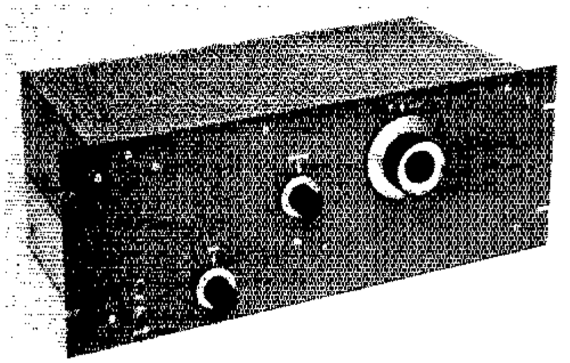
The 144-MHz amplifier is built in conventional rack and panel style, with the entire top of cane metal, to provide free air flow. Controls are grid-circuit tuning, C2, lower left; output loading capacitor, C5, center; and plate-circuit tuning, C4, with vernier dial, right. The slotted end of the Teflon shaft on C1 is visible as a white spot just below the loading control.



# New Ideas for the 2-Meter Kilowatt

## Easy-to-Make Tank Circuit, with Improved Tuning Device

BY THOMAS F. McMULLEN, JR,* W1QVF, AND EDWARD P. TILTON,** W1HDQ

IN DISCUSSING a 50-MHz amplifier built just before this one, the authors included a rationale for the grounded-grid approach to high power for that band.[1] Conversion to grounded-grid was considered for 144 MHz as well, but a low-drive grounded-cathode amplifier still looks like the best bet for high power on frequencies above the 50-MHz band.

While many transmitting tubes work well at 50 MHz, very few are really good much above that frequency. Those that do go higher are not well adapted to grounded-grid service, except for some medium-power types such as the 2C39. External-anode tetrodes (4X150A, 4X250B, 4CX250B, 4CX250R and 8122 are among the more common types) remain the logical choice for a 2-meter amplifier, and they are at their best in grounded-cathode applications. In Class AB1 service they require no driving power, and in Class C a few watts will drive them to better than 70-percent efficiency.

New tubes of this series and the air-system sockets for them are expensive, but both tubes and sockets can be found at times on the surplus market. Early tubes of the 4X150A and 4X250B type are as efficient as their ceramic-insulated replacements, identified by the C in the type number. Glass-insulated tubes will not take quite as severe punishment, but operated within their slightly-lower ratings they work extremely well on the vhf bands.

Sockets found on the surplus market are generally of good quality, but they probably will not have the raised-screen-ring construction of the latest types. Surplus sockets may require screen-ring shielding for effective neutralization, but this is readily installed.[2]

As far as operating efficiency is concerned, our new amplifier has nothing on its *QST* predecessors. Our objectives were mainly greater ease of construction, and a better method of tuning the plate circuit. The disk-type capacitor used in recent 2-meter amplifiers solves some earlier tuning problems, but it tends to cause others. Its effective tuning range is quite limited, and simple lead-screw arrangements may be prone to arcing troubles after appreciable use. Any simple mechanical linkage for driving the screw from the front panel tends to introduce electrical unbalance to ground, which may have to be corrected with another adjustable plate working against the other side of the plate line.

The simple moving-vane arrangement shown here is inherently balanced, in the manner of an ideal split-stator variable. It gets away from the multiple-ground paths and mechanical and electrical unbalance that are unavoidable in conventional capacitors. If it has any weak points, rigorous testing of the amplifier has not turned them up.

Other than in mechanical detail, this amplifier is rather like earlier designs using similar tubes. Its circuit diagram is almost identical, and it was tested on the power supplies and control circuits built for its *VHF Manual* and *Handbook* predecessor.

### Construction

The amplifier is built on a 17 by 8 by 3-inch aluminum chassis, fitted with a bottom cover which completes the shielding and directs the flow of cooling air. The top portion of the enclosure is of similar size, except that it is 3 3/4 inches high, and it has a cane-metal top. It was made by bending up the necessary sheet aluminum, but angle stock and flat sheets could be used equally

* RFD Collinsville, CT 06022.
** VHF Editor, *QST*.

[1] McMullen, "3-500Z Grounded-Grid Amplifier for 50 MHz," *QST*, December, 1970.

[2] "Kilowatt Amplifiers for 50 and 144 Mc.," February, 1964, *QST*. Also, *Radio Amateur's VHF Manual*, all editions, Chapter 6, and *Handbook* editions 1966 through 1970, Chapter 17. See section on neutralizing the 144-Mc amplifier.

