RCA Ham Tips

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NOVEL RIG GIVES TOP NOTCH PERFORMANCE ON 2 METERS

NEW, SMALL "IKE" FOR HAM VIDEO WORK

Amateur television will be given a good "shot in the arm" by this new two-inch diameter camera tube—the RCA-5527 Iconoscope. The equipment required for its operation is relatively simple and inexpensive. Using electrostatic deflection, the "Small Ike" eliminates the need for costly deflection coils and circuits as well as keystoning and shading circuits. It has a resolution capability of approximately 250 lines.

UNDERSTANDING FREQUENCY DOUBLERS AIDS IN EFFICIENT TUBE OPERATION

The phenomena of frequency multiplication is well known, even though it may not be as well understood by some Amateurs. It is safe to say that a Ham station without a doubler is as rare as a ham sandwich without mustard. But are these doublers being operated properly? Are they converting dc plate current into usable rf power, or are they dissipating it in the form of heat? The odds are that real improvements can be made. On this premise RCA engineers went about devising practical data for the guidance of Amateurs to help them select and operate tubes as frequency multipliers.

The Reason Why

Although the mechanics of handling doublers and triplers has now been reduced to a matter of simple arithmetic, an understanding of the basic engineering principles will assist in the solution of the formulas, and at the same time satisfy the Amateurs' natural curiosity and desire for "know-how."

Using a simple analogy, an electron tube frequency multiplier can be compared to a pendulum and its escapement (driving mechanism). The pendulum is the plate tank, and the escapement is the plate-current pulse. Now, if the escapement hits the pendulum once each cycle (360° excursion) the ratio is 1 to 1, and is equivalent to straight-through amplifier action. But if the escapement hits the pendulum once every two or every three cycles, the escapement frequency will be one-half or one-third the oscillation frequency of the pendulum, and the action will be equivalent to an electron tube operating as a doubler or tripler.

A moment of mental juggling with this analogy will make clear that for a given amount of driving

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UNIT DEVELOPS SIGNAL EASILY COPIED ON NARROW BAND SUPERHET' CONVERTER

By J. H. Owens, W2FTW

Wobbulated power oscillators and supperregen' swoosh-boxes are rapidly losing their popularity on 2 meters. Coming into favor are crystal-control transmitters and superhet' receivers. The band is going through the same process of evolution that cleaned up the 5-meter band pre-war. Eventually, it may become as thickly populated as the lower frequency bands, and then the need for VFO control will be realized.

Anticipating future needs, a project was opened to develop a medium-power transmitter that would generate a signal capable of being copied on a converter in conjunction with a narrow-band communications superhet'. Ordinarily this could be accomplished quite easily with four or five stages, many tubes, and two or three chassis loaded with wallet-flattening meters, condensers, and other parts. But could it be done the Amateur way—with low-cost tubes and components, together with some Ham ingenuity? The answer is "Yes."

The accompanying photographs show the transmitter which finally met all the Ham specifications set up for it. It is a three-stage job, consisting of a 36-megacycle electron-coupled oscillator which doubles in the plate circuit to 72 Mc, followed by a push-push doubler to 144 Mc, and then a 30 watt, 2-meter final amplifier.

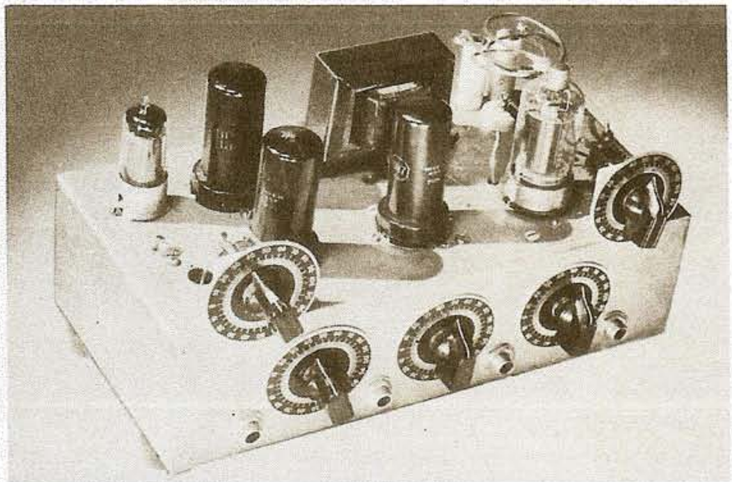
On the same chassis is a modulation transformer, which together with an audio oscillator tube, serves to make the transmitter suitable for MCW code work. The only other electronic component is a voltage-regulator tube which keeps the oscillator screen grid at 150 volts.

