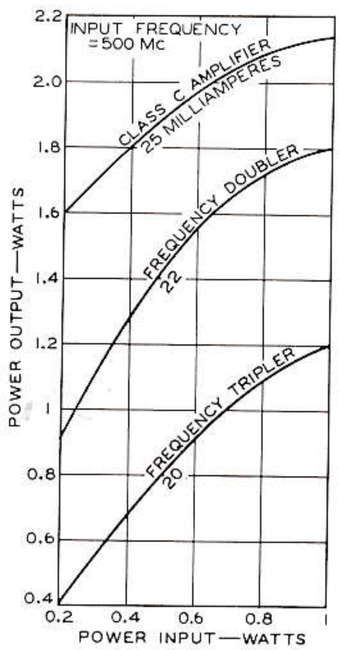


Fig. 15 - Class C performance of the RCA-7554.

of the best tube for a particular application. Because it is impossible to design one tube that fits all applications, RCA has developed a complete line of pencil tubes to meet differing requirements in the low-power uhf range.

At uhf it is virtually impossible to consider the tube and circuit separately. The frequency stability of an oscillator at uhf, for example, depends upon each circuit component. Stability is determined by the choice of tube, operating conditions, type and magnitude of feedback, output load coupling, and voltage and temperature variations.

The specific designs of cavities and associated circuits is beyond the scope of this booklet. However, a number of general suggestions are given which may assist the circuit designer.

Oscillators

In the design of oscillators, consideration should be given to frequency stability, circuit Q, feedback, output coupling, and tuning range.

Frequency Stability

Operating voltages and temperatures affect tube stability. In general, tube drift can be eliminated by use of a low and regulated plate-supply voltage to the tube and careful regulation of the heater-supply voltage. Low plate-supply voltages prevent the tube from exceeding the recommended operating plate temperature; a regulated voltage supply maintains constant input and output impedance.

The effect of supply-voltage variations on oscillator frequency for a typical pencil tube tends to be self-compensating, i.e., an increase in heater-supply voltage decreases the frequency, while an increase in plate-supply voltage increases the frequency.

Thus, if the plate and heater voltage are increased or decreased simultaneously, the net frequency shift is negligible. This self-compensating characteristic of pencil tubes is very desirable in battery-powered oscillators, airborne equipments, and any application in which line-voltage fluctuations might be encountered.

Circuit Q

The degree to which a resonant cavity controls the frequency stability of an oscillator depends upon its operating Q. Generally, higher operating Q produces better frequency stability. High Q is obtained in resonant cavities having a large ratio of volume to wall surface area because energy is stored in the volume of the cavity and lost only in the walls. Maximum Q of a concentric resonator is obtained when the ratio of the outer-conductor diameter to the inner-conductor diameter is 4.2 to 1. This ratio provides a characteristic impedance of 30 ohms.

Although the unloaded Q of a cavity operating in the $3\lambda/4$ mode is always higher than that of one in the $\lambda/4$ mode, $3\lambda/4$-mode operation may not be desirable because of large physical size. In addition, interfering-mode suppression becomes more difficult in the $3\lambda/4$ or higher-order modes, and erratic oscillations or "dead spots" (no oscillation) can develop.

For maximum frequency stability in the $\lambda/4$ mode, an output impedance of from 70 to 90 ohms is recommended. In the $3\lambda/4$ mode, the recommended output impedance is from 30 to 70 ohms.

Feedback

Because of the self-neutralizing effect of grounded-grid operation of pencil tubes (plate-to-cathode capacitances less than 0.1 micromicrofarad in all tubes), some external feedback is required to obtain efficient oscillator operation. In coaxial cavities, this feedback can be obtained in a number of ways. Usually feedback within the cavity itself is the most efficient and least frequency-sensitive. Either inductive loops, capacitive probes, or a combination of both are used to obtain wide oscillator-tuning ranges. These loops or probes can be mounted to the mechanism which supports the grid flange of the pencil tube. Use of this technique allows the feedback circuit to be simple and compact. Moreover, a feedback circuit of this type requires no adjustment unless the mode of operation of the oscillator is changed. Capacitive feedback probes are generally used at frequencies below 1700 megacycles, at which $\lambda/4$ mode operation is practical. Inductance loops are employed above 1700 megacycles in $3\lambda/4$-mode operation.

The amount of feedback is governed by the size and number of the loops or probes used, their proximity to the electric and current fields in the cavity, and their relative position with respect to the inner and outer conductors of the cavity. Insufficient feedback causes very low grid current and poor plate efficiency; excessive feedback causes high currents, low efficiency, and wide variations in power output over the tuning range.

Output Coupling

The type of output coupling depends on physical considerations as well as on electrical requirements in the cavity design. For fixed-frequency operation, either capacitive or inductive coupling works satisfactorily. In oscillators tuned over a wide frequency range, more uniform power output can be obtained by use of a capacitive probe located near the grid and extending radially inward from the outer cavity wall. The capacitive probe usually requires no more than a radial adjustment of its location in the cavity when frequency is changed. However, the inductive loop must not only be moved longitudinally within the cavity, but must also be altered in size. Another distinct advantage of a capacitive-output pickup is that it can be located in the cavity outside the range of plunger travel; the inductive pickup must necessarily be mounted in the face of the plate plunger and so must be allowed to move with the plunger when frequency is varied. Output coupling is considered to be optimized when the grid current of the unloaded oscillator is equal to twice the loaded grid current.

Loose load coupling is desirable for applications in which power output is not the prime concern. This type of coupling allows oscillator performance to be relatively independent of variations in the load impedance. Because any change in the VSWR in the output circuit exerts a frequency-pulling effect on the oscillator, tight output coupling requires careful impedance matching between the oscillator and the load, with a very low VSWR.

In applications requiring maximum available power output as well as frequency stability, Rieke diagrams* should be made of the circuits to indicate the best possible compromise. A Rieke diagram, when carefully plotted, shows the frequency-pulling and power-output sink points of the oscillator at which stable operation cannot be expected. The Rieke diagram also indicates the amount of frequency-pulling and power-output shift that can be anticipated over various values of output-circuit VSWR and phase angles. Two typical Rieke diagrams of a cw oscillator operating at 1680 megacycles are shown in Figs.16 and 17. Power-output contours are shown in percentage values with matched conditions indicated by 100-per-cent power output. Frequency contours are shown in increments of one megacycle.

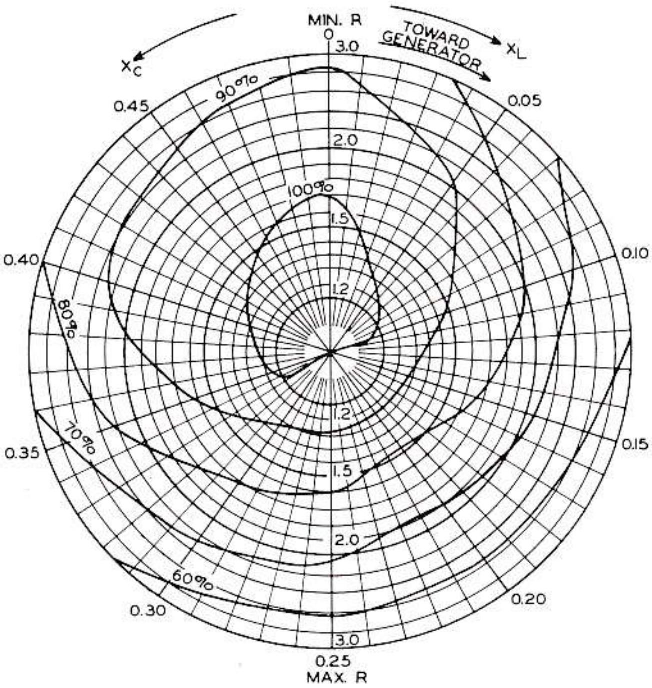


Fig. 16 - Rieke diagram—Power output contours for RCA-6562 at 1680 megacycles.

Frequency Tuning

Frequency tuning of a cavity can be accomplished by any means which alters the electrical length of the plate resonator. A shunt capacitance is very effective for tuning over a narrow range of frequencies. A large-faced plunger or plug which can be moved radially in the cavity provides a tuning range of about 5 per cent. Use of two tuning slugs doubles the range that can be obtained. Care must be exercised in placement of these tuning slugs so that distortion of the energy field within the cavity is avoided.

