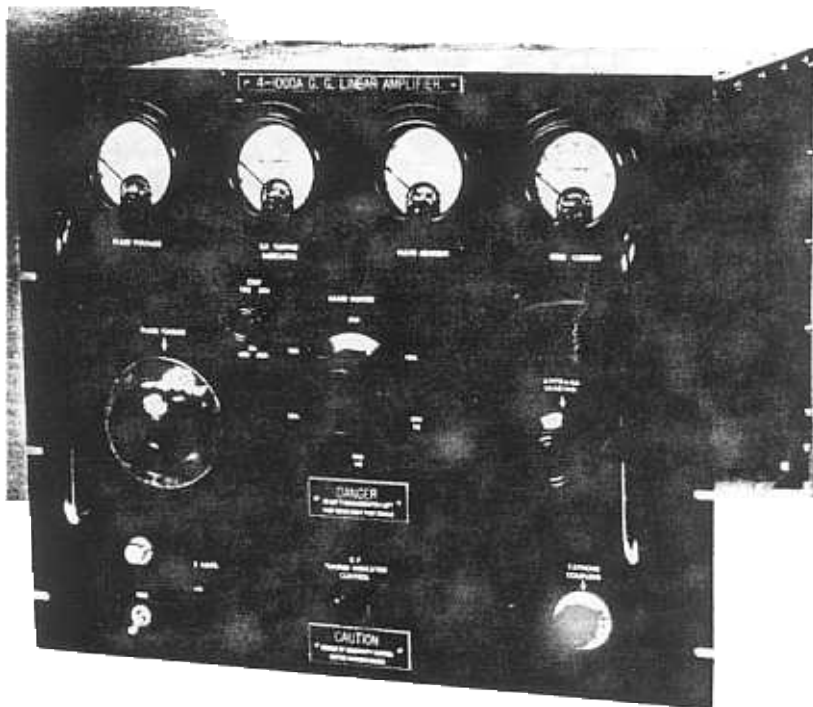


Fig. 1—K9LKA's kilowatt 4-1000A grounded-grid amplifier. Meters across the top of the panel are, from left to right, for plate voltage, relative r.f. output, plate current and grid current. The band-switch control is in the center, flanked by the plate tuning control and capacitor switch  $S_2$  on the left, and the output loading control on the right. Along the bottom are the filament switch, panel lamp and fuse; r.f.-indicator sensitivity control, and the input tuning control.



*Most high-power triodes available at surplus prices do not have a sufficiently high amplification factor to permit zero-bias operation. Tetrodes may be converted to high- $\mu$  triodes by connecting the screen to the control grid. However, in the case of most tetrodes, this connection results in excessive control-grid dissipation at the driving-power level required to obtain normal rated output. The 4-1000A is one of the few exceptions to this rule<sup>1</sup> and is also one that is available in usable condition at relatively low cost from a number of sources. The triode connection results in considerable circuit simplification, especially in grounded-grid operation, since regulated bias and screen supplies are eliminated and neutralization is not required.*

## Zero-Bias Triode Operation in a 1-Kw. Linear

By LARRY KLEBER,\* K9LKA

**M**ANY construction articles describe radio gear that is almost impossible to duplicate with facilities available to the ordinary ham because of unusual mechanical requirements. Complicated gearing, chain drives or special metal shapes that require power tools found only in machine shops sometimes cause an otherwise excellent article to be passed by. In addition to the mechanical problems, cost is frequently completely out of reach for the would-be constructor.

Here is a kilowatt linear amplifier covering 10 through 80 meters that has several features to recommend it to the fellow who wants to increase power. First of all is the cost. Using all new parts, except the meters which are readily

available from used- or surplus-equipment sources, the total expenditure will be less than \$150 plus the cost of the tube. If you are willing to do some horse trading, scrounging and junk-box raiding, you can do it for considerably less. Type 4-1000As from broadcast or police radio transmitters are readily available at prices from \$20 to \$50. Surplus JAN tubes are listed by several *QST* advertisers, and they are regularly offered in Ham-Ads. Remember, the Eimac 4-1000A is built like a Mack truck and, once you have acquired one of these tubes in good condition, you can expect years of satisfactory service if you don't abuse it by overdriving the grid. That is why a grid-current meter is mandatory.

Secondly, construction is extremely simple. All mechanical work can be performed with ordinary hand tools. An electric drill will cut the con-

\* 922 Whitney Blvd., Belvidere, Illinois.

<sup>1</sup> The Eimac data sheet on the 4-1000A as a grounded-grid triode qualifies this by adding, "... if a plate voltage of at least 3000 volts is used." — Editor.