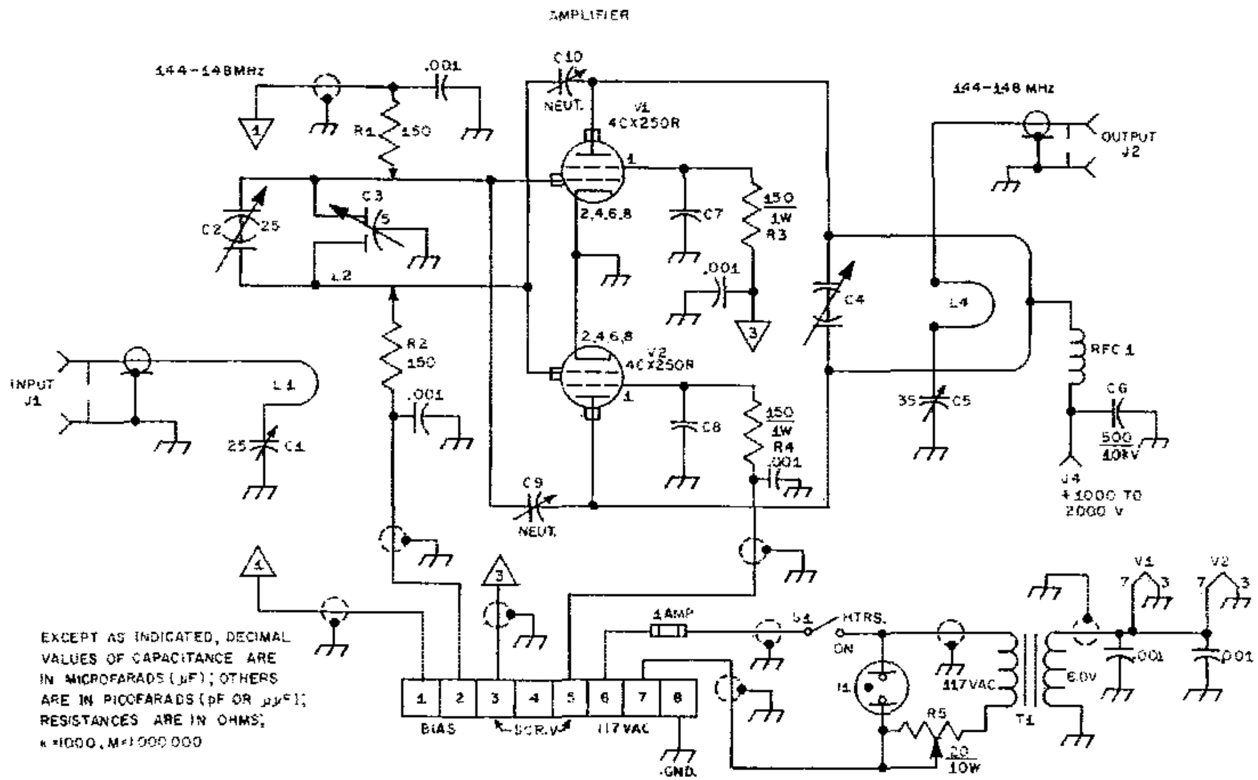
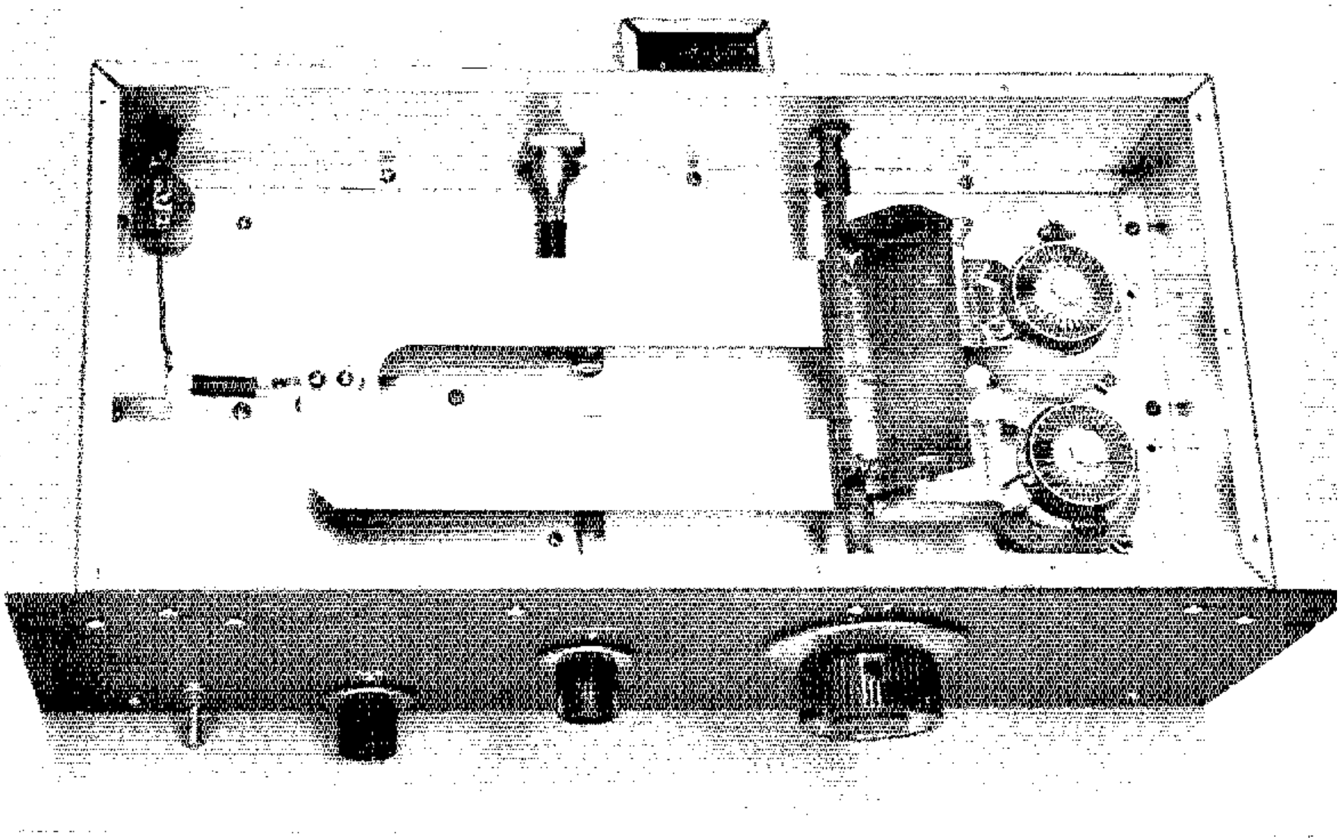