In the design of oscillators having wide tuning ranges, provision must be made to allow movement of both cathode-

* Details of the Rieke diagram are given in Volume 1 of *Very High Frequency Techniques* (see bibliography).

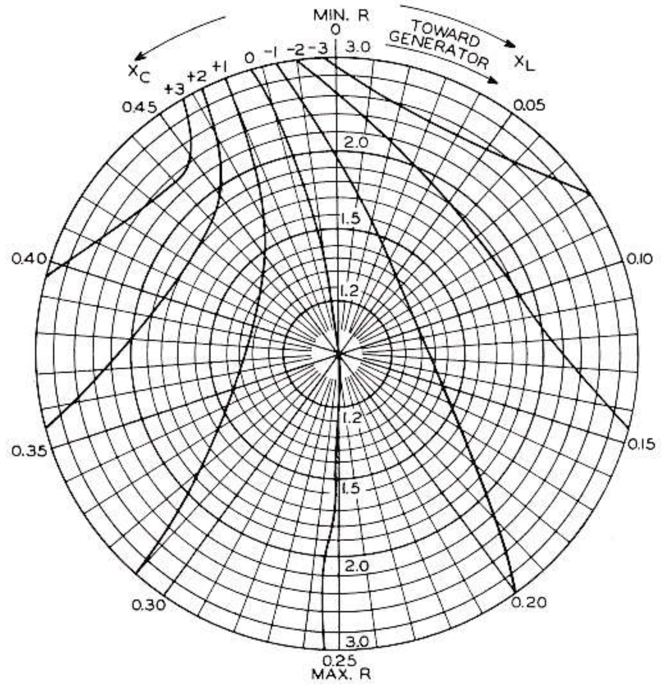


Fig. 17 - Rieke diagram—Frequency contours for RCA-6562 at 1680 megacycles.

and plate-shorting plungers. Contacting surfaces must be silver-plated to reduce resistive losses, and a rhodium flash-plating may be applied to improve wearing qualities. When noise-free operation is required, noncontacting resonant choke plungers, shown in Fig. 18, can be employed. However, these choke plungers must be $\lambda/4$ long and, therefore, may not be suitable for oscillators operating below 1000 megacycles. Noncontacting plungers must be concentric with the inner wall of the cavity and, to reduce rf leakage around them, must be very close to the cavity wall. Tolerances of 0.010 inch are considered acceptable.

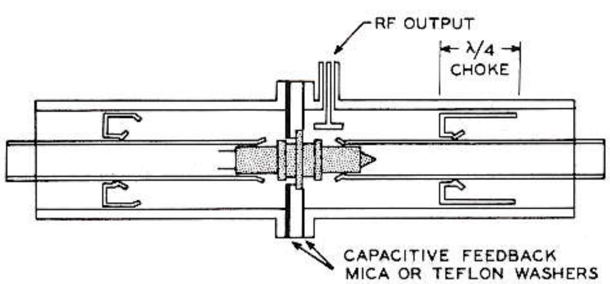


Fig. 18 - Grid separation cavity for continuous-wave oscillator using the RCA-7554.

Plate-Pulsed Oscillators

Plate-pulsed oscillators are used in equipment such as compact radar beacons, transponders, and telemetering transmitters. Prime requirements of a pulsed oscillator are high instantaneous peak powers plus frequency stability and long life.

Type of Cavity

A re-entrant type of cavity* is generally employed for plate-pulsed oscillators because of its mechanical simplicity and its high performance at ultra-high frequencies.

Basically, a re-entrant cavity consists of four transmission lines, as shown in Fig. 19. The lengths of lines 1 and 2 determine both the phase and magnitude of feedback; the lengths of lines 3 and 4 primarily determine the resonant frequency of the cavity. If the impedance of line 2 is low, the frequency of the cavity can be varied by a change in the length of line 3 only. However, because the length of line 4 is always a factor in determining frequency, there is a limit to the frequency range obtainable by adjustment of line 3 alone.

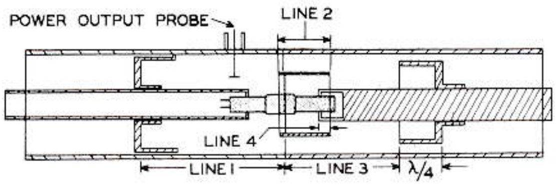


Fig. 19 - Re-entrant cavity.

Frequency Tuning

Re-entrant oscillators are tuned in the following ways:

(1) The length of the grid cylinder may be varied. This method presents so difficult a mechanical problem, however, that it is seldom used.

(2) For a frequency variation of ± 100 megacycles, the plate line may be moved back so that a portion of the center conductor of line 4 is the plate of the tube. If this method is used, care should be taken to provide adequate heat conduction from the plate.

* The electrical behavior of this type of cavity is analyzed in Volume 7 of the MIT Radiation Laboratory Series (see bibliography).

(3) If the impedance of line 2 is low (close spacing between the grid cylinder and outer cavity wall), frequency can be varied by moving the plate-shorting plunger, thereby changing the length of line 3. The effective length of line 3 may also be varied by the introduction of a shunt capacitance in the plate line.

For optimum results, any of these tuning methods should be accompanied by appropriate adjustments of line 1 (grid-cathode cavity) and output-load coupling as frequency is varied.

Output Coupling

Power output can be taken from a re-entrant cavity oscillator at almost any point in the circuit. An inductive loop can be used in the face of the plate plunger, or a capacitance probe can tap power either from the cathode line or at a high-voltage point along the grid cylinder.

Class A Amplifiers

Noise generated in the first stage of a receiver frequently determines the over-all sensitivity of a system. An ideal rf-amplifier tube would contribute no noise to the system; therefore, its noise figure would be unity or 0 db. However, because the electron tube is a thermionic device, it contributes additional noise to the signal applied to its input terminals. This noise is predominantly composed of the following constituents:

(1) Random emission of electrons from the cathode. This so-called "shot effect" produces random fluctuations in the plate current and appears as noise at the input of the following stage.

(2) Fluctuating currents induced in the grid. These fluctuations in the grid circuit, caused by the passage of the random electrons in the plate current, are amplified by the tube in the conventional manner and also appear as noise in the plate circuit.

Sources of Tube Noise

Sources of tube noise can be effectively described in terms of two equivalent noise parameters: G_{in}, the equivalent input noise conductance, and R_{eq}, the equivalent series noise resistance. G_{in}, which is associated with an induced noise voltage on the grid from random electron flow, is related to the geometry of the tube and includes transit-time effects. Therefore, it is a function of the frequency of operation and varies directly as the square of the operating frequency. R_{eq}, which is associated with the shot noise produced by plate current, is a function of tube design and operating parameters; it is more or less independent of the frequency of operation.

Theory indicates that in a triode having an oxide-coated cathode the equivalent series noise resistance is two and one-half times the transconductance factor of the tube (g_m).

Noise Figure

The noise figure of a given tube is the ratio of actual output noise appearing in the plate circuit to that which would appear if the tube amplified only the noise appearing at its input terminals. Noise figures can be measured in many ways. The commonly accepted method consists of applying the output of a standard "white" noise source, such as an argon discharge tube, to the input of the tube under test and measuring the total output noise component due to the tube with an automatic noise-figure indicator. In this comparison method, the noise source is automatically turned on and off by the noise meter while an if output is taken from the receiver ahead of the second detector.

Gain

Because gain is also an important tube characteristic in small-signal amplifiers, measurements of tube gain should be made under the same tube-operating conditions used for the determination of tube noise. Consequently, gain is measured by means of a calibrated signal source applied to the tube under test. Fig. 20 shows a block diagram of this test setup.

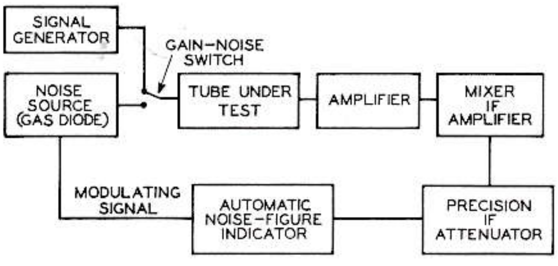


Fig. 20 - Block diagram of gain- and noise-test setup.