The Solution

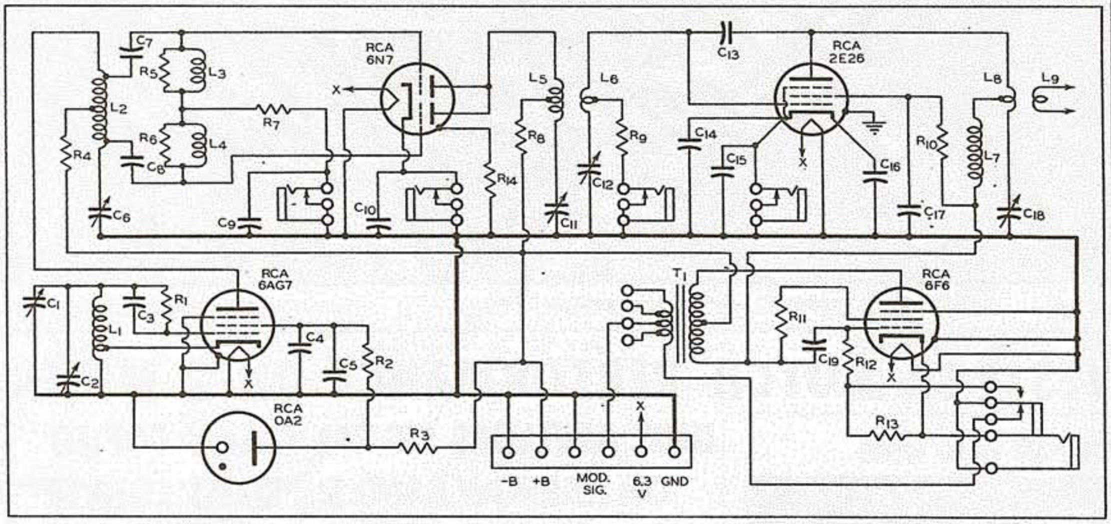
With the exception of the oscillator coil, all circuits are series tuned. Series tuning was used because it allows the use of low-cost single-section condensers, permits the rotors to be grounded, and suppresses parasitic oscillations. The total capacitance across the tank inductance is reduced, thereby permitting higher values of inductance, lower tank current, and

(Continued on Page 2, Column 1)

IT WORKS AS NICE AS IT LOOKS



The three-stage medium-power transmitter which is easily constructed with low-cost tubes and components.



2-meter rig schematic.

2-METER RIG

(Continued from Page 1, Column 4)

higher efficiency. In addition, it provides phase inversion where out-of-phase voltages are required.

Series tuning is *not* series resonance. A series-tuned circuit is properly described as a pi-section filter. A more descriptive expression would be "phantom tube tuning." To see this clearly, consider a regular push-pull plate tank whose resonant frequency is determined by the output capacitances of the two tubes, as well as by other factors. If the output capacitance of either one or both of the tubes could be made variable, it could be used to swing the tank frequency over a useful frequency range. It follows, therefore, that if one tube is removed from the circuit, a variable condenser can be substituted for it to serve as a convenient tuning control. This is series tuning of parallel resonance.

The overall arrangement results in a compact transmitter on a 3" x 5" x 10" bright-plated chassis—a unit that delivers 15 watts of clean 2-meter rf—with a total current drain of less than 175 ma at 400 volts. It is a complete transmitter, requiring only a power supply, a telegraph key, and an antenna. If a 15-watt speech amplifier is connected to it, it becomes a high-quality phone unit.

Circuit Details

The oscillator is conventional enough with the exception of the plate circuit. Series tuning was used to provide the necessary push-pull driving voltage for the 6N7 grids.

The 6N7 doubler is a conventional push-push hook-up except for its series tuned plate circuit. Notice that a metal, not a "GT", tube is used because the former has lower lead inductance. Notice also that the metal shell is *not* grounded directly, but through a 100,000 ohm resistor. This is important, because grounding the shell, or substituting a 6N7-GT will positively lower the output.

The 6N7 plate is electromagnetically coupled to the series-tuned 2E26 grid circuit. It is always good practice to couple in this manner, or through a link, when the tube to be driven requires neutralization.