Fig. 1 — Schematic diagram and parts information for the 144-MHz amplifier. Capacitors not described are disk ceramic.

C1 — 25-pF miniature variable (Hammarlund MAPC-25B).
C2 — 25-pF per section split-stator (Hammarlund HFD-25).
C3 — 1.5 to 5-pF differential (Hammarlund MAC-5-5)
C4 — Vane-type tuning capacitor; see text and photos.
C5 — 35-pF variable (Hammarlund HF-35).
C6 — 500-pF 10-kV TV "doorknob."
C7, C8 — Screen bypass; part of Eimac SK-620A socket.
C9, C10 — Neutralizing tabs 1/4 by 5/8-inch sheet copper, soldered to top of National FTB bushing.
I1 — 115-volt neon pilot lamp.
J1 — BNC coaxial jack.
J2 — Type N coaxial jack.
J3 — 8-pin power connector, male.
J4 — High-voltage power connector (Millen 37501).
L1 — Copper strip 1/4 by 4 inches. See Fig. 3.
L2 — 1/4-inch copper tubing 10 1/2 inches long, 15/16 inch center to center. Bend to Y shape 2 inches from tube end.
L3 — .065-inch sheet brass; see text and Fig. 2.
L4 — Copper strip 5/16 by 7 1/2 inches, bent to roughly elliptical shape. See text and Fig. 3.
R1, R2 — 150-ohm composition, 1/2 watt.
R3, R4 — 150-ohm composition, 1 watt.
R5 — 20-ohm 10-watt, slider type.
RFC 1 — 32 turns No. 24 enamel, closewound on 1/4-inch Teflon rod. See mounting position in interior photo.
S1 — Spst toggle switch.
T1 — 6.3-V 6-A. filament transformer (Merit P-2947).



Interior of the 2-meter amplifier, showing the brass plate-inductor and vane tuning system. Note the position of RFC1, at the far left, out of the main rf field. The output coupling loop, L4, just below the plate line and barely visible here, is connected to the output jack, J4, on the rear wall with a short section of coax; and to the loading capacitor, C5, on the front panel by means of copper strip.

well. Angle stock along the rear of the front panel completes the enclosure. The gray-wrinkle aluminum panel is 7 inches high.

The tube sockets are mounted 2 inches in from the right side, as seen in the photographs, and 2 5/8 inches apart, center to center. The Eimac SK620A sockets, with their integral screen-ring shielding, are recommended. Other sockets may require slightly greater spacing, and some modification of the plate-circuit dimensions. The raised screen-ring shield is also a great aid in neutralizing the amplifier. The need for isolating the tubes' screen structure was pointed out in earlier articles, and some form of shield should be added if early flat sockets are used. This need is particularly acute if the amplifier is to be operated in the Class AB1 mode, characterized by very-high power sensitivity.