Class C Amplifiers

Except in very special cases, uhf power amplifiers employ the grounded-grid or cathode-drive type of circuit. At high frequencies, distributed circuit parameters make it difficult to neutralize the amplifier in conventional grounded-cathode circuits because of feedback through the grid-plate capacitance of the tube. Use of the grid as a shield between input and output circuits reduces the amount of feedback by a factor of at least 200.

Grounded-Grid Power Amplifiers

Fig.21 shows the circuit configuration of a typical grounded-grid power amplifier. The grid-cathode capacitance and grid-plate capacitance of the tube become part of the input- and output-tank circuits, respectively. The feedback circuit consists essentially of the very low value of the plate-cathode capacitance of the tube.

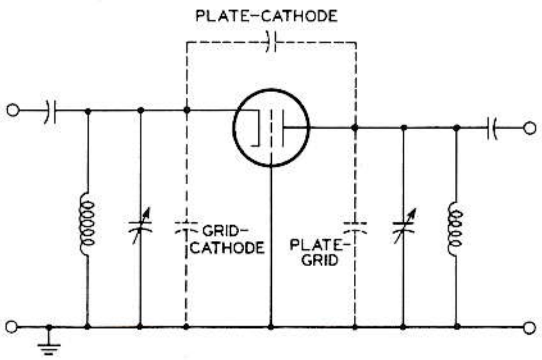


Fig.21 - Grounded-grid power amplifier.

The operation of a grounded-grid amplifier differs from that of conventional grounded-cathode amplifiers in that plate current flows through the input circuit of the tube, and the input and output circuits are in phase with each other. The grounded-grid circuit requires greater driving power; however, the additional driving power is passed on to the output circuit and adds to the power that the tube supplies.

Design Objectives

The normal design objectives for class C amplifiers are high efficiency, power output, and power sensitivity. High efficiency is obtained by means of a narrow plate-current conduction angle and a minimum instantaneous plate voltage which approaches the maximum instantaneous grid-voltage value. However, higher power output can be obtained by use of a conduction angle approaching 180 degrees. Therefore, a balance must be reached between efficiency and power output by the proper choice of plate-conduction angle. Generally, an angle between 120 and 145 degrees offers the best balance.

Choice of Tube

High power sensitivities in a class C amplifier are obtained with tubes having a relatively high amplification factor, μ. Again, a balance must be made in the proper choice of tube. If the μ is too high, the proportion of the space current absorbed by the grid becomes too large, and operation of the tube is limited by its grid-dissipation rating. Low μ in a tube results in excessive plate currents and low efficiency due to the poor cutoff properties of the grid. Operation of the tube is then limited by its plate-dissipation rating. Generally, a tube having an amplification factor between 35 and 65 serves best as a class C amplifier.

Care must be taken in the design of class C amplifiers to insure that peak cathode-current ratings of the tube are not exceeded. The ratio of peak instantaneous cathode current to average cathode current in class C operation ranges between 5 to 1 and 3 to 1 for conduction angles of 120 to 145 degrees. In no case should the peak instantaneous cathode current exceed the dc cathode-current rating by more than 10 to 1; higher ratios shorten the life of the tube.

Choice of Circuit

Mechanical considerations regarding output coupling and frequency tuning of a class C amplifier circuit are the same as those discussed previously for cw oscillator circuits. The use of the grounded-grid type of circuit is particularly advantageous in amplifier operation because of the isolation between input and output circuits which this type of circuit configuration affords. Elaborate neutralizing loops are unnecessary with grounded-grid circuits because regeneration through the plate-cathode capacitance is reduced to an insignificant level.

Bias for a class C amplifier may be obtained by the use of a grid resistor, a combination of grid resistor and fixed supply, or a combination of grid resistor and cathode resistor. The combination method for obtaining bias not only protects the tube from damage resulting from loss of driver power, but also minimizes distortion through bias-supply compensation.

In the tuning of a grounded-grid rf amplifier, it must be remembered that variations in the load of the output stage produce corresponding variations in the load of the driving stage. This effect causes a simultaneous increase in plate currents of both the output and driving stages.

Driving power may be introduced into the grid-cathode circuit of an amplifier cavity in a manner similar to that used for output coupling to the grid-plate circuit. However, because frequency stability is not a factor in grid-cathode circuits, the tube and circuit can be more tightly coupled at both the input and output to improve over-all circuit efficiency.

Frequency Multipliers

In most uhf transmitters, accuracy of frequency tuning and stability of operating frequency are important design considerations. As a result, crystal-controlled oscillators are usually employed to obtain the required frequency stability of the system. However, because crystals are too fragile to be reliable at frequencies above 100 megacycles, frequency-multiplier chains must be used to convert the crystal operating frequency to the desired frequency of the system.

Frequency multiplication in a transmitter chain can be accomplished in several ways. Figs. 22 and 23 show block diagrams of two representative transmitter chains operating in L-band and S-band, respectively. As shown, intermediate-power amplifiers following the frequency multipliers raise the power level to a point sufficient to drive the output tube in the transmitter.

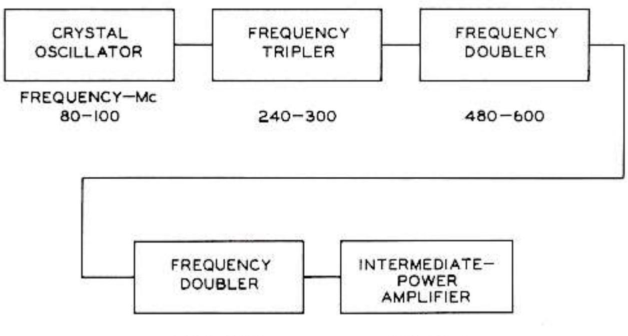


Fig. 22 - L-band transmitter chain.

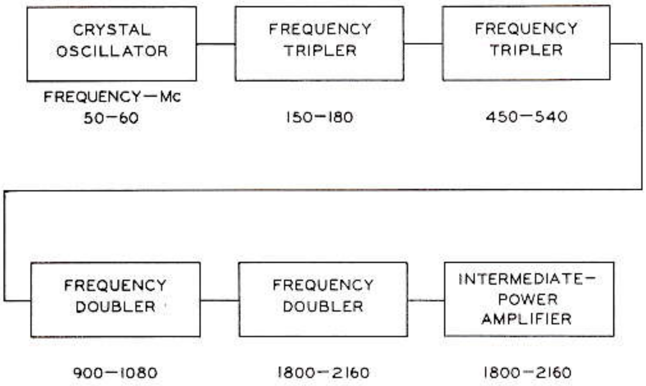


Fig. 23 - S-band transmitter chain.

The power output that can be obtained from a given tube when used as a frequency multiplier (or in any class C service) depends upon (1) the plate-current conduction angle, and (2) the maximum grid-current, plate-dissipation, and peak-cathode-current ratings of the tube.

The Plate-Current Conduction Angle

For optimum results, plate current should flow for no more than one-half cycle of the harmonic frequency for each primary cycle, because it is only during this time period that the load circuit absorbs any useful power. Thus, if the load circuit of the tube is tuned to the second harmonic, the plate-conduction angle should theoretically be 90 degrees. However, high values of bias must be employed to reduce the plate conduction angle, and the higher values of bias require correspondingly greater driver power levels. As a result, frequency multiplication beyond the third harmonic becomes impractical.

Maximum Grid Current

For efficient frequency multiplication, a tube must have a high amplification factor. This requirement necessitates the use of a tube having very close grid-to-cathode spacings and/or grid lateral wires with a high number of turns per inch. In either case, the grid intercepts a larger portion of the total cathode current and overheating of the grid structure becomes a problem. As a means of preventing overheating of the grid and subsequent impairment of tube operation, maximum-grid-current ratings are specified for each tube type. In many cases, this grid-current rating limits the amount of driver power which can be applied to the tube and thereby, in a sense, limits the amount of output power that can be obtained from the tube.

Maximum Plate Dissipation

Limits for maximum plate dissipation are also established for each tube type. The maximum plate-dissipation rating of a tube is intended to maintain plate temperatures within safe limits under typical operating conditions. Depending upon the efficiency of the output circuit, the maximum available power output from a given tube in frequency-multiplier service is limited by the plate-dissipation ratings of the tube.