Obtaining Neutralization

And here is a very interesting angle — neutralization is obtained by adding to the grid-plate-capacitance. The reason for this is that a voltage 180 degrees out-of-phase with the plate to ground voltage is developed across the screen-grid lead inductance. This voltage feeds back to the grid a neutralizing voltage, by way of the grid-to-screen-grid capacitance, which becomes excessive at two meters. So the excess neutralization must be balanced by additional capacitance from the plate to the grid.

In practice, the screen-grid lead inductance should be varied by by-passing the screen-grid to ground at a spot which makes the tube just a little over-neutralized and then balance out this over-neutralization by the addition of a very small amount of external grid-plate capacitance.

Like the other plate circuits, the 2E26 tank is series tuned. The coil is fed through an rf choke at its center where there is very little rf voltage. Inductive wire-wound dropping resistors are used to feed the plate voltage to the other tubes, and serve as rf choke as well as dropping resistors.

The following table gives tube voltages and currents normal for the transmitter:

Tube	*6AG7*	*6N7*	*2E26*	*6F6*
Eb	310	250	400	400 volts
Ib	22	25 per section	56	50 ma
Ec2	150		200	250 volts
Ic2	6		6.5	9 ma
Ec1	—30	—95	—50	—90 volts
Ic1	1.2	3	2.5	3 ma

The 6F6 oscillator is somewhat novel in that the screen grid is connected so that it acts like a control grid, thereby contributing feedback for oscillation. This will give more audio output for a given amount of input than a regular pentode or triode connection. It will deliver enough audio for 70% modulation. If more is desired, plug in a 6L6.

Construction Hints

Perhaps the most important thing to understand is that a cadmium-or zinc-plated chassis must be used. A black wrinkle enameled chassis simply will not do. Since the rf return from all of the series tuning condensers passes through the chassis, the rf resistance of the chassis must be kept low.

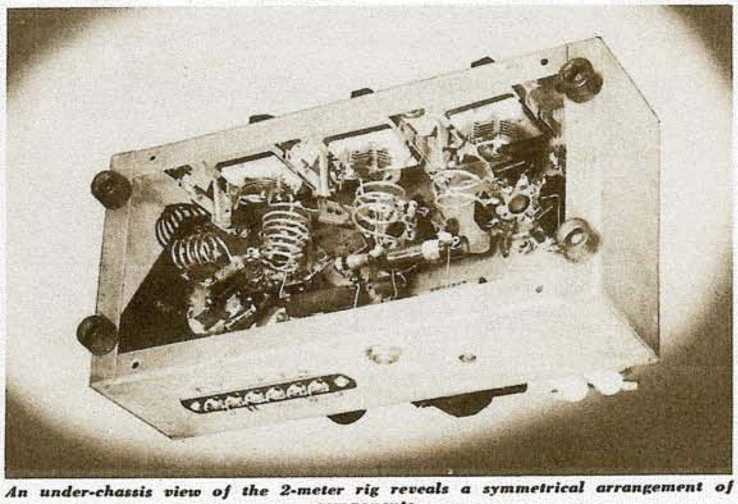
The modulation transformer is a universal output transformer, connected in reverse. It must first be disassembled and some spacing put between the E and I core sections to prevent them from becoming saturated by the 2E26 plate current. The transformer should be cushion-mounted on rubber grommets; otherwise, it may impart enough vibration to the chassis to shake the grid of the 6AG7 and cause some frequency modulation of the carrier.

Tuning Up

Aside from removing the plate supply voltage from the 2E26 screen grid and plate, no other precautions are necessary for tuning up. The full 400 volts can be applied to the oscillator and doubler safely. Adjust the band-spread oscillator trimmer to its midway position and tune the plate condenser for maximum 6N7 grid current. Then, tune the 6N7 plate and 2E26 grid condensers for maximum 2E26 grid current. Check the final frequency and repeat this procedure until the transmitter is inside of the 2-meter band.

The next step is to neutralize the 2E26. Adjust the neutralizing wire until the plate tuning condenser has the minimum effect on the 2E26 grid current. Connect the high voltage to the final, and the transmitter is ready for service.

Experimentation should be made in the degree of coupling between the 6N7 plate and 2E26 grid tank coils. Optimum coupling will provide maximum 2E26 grid current with minimum 6N7 plate current.