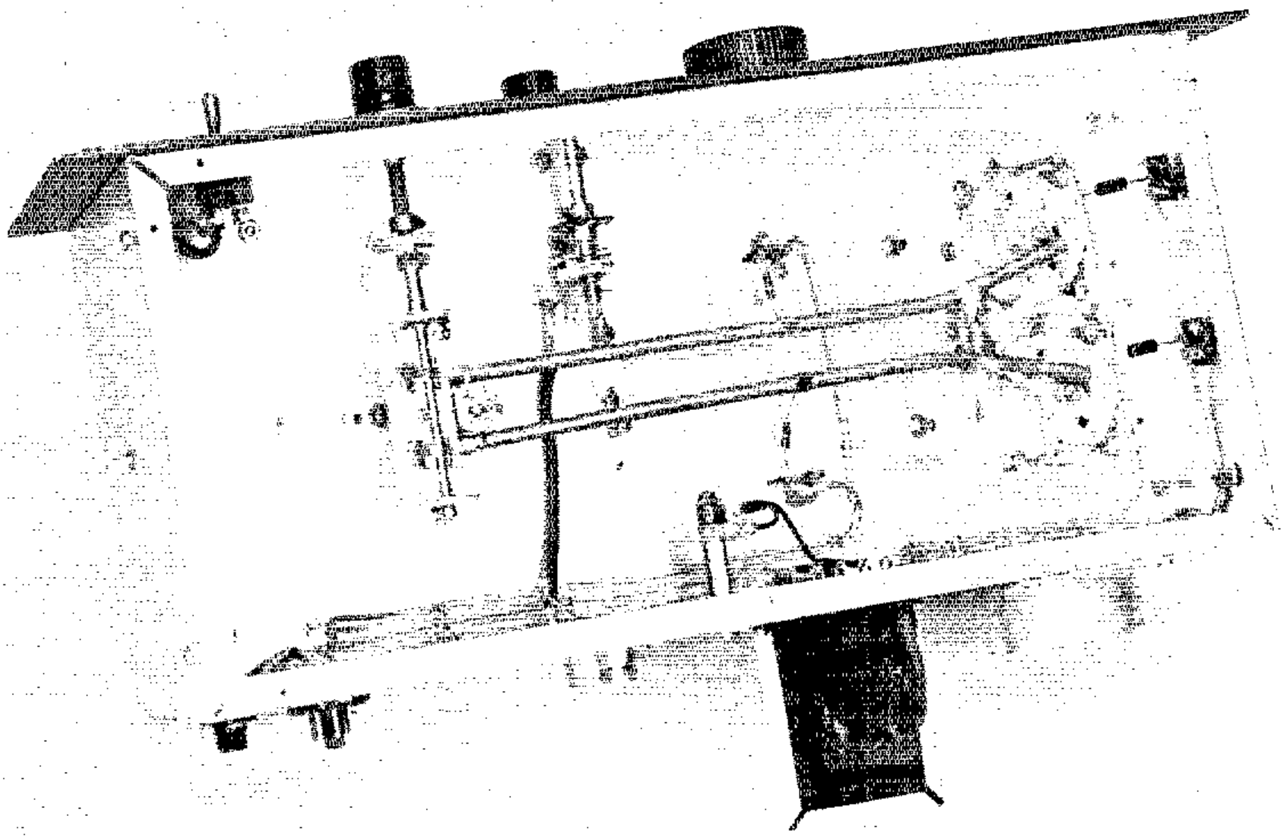
The half-wave-line grid circuit, L2, is tuned at the end away from the tubes by the split-stator variable, C2, and balanced to ground by means of C3, a differential capacitor. This is supported on its stator tabs, which are soldered directly to L2, immediately adjacent to C2. A strap of 1/4-inch copper connects the rotor of C3 to the chassis, in the shortest practical manner. The slotted shaft of C3 is reached through a hole in the bottom cover of the chassis. This hole is sealed with black plastic tape after the adjustment is completed, in order to avoid air leakage.

The input coupling loop, L1, is mounted between and just below the grid lines, with its closed end near the midpoint of the lines. The end toward the panel is soldered directly to its tuning capacitor, C1, and the other to an insulating tiepoint, which also has the center conductor of the RG-58/U coax to J1 connected to it. The position of L1 with respect to L2 can be adjusted by means of an insulating rod, through a hole in the bottom plate near the closed end of the loop. This hole is also taped over to prevent air leakage.

Leads to the neutralizing tabs, C9 and C10, are tapped on the grid lines at a point 1 3/4 inches from the grid end. Feedthrough bushings (not visible in the photographs) are under the lines. The crossover is made by copper strips from the lines to the bushings. Variable capacitance to the plate line is provided by copper tabs 1/4 by 5/8 inch in size, soldered to the top ends of the bushings, just below the plate line, L3. Adjusting their position with respect to L3 provides the required neutralizing capacitance.

Connections to the grid ends of L2 are made with wrap-around copper clips slipped over the tubing ends and fastened to the grid posts of the tube sockets with screws. They are soldered to the line ends, for permanence. The connections to C2 are made in somewhat the same way, except that the tabs are soldered to the stator lugs. Note that the rotor of C2 is not grounded. It is supported on ceramic standoffs 5/8 inch high.

The grid-circuit isolating resistors, R1 and R2, are connected to L2 by means of spring clips which are slid over the line before assembly. These can be tube grid clips, if available. They are moved along the line to the point of minimum rf voltage, using the familiar lead-pencil test.



The principal feature of the bottom view is the half-wave grid circuit. Its split-stator capacitor, C2, is at the left end of the line, L2. The differential balancing capacitor, C3, is also across the line, just to the right of C2. Isolating resistors in the grid circuit, R1 and R2, are near the middle of the picture. The screen isolating resistors, R3 and R4, run to tiepoints on the right wall of the chassis.