Peak-Cathode-Current Rating

For a tube having an oxide-coated cathode, investigations and experiments have shown that maximum life can be realized when the cathode-current density is kept below 150 milliamperes per square centimeter. In a typical pencil tube designed for class C amplifier and multiplier service, such as the 7554, the coated cathode area is approximately 0.165 square centimeter. The average cathode-current limit is 25 milliamperes in class C amplifier service. The ratio of peak instantaneous cathode current to average cathode current in class C amplifier service varies between 3 to 1 and 4 to 1, depending on the plate-conduction angle. In frequency-doubler service, this ratio increases to about 5 to 1, and ratios as high as 7 to 1 are common in frequency-tripler service. In order that reliable cathode-current densities be maintained, maximum cathode-current ratings for multiplier service are lower than those limits for single-frequency amplifier service.

MECHANICAL DESIGN CONSIDERATIONS

The pencil-type construction not only meets requirements as to minimum transit time, but also provides such other mechanical design features as extreme sturdiness, ease of plate cooling, and adaptability to microwave circuits. Various aspects of these features in relationship to tube use are discussed in the following sections.

Environmental Considerations

RCA pencil tubes are designed to meet the most severe environmental requirements in military applications. MIL specifications exist on the following types:

TYPE	MIL SPECIFICATION
5675	MIL-E-1/78C
5876	MIL-E-1/94D
5876-A	MIL-E-1/1043A
5893	MIL-E-1/96D
5794	MIL-E-1/180E
6173	MIL-E-1/670A
6263	MIL-E-1/1044AF
6264	MIL-E-1/1045AF
7533	MIL-E-1/1311SC
7554	MIL-E-1/1325N

Environmental tests performed include:

MIL-E-ID REFERENCE	TYPE OF TEST	TEST CONDITIONS
4.9.5.1	Torque	12.5 in.-lb. min.
4.9.19.1	Low-frequency vibration (25 cps)	2.5 g
4.9.19.2	High-frequency vibration (50 cps)	10 g
4.9.13.1	Low-pressure voltage breakdown	5675 100,000 ft. 5876 100,000 ft. 5893 100,000 ft. 6173 100,000 ft. 6263 60,000 ft. 6264 60,000 ft. 7552 100,000 ft. 7553 100,000 ft. 7554 100,000 ft.
4.9.20.5	Impact test	500 g
4.9.20.6	Fatigue vibration (96 hours)	2.5 g
4.9.20.3	Variable frequency (5-50 cps)	0.040 in. constant amplitude
4.9.20.3	Variable frequency (5-2000 cps)	10 g
—	Seal fracture	30 lbs. min.
—	Longitudinal acceleration	10,000 g
—	Rotation	7,000 rpm

All pencil tubes are designed to have fundamental resonant frequencies higher than 2,000 cycles; typical values are given below:

TUBE TYPE	RESONANT FREQUENCY CPS
5675	3150
5876	3500
5893	2500
6263	2100
6264	2300
6562/5794-A	3100
7554	2350
7552	2300
7553	5500
7533	3100

Mounting Considerations

The metal-to-ceramic or metal-to-glass seals used in pencil type triodes are very strong in compression, but less strong under conditions of tension, torque, or bending. Sufficient allowance should be made in the connectors for a small amount of terminal eccentricity or grid-flange tilt in the tubes. In general, one of the three electrode terminals of the tube—the cathode cylinder, the grid flange, or the plate cylinder—should be fastened fairly rigidly. Connectors to the other two terminals should have sufficient flexibility to allow for dimensional variations within the range of manufacturing tolerances. In particular, the grid flange should be connected at only three or four points. An outline drawing of the RCA-5893 pencil triode is shown in Fig.24. The maximum variations encountered under present specifications are indicated by dotted lines.

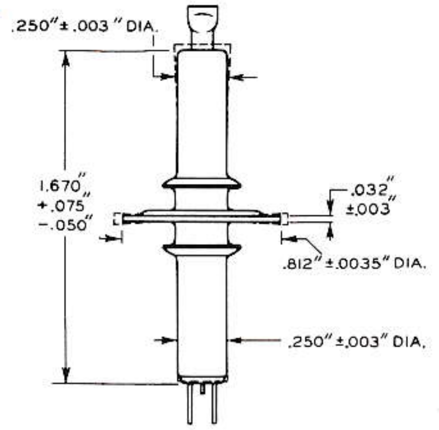


Fig.24 - Dimensional outline of the RCA-5893 pencil tube.

When circuit inductances and thermal conductivity are not major considerations (e.g., at lower power inputs and frequencies), fuse clips may be used for plate and cathode connections, and various types of spring clips for grid connections. Typical connectors suitable for applications in which power inputs and frequencies are relatively low are shown in Fig.25. For somewhat higher power inputs or frequencies, the plate connector shown in Fig.26(a) and the grid connectors of Fig.26(b) provide appreciably lower inductance and better heat conductivity than those of Fig.25.

In re-entrant-type oscillator circuits, the grid flange acts as a support for the cylindrical grid connector. The connector, therefore, must exert a clamping action on the grid flange. Fig.27 shows a grid connector for a re-entrant oscillator operating at 3375 megacycles. Clamping action is provided by means of a bevelled groove which forms a seat for the grid flange. The shape of this groove is such that the cathode side of the grid flange always rests on the slope of the groove.

As a result, the bevelled groove presses against the grid flange to seat it on the shoulder of the grid connector. The angle of the bevel is determined by the type of material used in the connector, the thickness of the material, and the amount of clamping action desired. For the 1/16-inch-thick brass connector shown in Fig.27 a suitable angle of the bevel is 15 degrees. For applications in which the oscillator may be subjected to vibrations, it may be advisable to increase the angle. A large angle of bevel, however, tends to produce a clamping action so tight that it is difficult to remove the connector from the grid flange without the use of special tools.

Thermal Considerations

Maximum seal temperatures on the RCA pencil tubes are 175 degrees centigrade for glass types and 225 degrees centigrade for ceramic types. Normally, maximum seal temperatures will not be exceeded if plate voltage and plate current are kept within published ratings. In coaxial circuits, a large-surface plate contact is generally adequate to maintain low plate-seal temperatures. In other applications, such as the lumped-constant or parallel-line type, such precautions as forced-air cooling may have to be provided to prevent overheating of the plate. It is generally known that the life of an electron tube can be extended by a reduction in the plate temperature. Consequently, for reliable performance and maximum tube life, plate-operating temperatures should be kept as low as possible.

When the plate dissipation of a pencil-type triode exceeds 2.5 watts, special measures are usually necessary to cool the plate so that the temperature of the plate seal is kept within published ratings. Cooling can be accomplished by the use of a connector which makes a firm and large-area contact with the plate and, therefore, conducts as

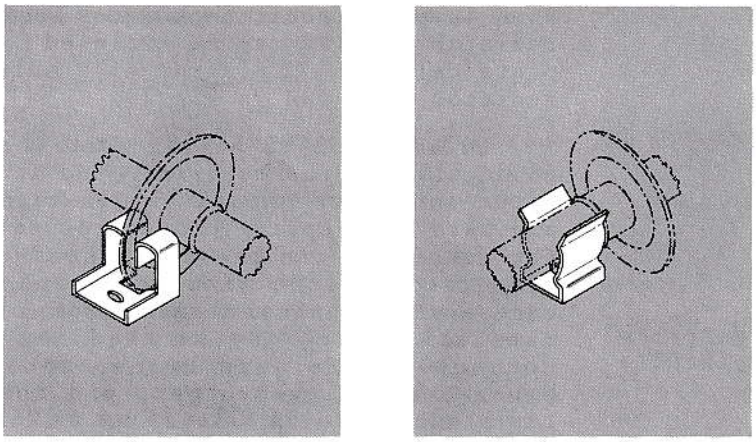


Fig. 25 - Electrode-terminal connectors for use at relatively low power inputs and frequencies.

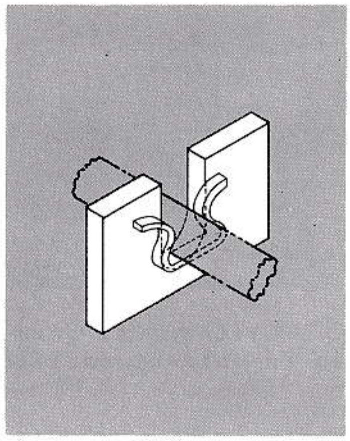


Fig. 26(a) - Anode connector for use at higher power inputs and frequencies.