An under-chassis view of the 2-meter rig reveals a symmetrical arrangement of components.

PARTS LIST

L1	5 turns #14, ½" ID, 1" lg., cathode tap 1st turn
L2	6 turns #14, ¾" ID, 1½" lg., B+tap in center
L3, L4	40 inches #30 wire wound around R5 and R6
L5	3 turns, #14, ¾" ID, ¾" lg.
L6	2 turns, #14, ¾" ID, ¾" lg.
L7	20" #18 wire, ¼" ID, 1" lg.
L8	2 turns, 1½" ID (11" #12 wire)
L9	1-or-2 turn antenna pickup coil
T1	Universal Output Xfmr (air-gap in core)
C1	50 uuf, APC, air padder
C2, C12	35 uuf, variable (HF-35)
C3	100 uuf midget mica
C4, C10	500 uuf midget mica
C5	10 uf, 150 volt electrolytic
C6, C11	15 uuf variable (HF-15)
C7, C8, C9	50 uuf, midget mica
C13	Neutralizing wire see text
C14, C15, C16, C17	500 uuf, midget mica
C18	15 uuf, double spaced (HF-15X)
C19	0.02 uf, 600 volt, paper
R1	24000 ohms, 1 watt, carbon
R2	100 ohms, ½ watt, carbon
R3	10000 ohms, 10 watt, WW
R4	4000 ohms, 10 watt, WW
R5, R6	500000 ohms, 1 watt
R7	30000 ohms, 1 watt, carbon
R8	3000 ohms, 10 watt, WW
R9	20000 ohms, 1 watt, carbon
R10	30000 ohms, 2 watt, carbon
R11	25000 ohms, 10 watt, WW
R12	10000 ohms, 2 watt, carbon
R13	2200 ohms, 2 watt, carbon
R14	100000 ohms, ½ watt, carbon

FREQUENCY DOUBLERS

(Continued from Page 1, Column 2)

force, the excursion of the pendulum will become smaller when the harmonic number is increased, simply because the escapement strikes the pendulum less often. Likewise, in an electron-tube circuit, as the harmonic number is increased, the plate-current pulse occurs less often. This means that the plate pulse power must be increased as the harmonic number is increased, if the dc plate input power is to remain unchanged.

Frequency Doubler Action

There are three main factors which limit the performance of frequency multipliers, viz., maximum peak cathode current, maximum negative grid bias, and maximum rated plate dissipation. Inasmuch as tubes are rated near their limits for amplifier service, and since the efficiency of frequency multipliers is generally less than that of amplifiers, multiplier applications will usually allow less plate power input. Otherwise, tube ratings will be exceeded.

Figure I shows graphically the action in a frequency doubler. The relationships illustrated are, of necessity, approximations, but they paint a representative picture of what occurs. For instance, it is shown that the plate current pulse occurs between the point of cutoff bias and the most positive excursion of the grid. This indicates that the correct bias voltage is not only a function of the mu-factor of the tube but that it is determined by the combined effects of cutoff voltage and peak positive grid voltage.

The function of high grid bias is to shape the plate-current pulse so that it approximates the shape of a half cycle of a wave of twice the grid-signal frequency. Note that the plate-current pulse (X) has the same width as the grid-voltage wave (X') during the period of plate-current conduction. Note also that two complete oscillations occur in the plate circuit for each grid circuit cycle (2F'=F). It can be seen, therefore, that the grid circuit and plate circuit are synchronized. The lower-frequency grid voltage oscillates in perfect 1-to-2 timing in relation to the higher frequency ac plate voltage, and periodically produces pulses of plate current at exactly the right instant, every other plate-voltage cycle, to keep the plate circuit oscillating. For purposes of illustration, the drawing shows that plate current flows for exactly one-quarter of a grid-voltage cycle. Actually, this 90° conduction period may vary from 80° to 140° and still give excellent results. The grid-bias formulas given in Table I are based on a conduction angle of 120° for doubler operation. For triplers, a 100° conduction angle was used and for quadruplers the angle chosen was 80°.

Performance Limitations and Efficiency

Optimum multiplier efficiency is a compromise. Although it is possible to obtain the same plate-circuit efficiency in a multiplier stage as is attainable in a "straight through" amplifier stage, limitations in the peak cathode current available and in the maximum grid-bias ratings of the tube reduce the output power to a fraction of that attainable by operating the tube with less plate circuit efficiency.