The shaft of C2 is rotated through an insulating shaft, fitted with an insulating flexible coupling, to minimize any tendency to unbalance the grid circuit. The shaft from C1 is also insulating material, and it has a flexible coupling. The capacitor is not adjusted often, so the shaft end is slotted, and is allowed to protrude through the front panel. It is just visible in the front view, below the output-loading control.

All power leads are made with shielded wire, bonded together by frequent spot-soldering, and to the chassis by means of grounding lugs. Exposed terminals are bypassed wherever necessary, to prevent rf pickup.

Each cathode pin on the socket is grounded directly through a separate lug, and nothing else uses these lugs for a ground path. Minimum cathode-lead inductance is important, and even the shortest lead shared with another circuit can cause unwanted coupling in a vhf amplifier.

The plate inductor, L3, is made of sheet brass, in the form of a U. Principal dimensions are given in Fig. 2. The stator plates of the tuning capacitor, C4, part A in Fig. 2, are soldered to the plate line with their right edges 5/8 inch from the tube anodes. Connection to the latter is made with two brass tabs, part B in Fig. 2, at the tube ends of the line. These were omitted from the drawing of the assembly in Fig. 2, in the interest of clarity, but their position is clearly visible in the photographs. These tabs are curved slightly after bending, to provide more contact surface to the anode ring. Clamping rings made of flashing copper wrap around the anode structure and hold the tabs tightly to it. This is a point of low rf current, so a large contact area is not vital.

The plate line was made flat originally, but when the amplifier was tested it was found that this did not allow sufficient room to adjust the output coupling loop, L4, to the optimum position. The half-inch offset shown in Fig. 2 (but not in the photographs, as the change was made after the pictures were taken) netted about a 10-percent improvement in efficiency. It may be of interest here, that the entire plate circuit was silver-plated after the photography. Careful checks on performance indicated not the slightest difference, before and after plating. This is not to discourage the builder from doing a plating job, as it may be desirable on a long-term basis. Silver oxide is a good conductor; other oxides are not. Any of the simple rub-on plating methods will do.[3]

The "stators" and the tabs for the anode connection were silver-soldered to L3. If you can't do this, ordinary soldering will be adequate, but it might be well to use screws to hold the tabs onto L3, as a precautionary measure. The stator plates have flat-head screws running through them and L3, into the insulating supports for the latter. These are 1-inch ceramic pillars. The closed end of the loop is supported on a 1 1/2-inch pillar.

The holes for mounting these supports can be made slightly oval, to position the assembly so that

[3]Methods of silver plating at home are given in Chapter 13, *Radio Amateur's VHF Manual*. Immersion electroplating does the best job, but rub-on methods are usable here.

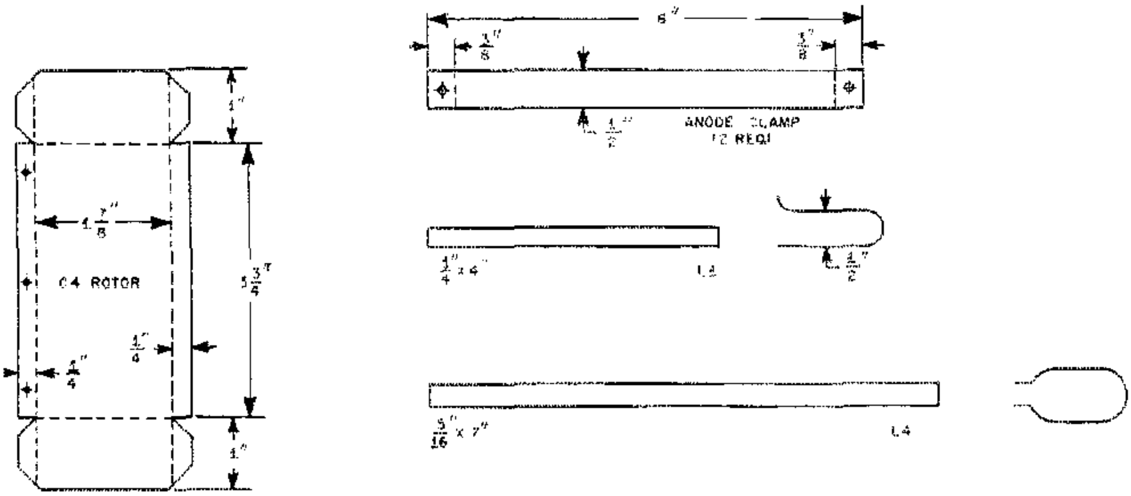



Fig. 2 — Principal dimensions of the brass parts of the amplifier plate circuit. The U-shaped inductor is shown in both top and side views, with the stator plates of C4 in place. These plates (A) are shown before bending, at the upper left. The small brackets (B) make contact with the tube anodes. Slight curvature, to fit tube anode, can be imparted by tapping with a small hammer, against a 1 1/2-inch pipe or rod, used as an anvil.

no strain on tubes or sockets is caused when the anode rings are tightened. Note that the mounting hole in the closed end of L3 is also elongated. The screw that holds the line on its support has Teflon washers above and below L3, to permit the line to move on its support, if expansion and contraction with heating and cooling of the line should be appreciable.