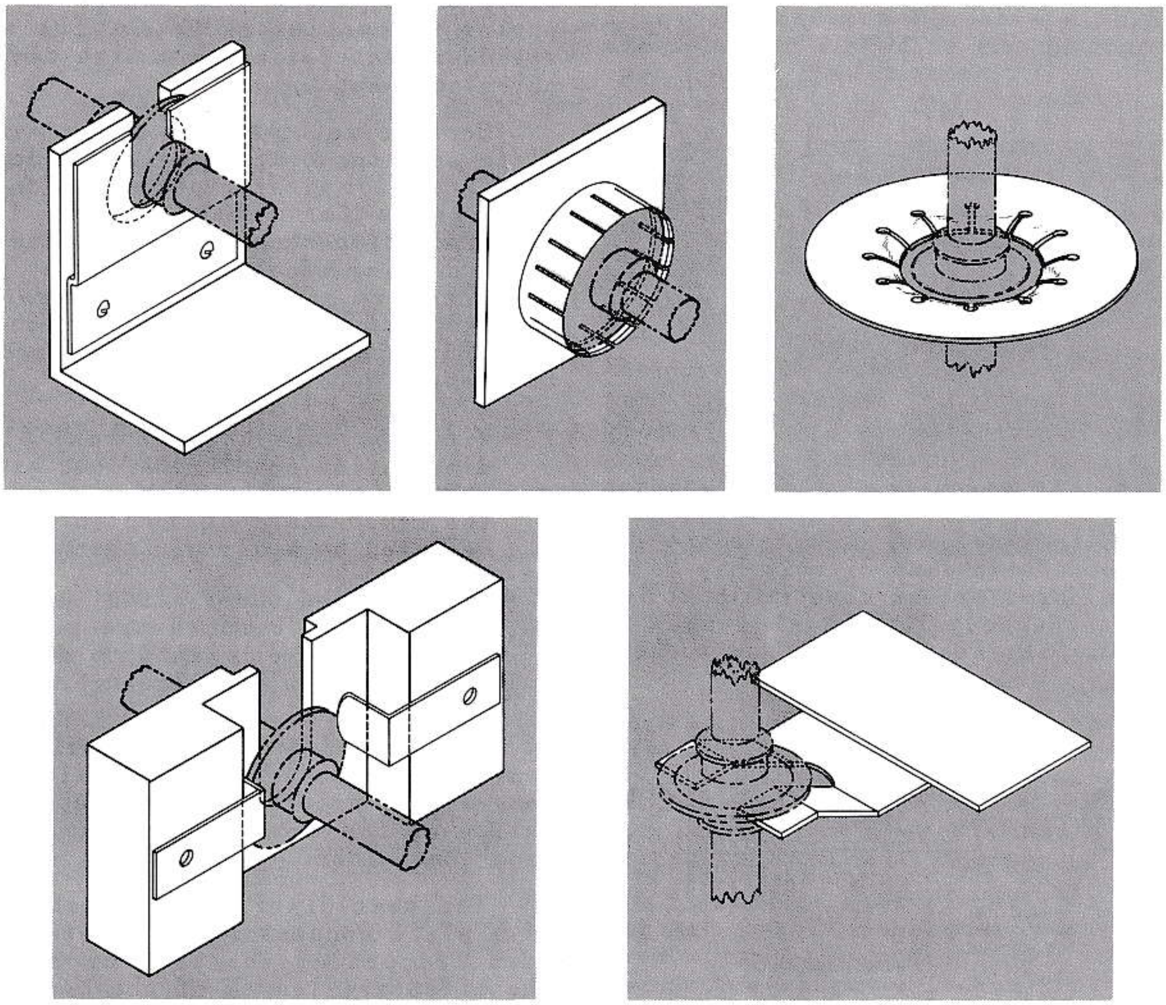


Fig. 26(b) - Typical grid connectors having lower inductance and better heat conductivity than the spring clip shown in Fig. 25.

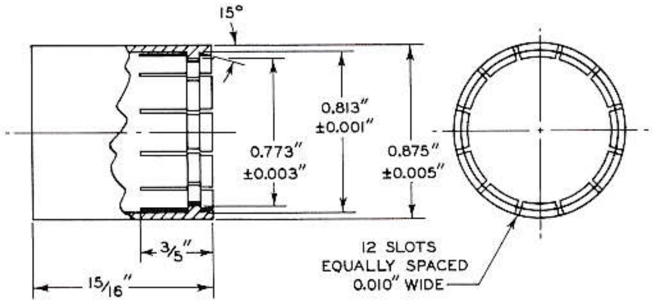


Fig. 27 - Cylindrical grid connector for use in re-entrant oscillator circuits.

much heat as possible to elements of the external circuit. Heat conducted to the external circuit can then be removed by radiation or by convection. The heat-conducting path may conveniently be a part of the electrical circuit, such as the center conductor of a coaxial line.

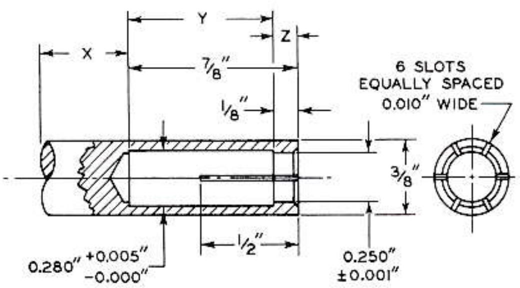


Fig. 28 - Anode connector for use in concentric-line circuits.

Fig. 28 illustrates a satisfactory type of plate contact for use in concentric-line circuits. Such a contact provides both good electrical connection and good cooling. The cathode connector for a concentric-line circuit may be of the same form, except that it should be hollow throughout its entire length to accommodate the heater leads and socket.

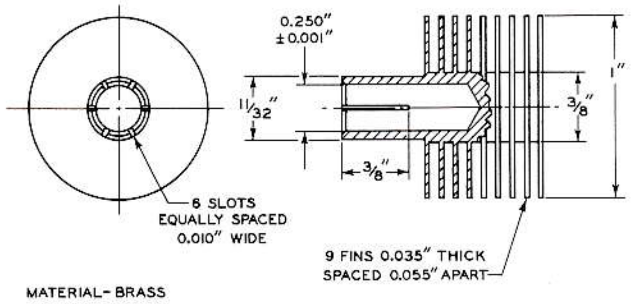


Fig. 29 - Radiator suitable for cooling the anode in lumped circuits.

When lumped-circuit techniques are used, radiator cooling may be employed for the plate cylinder. A diagram of a suitable radiator is shown in Fig. 29.

In addition to having good thermal conductivity, the material used for the plate connector should be non-magnetic and have good spring properties so that the connector can provide a good electrical connection without introducing excessive mechanical strain. Some of the materials which may be used for such connectors are hard brass, phosphor bronze, beryllium copper, and special resistance-welding alloys such as Mallory 100. Beryllium copper and phosphor bronze, which are generally used for conventional spring connectors, have rather low thermal conductivity. Brass has reasonably high thermal conductivity, but spring fingers made from it tend to weaken and break after repeated flexing. Mallory 100 alloy has superior thermal conductivity to brass and about the same spring properties as brass, but withstands repeated flexing at high temperatures somewhat better.

Because maintenance of the maximum plate-seal temperature below 175 degrees centigrade for glass types or 225 degrees centigrade for ceramic types is of the utmost importance, the ultimate test of the cooling capabilities of any plate connector is an actual measurement of the temperature of the seal. Either of the following methods may be used for this measurement:

1. With the tube under normal plate-dissipation conditions, but without radio-frequency voltages present, the temperature of the plate seal is measured by means of a thermocouple.
2. With the tube under actual operating conditions, temperature-sensitive paint or crayon is used to determine the plate-seal temperature.

The second method is usually more convenient because of the difficulty of determining accurately the plate dissipation of the tube under actual operating conditions.

The heat-dissipation capabilities of a plate connector are determined by such factors as the area of contact, the effective length of the conducting path, the thermal conductivity of the metal used, and the ambient temperature of operation.