Furthermore, high-efficiency multiplier operation requires increased driving power, which results in low power gain per stage. The efficiencies shown in Table I are, therefore, compromise efficiencies. Even with recommended multiplier efficiency, the power gain is less than that of an amplifier, and the driving power requirements are considerably higher.

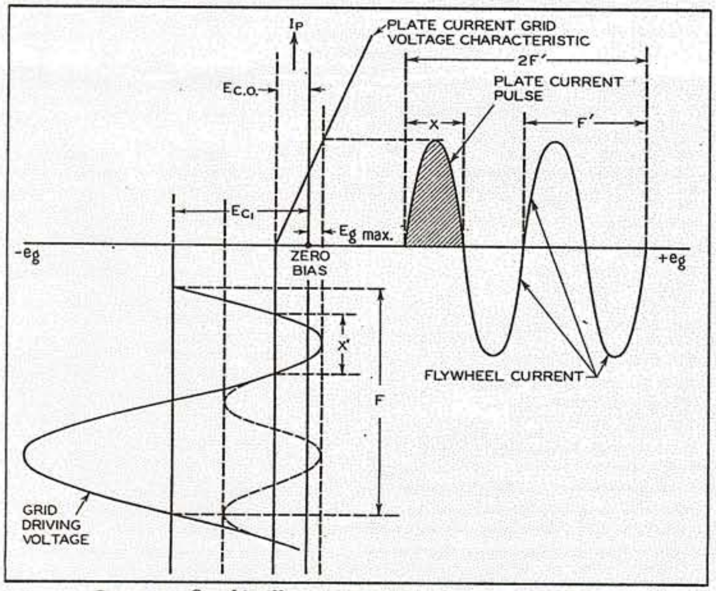


Figure I. Graphic illustration of frequency doubler action.

Frequency Multiplier Factors	*Doubler Service*	*Tripler Service*	*Quadrupler Service*
Power input ratio of input rating to plate dissipation rating (approx.)	2 to 1	1.6 to 1	1.4 to 1
Beam tube or pentode grid bias	2 Eco+0.8 Eg max.	3 Eco+1.5 Eg max.	4.5 Eco+3 Eg max.
Triode grid bias	3 Eco+0.8 Eg max.	5 Eco+1.5 Eg max.	8 Eco+3 Eg max.
Optimum efficiency for max. output	50%	38%	28%
Power output ratio of output to plate dissipation (approx.)	1 to 1	0.6 to 1	0.4 to 1

Table I

Preferred Tubes

The great number of limitations and compromise factors suggest that all tubes are not good frequency multipliers. A satisfactory triode type is one that has a combination of high mu and a high-wattage filament. The 808, 826, 809, and 811 make an excellent group.

Beam tubes and pentodes, because of their extremely high grid-plate amplification factor, are naturally good multipliers, but some are better than others. High-wattage filaments (or heater cathodes) and high transconductance are two prime quality factors. In the transmitting power class, the 2E26 and 807 are preferred types, with the 815 and 829-B taking the lead for tripler service.

Application Considerations

Probably the best way to become acquainted with the use of Table I is to work out an illustrative example. Regular ICAS Class C telegraphy data is also needed, and inasmuch as the 2E26 is featured on page 4 of this issue of HAM TIPS, it will serve as the number-one guinea pig. Using maximum ratings and typical operating conditions, take the following steps to determine optimum data for doubler service.

(1) To determine the maximum power input, multiply the plate dissipation by the power input ratio: as shown in Table I.

13.5 × 2 = 27 watts = Pin

(2) To determine the maximum plate current, divide the power input by the chosen plate voltage:

27 ÷ 600 = 45 ma = Ib

(3) To determine the cutoff bias, divide the chosen screen voltage by the grid-to-screen mu-factor:

185 ÷ 6.5 = —28 volts = Eco

(4) To determine the peak positive grid voltage, subtract the Class C telegraphy dc grid bias from the peak rf grid voltage:

57 — 45 = 12 volts = Eg max.

(5) To determine the grid bias, multiply the cutoff bias by 2; multiply the peak positive grid voltage by 0.8, and add their products:

(2 × 28) + (0.8 × 12) = —66 Ecl

These values are given in the line labeled doubler service for pentodes or beam tubes in Table I.