The rotor of C4 is in the form of a shallow box made of flashing copper. It is shown in flat form in Fig. 3, along with other copper parts of the plate circuit. Its ends, 1 inch high, provide the variable capacitance to the stator plates on L3. After the box is bent to the desired form, its adjoining surfaces are soldered for additional strength and rigidity. The edge away from the tube anodes is supported on a fiberglass rod, with 4-40 screws, the rod surface having been filed flat in this area previously. Reducing couplers at each end of the rod permit use of a 1/4-inch shaft bearing at the rear, and a National Velvet Vernier dial mechanism at the front. Do not use heat-sensitive rod such as Lucite or Plexiglas. Nylon and some types of Bakelite are unstable in strong rf fields, and are also unsatisfactory. Teflon is probably good, but the fiberglass rod is stronger and easy to work. It is 6 3/8 inches long, and may be 1/2- or 3/8-inch diameter.

Mechanical stops for the rotor are provided at both ends of its normal travel. A 3/8-inch Teflon rod 1 3/8 inches high, fastened to the chassis between the neutralizing feed-through bushings, stops the rotor in the horizontal position. The rotor is prevented from "going through the roof" by using a 1-inch setscrew in the vernier-drive hub, and a longer-than-normal screw for the lower left mounting screw for the drive assembly. These tricks are visible in the close-up photograph.

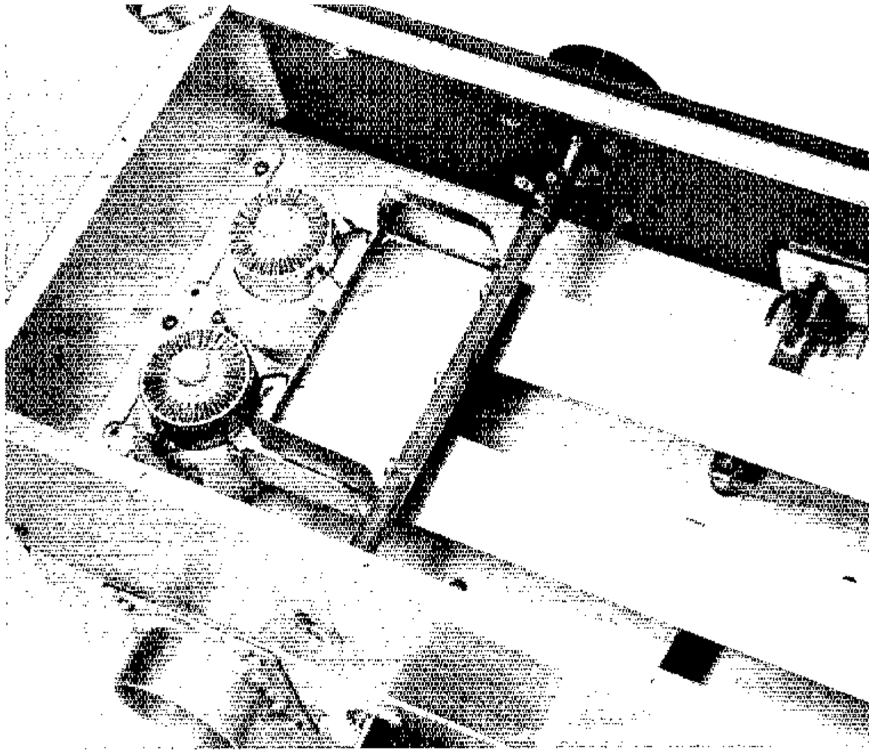
In the final assembly, the rotor in its horizontal position is approximately 1/4 inch above L3, and the spacing at the ends of the rotor is also 1/4 inch. The tubes are fitted with Eimac SK626 chimneys. The under surface of L3 should just clear these. If it does not, it should be raised by putting washers on the screws that run into the 1-inch pillars.

The output loop, L4, is supported under L3 by two 1/2-inch ceramic insulators. Some small pillars have threaded holes that go the whole length. Be sure that the mounting screws do not ground the loop, or come close enough to allow arcing to ground. Connection to the coaxial output jack, J2, is made with a short piece of RG-8/U coax, using a shielding cone at the J2 end. The coax shield is grounded to chassis with a copper strap at the L4 end also, to make the rf path to ground independent of the chassis bonding. The rotor of C5 is also grounded independently. A copper strap connects the stator of C5 to the end of L4. After the final form and size of L4 have been determined, the connection to the strap should be soldered, so as not to leave rf bonding to the mounting screw. These circuits carry high rf currents, and permanent low-resistance connections are important. The performance of many amplifiers falls off with aging, because factors like this were overlooked.