Coaxial Circuits

RCA pencil tubes are widely used in coaxial circuits operating from 200 megacycles up to 4000 megacycles. Their small size and double-ended construction facilitate their use in compact, rugged cavity resonators. Typical of the cavity resonators employing RCA pencil tubes are the 6562 shown in Fig. 30 and the

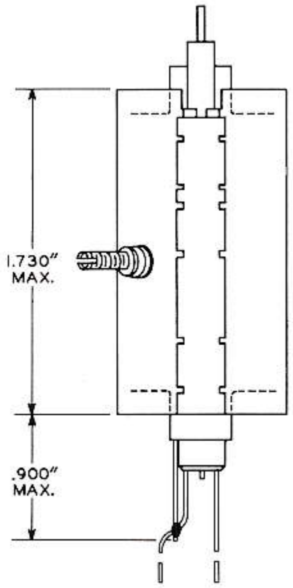


Fig. 30 - Dimensional outline of the RCA-6562.

developmental type shown in Fig. 31. The developmental tube is a ruggedized S-band integral-cavity tunable oscillator capable of withstanding 10,000 g of acceleration in missile and rocket beacon applications.

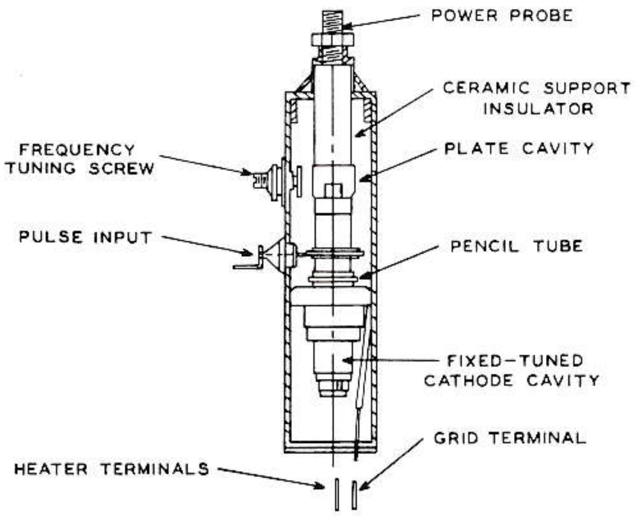


Fig. 31 - Cutaway drawing of developmental ruggedized, S-band, integral cavity unit.

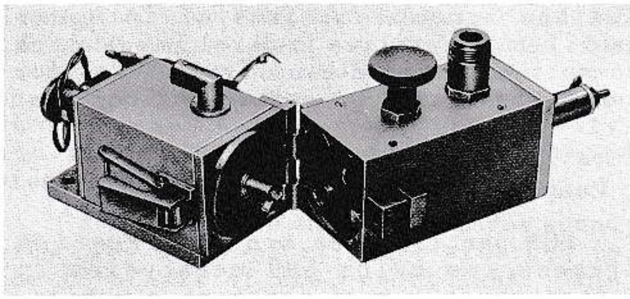


Fig. 32 - RCA-7554—coaxial-line amplifier cavity operating at 550 megacycles.

In either cylindrical or rectangular coaxial cavities, the plate and cathode terminals become extensions of the inner conductor, as shown in Figs. 32 and 33. Because these lines can be as small as 1/4 inch in diameter, cavities having a characteristic impedance of 50 ohms need be only one inch in outside diameter. The diameter of the grid disc (0.812 inch) of most pencil tubes eliminates the need for elaborate grid supports in cavities of this diameter.

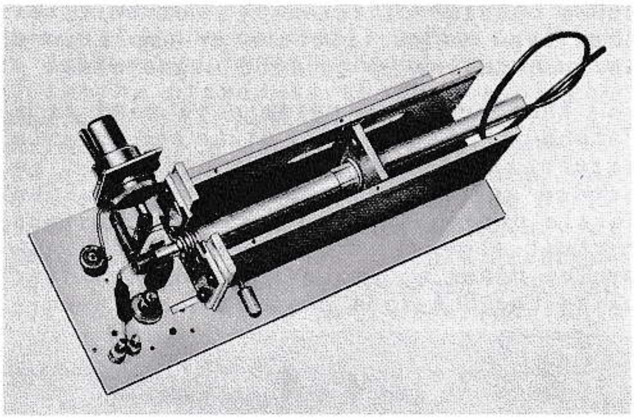


Fig. 33 - RCA-7554 frequency-multiplier cavity using rectangular coaxial-line output and direct cathode drive.

Because the structure of the pencil tube lends itself equally well to grounded-grid, grounded-cathode, or grounded-plate circuits, the tubes provide sorely needed versatility in electronic-components design.

A complete line of cavities for RCA ceramic pencil tubes is now available from various vendors. Cavities cover the entire range of frequencies and are available for class C or class A amplifiers, cw or plate-pulsed oscillators, and frequency multipliers. In addition, RCA has a complete line of integral pencil-tube cavities in development which cover the L- and S-band frequencies for continuous-wave and pulse service.

Parallel-Line and Lumped-Constant Circuits

RCA pencil tubes are widely used at frequencies below 500 megacycles in conventional lumped-constant circuits. Sockets designed to adapt pencil tubes to low-frequency service may be easily fabricated or readily obtained from commercial vendors.

The heater leads of all pencil tubes fit commercial sockets. Heater leads should not be soldered directly to circuit elements because of the possibility of damage to the seals between the heater leads and the stem of the tube.

The tank circuit can take the form of parallel rods (lecher wires), air coils, or flat or curved plates. Tuning is best accomplished with glass or ceramic capacitors. Negative temperature-compensating capacitors may be employed to improve frequency stability. Pencil tubes operate efficiently in circuits of this type as oscillators or amplifiers at frequencies up to 1100 megacycles.

When beryllia ceramic is used as a "stand-off" between the plate and chassis, external cooling will probably not be needed and rf performance will suffer little degradation. The lumped-constant circuit shown in Fig.34 is a 550-megacycle, class C, grounded-grid amplifier using the RCA-7554 ceramic-metal pencil

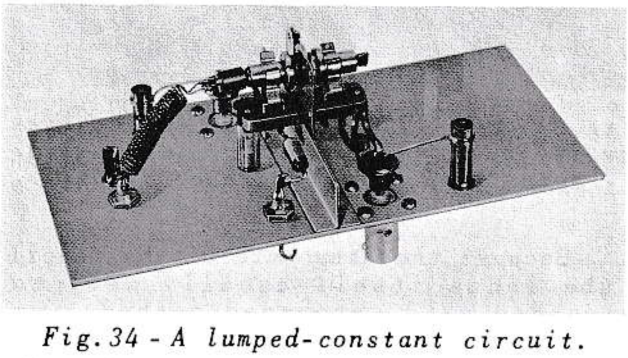


Fig.34 - A lumped-constant circuit.

tube. The components of the circuit are spread out mainly to facilitate modification or replacement of these parts during laboratory experiments. Fig.35 shows that the plate dissipation in this type of circuit could be raised to 2.5 watts at an ambient temperature of 175 degrees centigrade without exceeding the maximum allowable plate-seal temperature of 225 degrees centigrade. Adequate cooling is readily provided by the plate-connector clip and by conduction to the grid flange and its support through the thermally conductive ceramic.

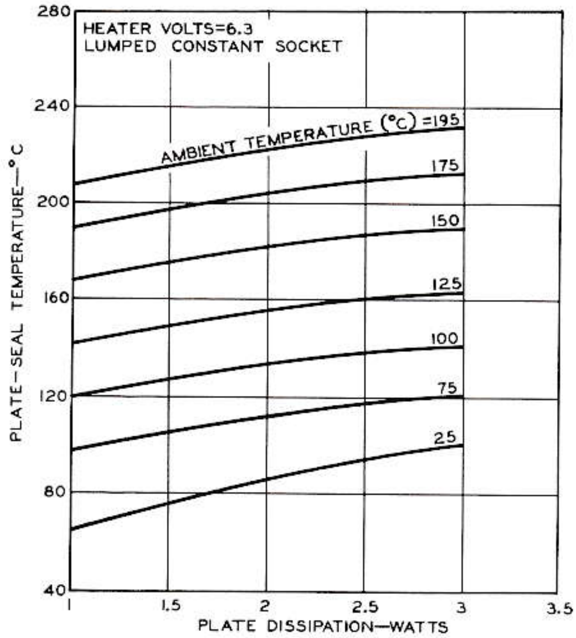


Fig.35 - RCA-7554 plate-seal temperature as a function of ambient temperature with lumped-constant circuit.