(6) a. To determine the expected power output, multiply the power input by the optimum efficiency:

27 × 0.50 = 13.5 watts = Po

(6) b. The power output can also be estimated by multiplying the plate dissipation by the power ratio of output to plate dissipation:

13.5 × 1 = 13.5 watts = Po

The procedure is the same for triodes except that the grid-to-plate mu factor is used instead of the grid-to-screen mu factor. It will be seen that triodes require a larger cutoff voltage multiplier than screen-grid tubes. The reason is that the value of cut-off bias varies with the instantaneous plate voltage. For practical multiplier operation, the effect of this variation is to increase the required grid bias. In screen-grid tubes the cut-off bias is not a function of the plate voltage and, therefore, this effect is not present.

Parallel, Push-Pull, and Push-Push Operation

When more power is needed than a single tube will deliver, and a tube of the right size and proper characteristics is not available, two tubes may be used. If the tubes are connected in parallel, the operation will be essentially the same as for a single tube, except that the power output will be doubled, and the input and output capacitances will be doubled.

Push-pull operation is not so simple. It suppresses even-order harmonics and accentuates the odd ones; therefore, it is used in tripler and quintupler circuits. As compared with the parallel connection, the input and output capacitances are halved instead of doubled—an important advantage at very high frequencies.

Push-push (push-pull grids and parallel plates) is exactly the opposite of push-pull in that the even harmonics are accentuated and the odd multiples suppressed. It is used for doubler and quadrupler service, and can be expected to give somewhat higher power gain than parallel operation. Because the plate circuit receives twice as many pulses as a single-ended doubler, decrement losses are minimized; I^2R losses are reduced because some circuit components are required to carry only one-half the peak current normal to a regular doubler.

ECHOS

The "Super-Slugger" article which appeared in the September issue of Ham Tips referred to a pair of National TMA-100-DA split-stator variable condensers. Actually, the condensers used in the unit's construction were the TMA-50-DA type.

V-H-F BEAM POWER AMPLIFIER

35 WATTS at 2 Meters

Amateur Net **$3.50**

RCA 2E26

Features

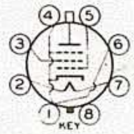
- *Small size.* For compact transmitters and efficient VHF mechanical designs.
- *Low lead inductance.* Short internal leads keep tube easy to drive at VHF.
- *Shielding.* Internal and external shielding provides exceptional circuit stability.
- *High power gain.* Minimizes number of buffer-amplifier stages required.
- *Versatility.* Excellent crystal oscillator, frequency multiplier, ECO, or amplifier.
- *VHF design.* Permits full input to 125 megacycles, and 83% of full input to 150 megacycles.
- *Micanol base.* High-frequency, mica-filled phenolic type. For use with low-cost octal sockets.

Application

- ***Plate Modulation.*** **Modulate screen grid simultaneously with plate by feeding through dropping resistor from modulation transformer. Do not bypass the screen grid for audio frequencies—500 uuf to 5000 uuf is ample for VHF or HF service.**
- ***Overloading.*** **Do not allow the plate or screen grid to show color as this is proof that tube dissipation is in excess of maximum ratings.**
- ***Grounding.*** **All three cathode socket terminals must be grounded directly or through individual mica bypass capacitors of 500 uuf to 5000 uuf each.**
- ***Feedback.*** **The small residual grid-plate capacitance will allow the tube to operate without neutralization in the region between 75 and 10 meters.**
- ***Grid Driver.*** **Almost any small receiving tube will do the job in HF service. At 2 meters, more drive is required, and a 6N7 push-push doubler is recommended.**
- ***Shielding.*** **The high power gain of the tube necessitates complete isolation of the grid and plate circuits. A good technique is to keep the grid tank under the chassis and the plate tank on top of the chassis.**
- ***Stabilization.*** **In HF service between 3 and 30 Mc, where grid-driving requirements are extremely low, a few ohms of resistance directly in series with the grid will make the circuit extra stable and will not impair the plate efficiency.**
- ***VHF Service.*** **At 6 and 2 meters, neutralization may be required. In some mechanical arrangements, the tube will be over-neutralized—then it may be necessary to *add* a small amount of grid-plate capacitance.**

BASING DIAGRAM

Pin 1—Cathode, Grid No. 3, Int. Shield
Pin 2—Heater
Pin 3—Grid No. 2
Pin 4—Cathode, Grid No. 3, Int. Shield
Pin 5—Grid No. 1
Pin 6—Cathode, Grid No. 3, Int. Shield
Pin 7—Heater
Pin 8—Base Sleeve
Cap—Plate