The tube manufacturer states that there should be an air flow of 4.6 cubic feet per minute, minimum, through each tube anode. Much higher blower capacity than this should be provided. The blower used here has a wheel three inches in diameter, turning at 3300 rpm. It is connected to the rear of the chassis by way of a flexible hose 2 1/8 inch in diameter. Automotive defroster hose is fine where one blower may be used for several different amplifiers.

### *Adjustment*

Heater voltage (at the socket) should be 6.0 volts. This is adjusted by means of the slider on R5. Set the sliding clips on L2 at the approximate midpoint. Now apply 1 to 2 watts drive to the grid circuit, adjusting the position of L1 and the tuning of C1 and C2 for minimum reflected power,



Close-up view of the interior, showing details of the tuning device, C4, and connections to the tube anodes. The clamping ring was removed from the upper tube to show the ring and the anode-contact tabs in clearer detail. Note that the output loading capacitor, C5, has its own grounding bracket, so that it does not rely on the panel for ground return.

indicated on an SWR bridge connected between the exciter and J1.

With enough drive so that grid current will be measurable, meter each grid separately, and adjust the balancing capacitor, C3, for as near to the same value for each grid as possible. Readjust C2 for each change. When the currents are approximately equal, the neutralization should be adjusted. With a 50-ohm load connected to J2, and with the screen and plate circuits having some dc path to ground, such as through power supply bleeders, couple a sensitive rf indicator to L3. Still with no plate or screen voltage applied, tune C2 and C4 for maximum indication, then adjust the positions of the neutralizing tabs, C9 and C10, carefully for *minimum* rf feedthrough. Recheck the grid circuit balance and tuning each time a tab setting is changed.

The points of connection of the 150-ohm resistors, R1 and R2, on the lines comprising L2 are not particularly critical, unless the exciter is low on output, but they should be at the points of lowest rf voltage along the line. This is checked readily by running a pencil lead along the line and watching the grid current. The point at which there is no change in the meter indication is where the clip should be. Recheck all adjustments after appreciable change in the connection points.

For initial testing with plate power applied, the plate voltage should be on the order of 800 to 1000, and the screen supply should be no more than 250 volts, preferably regulated. There will be almost no difference in tuning or output, with the cover on or off, so, with due regard to safety, leave it off at first. Never, under any circumstances, reach inside the plate compartment when the power is on. Be *sure* that it *is* off. Using an insulated screwdriver or other safe shorting device, short L3 to the chassis *every time* before making any adjustment inside the compartment. Quite a bit of reaching in will be necessary, but don't let temptation get the better of you. Play it safe. Better a big bang with the screwdriver than a dead or injured operator!

The approximate tuning range of the plate circuit can be checked readily with a grid-dip meter, with no power on the amplifier. It should be considerably wider than the 2-meter band. Now, with an output indicator and a good 50-ohm load connected to J2, the amplifier is ready for power. Apply plate and screen voltage, in that order. Adjust the bias so that the plate current, with no driving power applied, is around 150 mA. Apply drive, and tune C4 and C5 for maximum power output. With enough drive to show about 5 mA grid current per tube, the plate efficiency should approach 70 percent. The position of L4 with respect to L3 has to be adjusted with some care to do this well. The optimum position of the loop and both tuning adjustments, will change with plate voltage and drive level, so adjustment should be made with the operating conditions for which you will want the highest efficiency and best amplifier linearity.

Adjustment of the shape and position of L4 is likely to be the most critical operation. For high-efficiency Class-C operation, we got best results with the loop roughly elliptical in shape, and about 3/8 inch below L3. Efficiency seems to be highest at plate voltages between 1200 and 1800, a condition we've found with other amplifiers using these tubes. The manufacturer's typical operating conditions are your best guide in setting up the amplifier for your circumstances. Bear in mind that these are only *typical*; so long as you do not exceed the various maxima for grid,