OTHER APPLICATIONS

Harmonic Generator

Generation or amplification of microwave signals at frequencies higher than 4,000 megacycles is impractical with negative-grid triodes. Although transit-time devices, such as klystrons and magnetrons, are used for many narrow-band cw-oscillator applications in C- and X-band, these devices are bulky and costly. It has been demonstrated in the laboratory, however, that a pencil tube in combination with a variable-capacitance diode, both located coaxially within a tri-separation cavity, can deliver useful cw power in C-band.

The fundamentals of operation are as follows: A pencil tube located within a closed-cavity coaxial resonator operates as a cw oscillator at a fundamental frequency. The output power is fed directly into another cavity (which can be integrated with the pencil-tube cavity) containing a variable-capacitance diode. The diode cavity is tuned to the fundamental resonant frequency of the oscillator and thus is tuned also to higher harmonic frequencies. By means of coupling techniques and filters, the desired harmonic power is obtained and unwanted harmonics and the fundamental frequency are attenuated. The variable-capacitance diode has a conversion efficiency of approximately -1.5 db per harmonic.

Another benefit of this device is that frequency stability is easier to obtain than in a fundamental-frequency device because frequency compensators can be used at the lower frequency and thus can be located more in the pencil-tube cavity. The diode cavity, of course, needs no compensation because it is tuned to the fundamental frequency of the pencil tube.

Voltage-Tunable Pencil Tube and Cavity

One limitation of a uhf tube and cavity is that wide frequency tuning can be accomplished only by mechanical adjustments. For this reason, tube-and-cavity combinations are not suitable for remote frequency tuning, automatic frequency control, frequency modulation, or wide-band-tracking.

A variable-capacitance diode can also be used to change the frequency of oscillation in a pencil-tube-and-cavity combination. Small changes in the voltage applied to the diode change the diode capacitance and thus change the effective plate-line length (resonant tank circuit) of the pencil-tube cavity.

In the type 6562/5794-A pencil-tube-and-cavity combination, the mechanically adjusted tuning screw allows a frequency variation of approximately 40 to 60 megacycles. The maximum capacitance variation of the tuning screw is approximately 2 micromicrofarads. Diodes which exhibit a 2-micromicrofarad change in capacitance with a 6-volt change in bias are available. Such a device is not only useful as a voltage-tunable local oscillator, but can also be used in afc or FM circuits.

RF Amplifier Tube-and-Cavity Combination

Lumped-constant circuits are often used in airborne systems operating in the vhf band. It is possible to design a low-noise pencil-tube-and-cavity combination for such applications which not only reduces the over-all cost of the system, but also improves performance. Because a conventional coaxial cavity suitable for use at vhf would be extremely long and cumbersome, however, the following method has been devised to shorten the cavity length appreciably and at the same time to incorporate wide-band tuning.

Cylindrical insulating sleeves wound with a few turns of wire are attached to the terminals of the pencil tube. The wire adds inductance in series with the terminals of the tube and thereby shortens the effective length of the center conductors of the cavity. This value of inductance (and, therefore, frequency) can be varied, however, by means of a sliding copper slug located within the insulating sleeve. The entire assembly is enclosed within a cylindrical resonator comparable in size to that of the RCA-6562.

Frequency-Tunable S-Band Tube and Cavity

Present developmental S-band pencil-tube-and-cavity combinations are fixed-tuned to 2900 megacycles. Fine-tuning adjustments, by means of a tuning screw, allow a variation in operating frequency of 100 megacycles. The resonant frequency of these extremely rugged cavities is determined by the length of a piece of tubing brazed to the plate of the tube and to the nose-piece assembly. If the nose-piece assembly is threaded to the cavity wall, the tubing can be made to move back and forth along the plate of the tube and change the frequency of operation. By the use of this arrangement, frequency tuning between 2000 and 3000 megacycles has been observed.

Custom-Made Cavities

The advantages of integral tube-and-cavity units are becoming more apparent. As a result, RCA is developing several such units suitable for many applications. Furthermore, although these existing units can be frequency adjusted at the factory over a relatively wide range, RCA is prepared to provide the equipment designer with a cavity "tailored" to his particular specifications.

Table II lists the RCA developmental continuous-wave and plate-pulsed tube-cavity units presently available on a limited basis. The basic units, which are designed to meet normal airborne environmental specifications, employ Microdot (type 3102) output connectors which facilitate laboratory testing and installation.

CONTINUOUS			PULSED			
CENTER FREQUENCY (Megacycles)	TUNING RANGE (Megacycles)	POWER (Milliwatts)	CENTER FREQUENCY (Megacycles)	TUNING RANGE (Megacycles)	POWER (Watts)	DUTY FACTOR
900-1050	± 25	1500	900-1050	± 25	800	(0.1%)
1000-1300	± 25	1000	1000-1300	± 25	600	(0.1%)
1250-1600	± 25	800	1250-1600	± 25	500	(0.1%)
1550-1900	± 25	600	1550-1900	± 25	400	(0.1%)
1850-2200	± 50	300	1850-2200	± 50	300	(0.1%)
2150-2500	± 50	200	2150-2500	± 50	200	(0.1%)
2450-2800	± 50	150	2450-2800	± 50	150	(0.1%)
2750-3100	± 50	100	2750-3100	± 50	100	(0.1%)
3050-3400	± 50	50	3050-3400	± 50	50	(0.1%)

Table II - RCA developmental pencil-tube-and-cavity oscillators.

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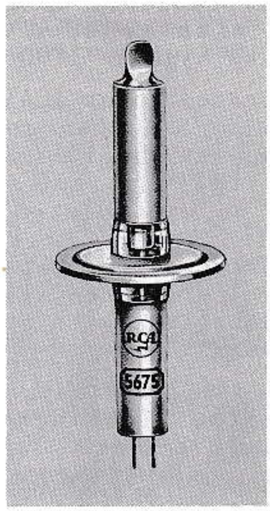
TUBE DATA

RCA-5675

The RCA-5675 is a medium-mu triode designed for use in cathode-drive circuits at frequencies up to 3000 megacycles. As a local-oscillator tube, it provides a power output of 475 milliwatts at 1700 megacycles and about 50 milliwatts at 3000 megacycles.



Heater volts, 6.3; amperes, 0.135. Maximum length, 2.252 inches; maximum diameter, 0.816 inch.

RCA-5876, RCA-5876-A

The RCA-5876 is a general-purpose, high-mu triode intended particularly for use in cathode-drive service as an rf amplifier, if amplifier, or mixer tube in receivers operating at frequencies up to about 1000 megacycles. In addition, it may be used as a frequency multiplier up to 1500 megacycles, as an oscillator up to 1700 megacycles in mobile transmitter applications, and as a low-power rf amplifier.

As an unmodulated class C rf amplifier, the 5876 is capable of providing a useful power output of 5 watts at 500 megacycles; as an unmodulated class C oscillator, this tube can deliver a useful power output of 3 watts at 500 megacycles and 750 milliwatts at 1700 megacycles.

The RCA-5876-A is a high-mu triode similar to the 5876 but intended for military and critical industrial applications.

Heater volts, 6.3; amperes, 0.135. Maximum length, 2.252 inches; maximum diameter, 0.816 inch.

RCA-5893

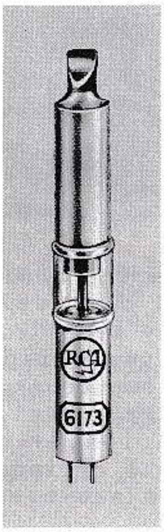
The RCA-5893 is a medium-mu triode intended for use in cathode-drive service as a plate-pulsed oscillator tube at frequencies up to 3300 megacycles. In such service it is capable of providing a useful peak-power output of 1200 watts.

At frequencies up to 1000 megacycles, the 5893 may be used as an rf power amplifier, cw oscillator, or frequency doubler, particularly in low-power mobile transmitters. As an unmodulated class C rf power amplifier under ICAS conditions, this tube is capable of delivering a useful power output of approximately 6 watts at 1000 megacycles.

Heater volts, 6.0; amperes, 0.280. Maximum length, 2.297 inches; maximum diameter, 0.816 inch.