CHARACTERISTICS AND RATINGS

GENERAL DATA

Heater, for Unipotential Cathode:		
Voltage	6.3	ac or dc volts
Current	0.8	amp.
Transconductance for plate current of 20 ma.	3500	μmhos
Grid-Screen Mu-Factor	6.5	
Direct Interelectrode Capacitances:*		
Grid to plate	0.20 max.	$\mu\mu$f
Input	13	$\mu\mu$f
Output	7	$\mu\mu$f

PEAK HEATER-CATHODE VOLTAGE:	CCS	ICAS	
Heater negative with respect to cathode	100 max.	100 max.	volts
Heater positive with respect to cathode	100 max.	100 max.	volts
Mounting Position		Any	
Maximum Circuit Values:			
Grid-No. 1-Circuit Resistance	30000 max.	30000 max.	ohms

PLATE-MODULATED RF POWER AMPLIFIER—Class C Telephony

Carrier conditions per tube for use with a maximum modulation factor of 1.0

Maximum Ratings, *Absolute Values:*	CCS	ICAS	
DC PLATE VOLTAGE	400 max.	500 max.	volts
DC GRID-No. 2 (SCREEN) VOLTAGE	200 max.	200 max.	volts
DC GRID-No. 1 (CONTROL GRID) VOLTAGE	—175 max.	—175 max.	volts
DC PLATE CURRENT	60 max.	60 max.	ma.
DC GRID-No. 1 CURRENT	3.5 max.	3.5 max.	ma.
PLATE INPUT	20 max.	27 max.	watts
GRID-No. 2 INPUT	1.7 max.	2.3 max.	watts
PLATE DISSIPATION	6.7 max.	9 max.	watts
Typical Operation:			
DC Plate Voltage	400	500	volts
DC Grid-No. 2 Voltage†	160	180	volts
	32000	35500	ohms
DC Grid-No. 1 Voltage	—50	—50	volts
	20000	20000	ohms
Peak RF Grid-No. 1 Voltage	60	60	volts
DC Plate Current	50	54	ma.
DC Grid-No. 2 Current	7.5	9	ma.
DC Grid-No. 1 Current (Approx.)	2.5	2.5	ma.
Driving Power (Approx.)	0.15	0.15	watt
Power Output (Approx.)	13.5	18	watts

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H. S. STAMM ..... *Editor*
J. H. OWENS ..... *Technical Editor*

RF POWER AMPLIFIER & OSCILLATOR—Class C Telegraphy

Maximum Ratings, *Absolute Values:*	CCS	ICAS	
DC PLATE VOLTAGE	500 max.	600 max.	volts
DC GRID-No. 2 (SCREEN) VOLTAGE	200 max.	200 max.	volts
DC GRID-No. 1 (CONTROL GRID) VOLTAGE	—175 max.	—175 max.	volts
DC PLATE CURRENT	75 max.	75 max.	ma.
DC GRID-No. 1 CURRENT	3.5 max.	3.5 max.	ma.
PLATE INPUT	30 max.	40 max.	watts
GRID-No. 2 INPUT	2.5 max.	2.5 max.	watts
PLATE DISSIPATION	10 max.	13.5 max.	watts

Typical Operation:				
DC Plate Voltage	400	500	600	volts
DC Grid-No. 2 Voltage§	190	185	185	volts
	19000	28500	41500	ohms
DC Grid-No. 1 Voltage¶	—30	—40	—45	volts
	10000	13500	15000	ohms
Peak RF Grid-No. 1 Voltage	41	50	57	volts
DC Plate Current	75	60	66	ma.
DC Grid-No. 2 Current	11	11	10	ma.
DC Grid-No. 1 Current (Approx.)	3	3	3	ma.
Driving Power (Approx.)	0.12	0.15	0.17	watt
Power Output (Approx.)	20	20	27	watts

*With no external shielding, and with base sleeve connected to ground.

†Obtained preferably from a separate source modulated with the plate supply, or from the modulated plate-supply through a series resistor of the value shown.

§Obtained preferably from a separate source, or from the plate-voltage supply with a voltage-divider, or through a series resistor of the value shown. The grid-No. 2 voltage must not exceed 600 volts under key-up conditions.

¶Obtained from fixed supply or by grid-No. 1 resistor of value shown.