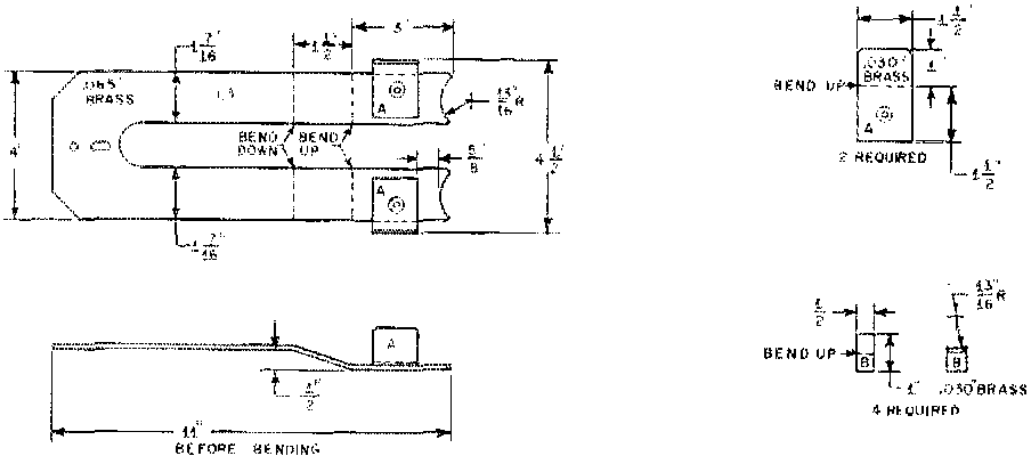



Fig. 3 — Flashing-copper parts used in the 2-meter amplifier. Broken lines indicate 90-degree bending required. The surfaces of the C4 rotor are soldered together after bending, for rigidity. The anode clamps, upper right, wrap around the tube cooling ring, and hold the brass tabs (Fig. 2) firmly in place. L1 and L4 are shown in the approximate shape, after bending, at the right.

screen and plate dissipation, you can have an interesting and profitable time of it experimenting with an amplifier of this kind.

Depending on your interests, many variations are possible. The writers, for example, like an amplifier to work best on high-power cw, with ssb running a close second, and a-m linear a conservative third. With the amplifier set up for the first two conditions, only a slight change in grid drive is needed to go from one to the other. For top performance it is desirable to switch screen voltage, too, and this is done readily enough if something like the previous method of providing regulated 250 and 350 for the screens is used.[4] With Class AB1 linear operation (a-m or ssb) the screen voltage should be 350. If the drive is kept low in going to cw, the screens can be left at 350 volts, but for increased drive and higher efficiency the voltage should be dropped to 250, to avoid excessive screen current.

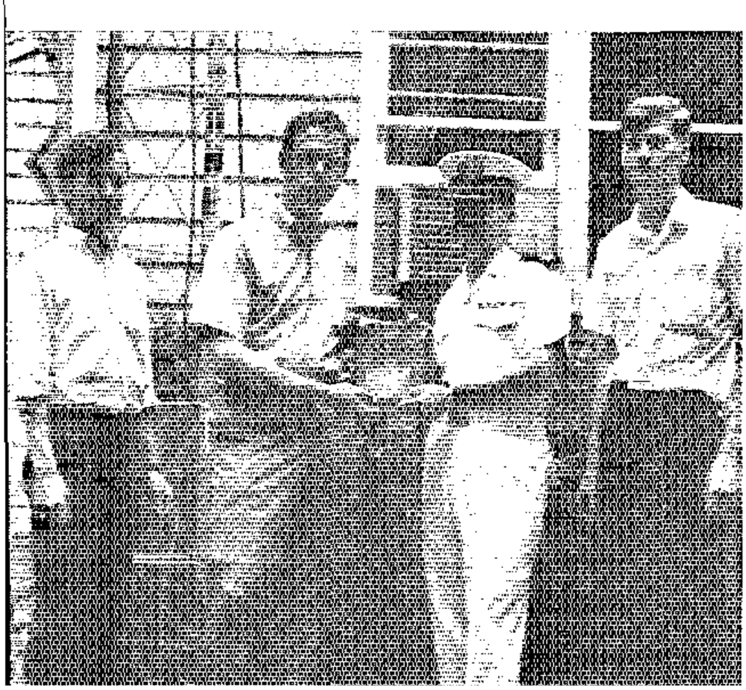
In vhf work it is often desirable to operate at moderate power levels, and this amplifier will drop down nicely. By varying the plate voltage between 800 and 2000, and the grid drive up or down as you wish, a choice of output levels from less than 50 watts to more than 700 is readily available. Linear operation is the critical mode, of course. For more on the fine points of linear adjustment, see any edition of the *Handbook* or the *Radio Amateur's VHF Manual*.

Our amplifier combines a few new ideas with many old and well-proven ones. In addition to the references footnoted in the text, the following *QST* articles are worth reviewing, if you are embarking on a vhf amplifier project:

Maer, "Perseids Powehouse," October, 1959. (Two-band amplifier, 50 and 144 MHz.) "High-Efficiency 2-Meter Kilowatt," February, 1960. (Uses 4CX-300As.) Breyfogle, "Top Efficiency at 144 Mc. with 4X250Bs," December, 1961.

[4]See section on controls and metering, Reference 2. A recommended addition is a bleeder from screen to ground. If this is connected to the positive side of the screen meter to ground in the circuit shown in this reference, the current it draws will not be added to the screen current indicated on the meter. About 25,000 ohms, 10 watts, will do.

## Strays



Dave Porter, K2BPP, is shown receiving from Lt. Douglas Zaugot a plaque commemorating the 50,000th phone patch handled by Dave for men in the Antarctic during the past 15 years. From left are Rich Hill, Dave, K2BPP, Lt. Zangot, and Rick Hagen. As an additional expression of appreciation, the men at "Operation Deep Freeze" will play host to Dave for a one-week visit during December (that's summertime on the ice!).