RCA-6173

The RCA-6173 is a high-perveance uhf diode intended particularly for use in pulse-detection and pulse-power measuring service. It may be operated



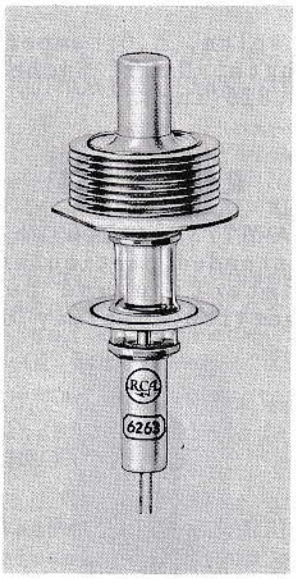
at frequencies of 3300 megacycles in pulse power operation or at frequencies as high as 10,000 megacycles in pulse detection service. Because of its frequency capability and small size, this tube is especially useful in rf probes of electronic voltmeters.

Heater volts, 6.3; amperes, 0.135. Maximum length, 2.227 inches; maximum diameter, 0.320 inch.

RCA-6263

The RCA-6263 is a uhf triode having an external plate radiator. It has an amplification factor of 27 and is intended for use as an rf power amplifier and oscillator tube in mobile equipment and in aircraft transmitters operating at altitudes up to 60,000 feet without pressurized chambers.

The 6263 can be operated with full ratings at frequencies up to 500 megacycles and with reduced ratings at frequencies as high as 1700 megacycles per second.



Featured in the design of the 6263 is an efficient disk-type radiator for plate cooling by means of convection or forced air. A sturdy grid flange permits the use of a clamp connector which will not subject the grid seal to appreciable strain, and a longer glass section between the plate cylinder and the grid flange prevents arc-over at very high altitudes.

Heater volts, 6.0; amperes, 0.280. Maximum length, 2.63 inches; maximum diameter, 1.010 inches.

RCA-6264-A

The RCA-6264-A is a uhf triode having an external plate radiator intended for use in military and critical industrial applications. It is designed for use as a frequency-multiplier, an rf-power-amplifier, and oscillator tube in mobile equipment and in aircraft transmitters operating at altitudes up to 60,000 feet without pressurized chambers.

The 6264-A may be operated at full ratings at frequencies up to 500 megacycles and with reduced ratings at frequencies as high as 1700 megacycles.

When operated under ICAS conditions the 6264-A can deliver useful power outputs of approximately 3.4 watts as a frequency tripler to 510 megacycles, 10 watts as an unmodulated class C rf power amplifier at 500 megacycles, and 6 watts as unmodulated class C oscillator at 500 megacycles. The oscillator output of 6 watts is obtained with a plate input of only 12 watts.

Heater volts, 6.0; amperes, 0.280. Maximum length, 2.63 inches; maximum diameter, 1.010 inches.

RCA-6562 5794-A

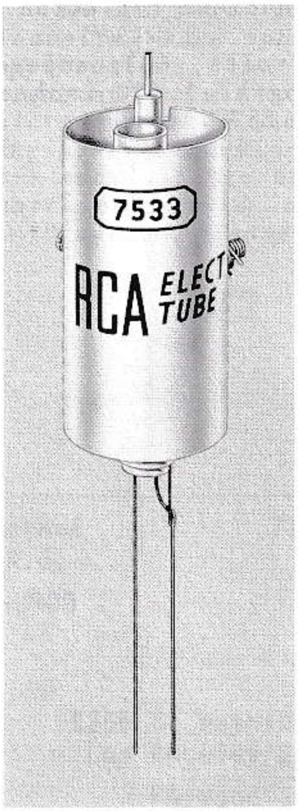
The RCA-6562/5794-A is a fixed-tuned ultra-high-frequency oscillator triode intended for transmitting service in radiosonde applications. It has two resonators which are integral parts of the tube. One of the resonators, which is fixed-tuned, is connected between the grid and cathode; the other, which is connected between the grid and plate, is loop-coupled to a coaxial rf-output terminal and can be tuned to 1680 megacycles by a frequency-adjustment screw. The tube has a useful power output on the order of 600 milliwatts.

External connection of the cathode to one of the heater leads simplifies circuit connections. The flexible heater leads can be soldered or welded into the associated circuit.

Heater volts, 6.0; amperes, 0.16. Maximum length, 4.50 inches; maximum cavity diameter, 0.980 inch; maximum radius, 0.865 inch. $U_A = 120V$

RCA-7533

The RCA-7533 is a tunable oscillator triode designed for battery-powered radiosonde applications in which high efficiency, light weight, low battery drain, and small frequency drift are important considerations. Two resonators are integral parts of the tube. One resonator which is connected between grid and cathode is fixed tuned to provide relatively uniform power output over the operating frequency range. The other resonator, connected between grid and plate, is loop-coupled to a coaxial rf output terminal and can be tuned capacitively within the 1660- to 1700-megacycle range by means of two frequency-adjustment screws.



Heater volts, 6.0; amperes, 0.16. Maximum length, 4.48 inches (including flexible heater leads); maximum cavity diameter, 0.980 inch; maximum radius, 0.865 inch.

RCA-7552

The RCA-7552 is a high-mu ceramic-metal triode designed for use as a low-noise uhf amplifier tube in compact mobile and aircraft equipment at altitudes up to 100,000 feet without pressurization. The tube has a maximum plate dissipation of 2.5 watts and can be operated with full ratings at frequencies up to 1000 megacycles.

In a typical cathode-drive circuit having a bandwidth of 5 megacycles and operating at a frequency of 800 megacycles, the 7552 has a power gain of 18 db and a noise figure of about 8.5 db.

The relatively large area of the plate cylinder allows fast heat dissipation, a significant advantage in compact equipment. The silver-plated electrode surfaces are separated by ceramic bushings.

Heater volts, 6.3; amperes, 0.225. Maximum length, 1.620 inches; maximum diameter, 0.557 inch.

RCA-7553

The RCA-7553 is a high-mu ceramic-metal triode designed specifically for applications requiring dependable performance under conditions of severe shock and vibration. It is intended as a low-noise uhf amplifier tube in missile guidance systems and in compact mobile and aircraft equipment at altitudes up to 100,000 feet without pressurization.

The tube has a maximum plate dissipation of 2.5 watts and can be operated at frequencies up to 1000 megacycles.

In a typical cathode-drive circuit having a bandwidth of 5 megacycles and operating at a frequency of 700 megacycles, the 7553 has a power gain of about 17 db and a noise factor of about 7 db.

The relatively large area of the plate cylinder allows fast heat dissipation, a significant advantage in compact equipment.

In addition, the ceramic-metal construction permits plate-seal operating temperatures as high as 225 degrees centigrade and reduces the effects of nuclear radiation.

Heater volts, 6.3; amperes, 0.225. Maximum length, 1.620 inches; maximum diameter, 0.557 inch.

RCA-7554

The RCA-7554 is a high-mu ceramic-metal triode designed for use as a uhf-power-amplifier, oscillator, and frequency-multiplier tube in compact mobile and aircraft equipment at altitudes up to 100,000 feet without pressurization. The tube has a maximum plate dissipation of 2.5 watts and can be operated at frequencies up to 3000 megacycles.

In a typical cathode-drive circuit when the tube is used as a power amplifier at 1000 megacycles, the RCA-7554 would provide about 1.4 watts of output with a driver power of 0.2 watt.

The relatively large area of the plate cylinder allows fast heat dissipation; a significant advantage in compact equipment.

In addition, the ceramic-metal construction permits plate-seal operating temperatures as high as 225 degrees centigrade and reduces the effects of nuclear radiation.

Heater volts, 6.3; amperes, 0.225. Maximum length, 1.620 inches; maximum diameter, 0.557 inch.

The RCA Electron Tube Division is actively engaged in extensive programs for the development of special tubes for ultra-high frequencies. Commercially available pencil tubes have been described in the foregoing Tube Data Section. A number of types of magnetrons and traveling-wave tubes are also available commercially. Information on these tubes may be obtained from the RCA Tube Handbook HB-3, the RCA Magnetron and Traveling-Wave Tube booklet MT-301A, or from Commercial Engineering, RCA Electron Tube Division, Harrison, N.J.

In addition, many types of pencil tubes, magnetrons, and traveling-wave tubes are developed by RCA to meet specific applications. Your RCA field representative will be pleased to acquaint you with our extensive line of pencil tubes and other microwave tubes and to discuss your particular needs. Field Engineering and Microwave-Tube Application Engineering services are available to assist you and help you fill your tube requirements on an equipment-production basis. For further information, please call the Equipment Sales Office nearest you.

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