*Tank coil 4 turns on propane can*

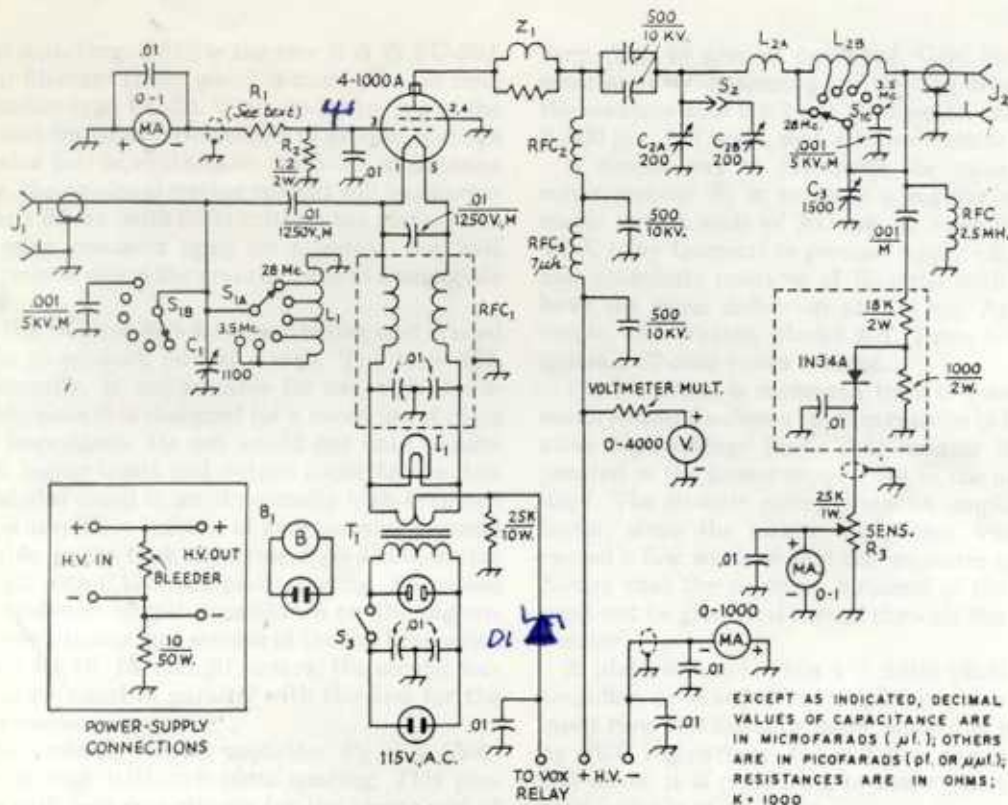


Fig. 2—Circuit of the 4-1000A grounded-grid amplifier. The 500-pf. 10-kv. fixed capacitors are TV doorknob type; others are 1-kv. disk ceramic, except M indicates mica.

- B<sub>1</sub>—Centrifugal blower, 60 c.f.m. at 0.6-inch static pressure (Ripley 8472).  
 C<sub>1</sub>—Triple-section broadcast-replacement-type variable, 365 pf. or more per section, sections connected in parallel.  
 C<sub>2</sub>—Dual air variable, 200 pf. per section, 7000 volts (Johnson 152-503/200CD70).  
 C<sub>3</sub>—Air variable, 0.03-inch plate spacing (Cardwell PL-8013 or B & W 51241).  
 L<sub>1</sub>—6-8-volt panel lamp.  
 J<sub>1</sub>, J<sub>2</sub>—Chassis-mounting coaxial receptacle (SO-239).  
 L<sub>2</sub>—6 turns No. 10, 1½-inch diam., 1½ inches long, tapped at 1¼, 1½, 2½, and 4½ turns from ground end.

*D<sub>1</sub> 50W Zener*

\* The Cardwell capacitor is listed in the 1963 Allied catalog. The B & W capacitor, which is identical, is not stocked by B & W as a retail item, and may or may not be available at any particular time, depending on manufacturing needs. It is advisable to check with B & W before ordering from this source.

- L<sub>2</sub>—Approximately 14 μh., tapped at 7, 3.5, 2.5 and 1.75 μh. (Barker & Williamson 850A band-switching inductor).  
 R<sub>1</sub>—Approx. 27 ohms; see text.  
 R<sub>2</sub>—Made up of four 4.7-ohm ½-watt carbon resistors in parallel.  
 R<sub>3</sub>—Linear control.  
 RFC<sub>1</sub>—30-amp. bifilar filament choke (B & W FC30A).  
 RFC<sub>2</sub>—Solenoid r.f. choke (B & W 800).  
 RFC<sub>3</sub>—Solenoid r.f. choke (Ohmite Z-50).  
 S<sub>1A-B</sub>—Single-section double-pole six-position ceramic rotary switch, 60-degree index (CRL 2551).  
 S<sub>1C</sub>—Heavy-duty single-pole six-position rotary switch (part of L<sub>2</sub> coil assembly, modified as described in the text).  
 S<sub>2</sub>—See text.  
 S<sub>3</sub>—S.p.s.t. toggle switch.  
 T<sub>1</sub>—7.5-volt, c.t., 21-amp. filament transformer (Stancor P-6457, Chicago F-725).  
 Z<sub>1</sub>—2 turns No. 8, ½-inch diam., shunted by three 150-ohm 1-watt carbon resistors in parallel.

*Z<sub>1</sub> 2 turns ½ wide copper wire*

offers several advantages for sideband operation. First, no grid-bias or screen-voltage power supplies are needed. In addition, the drive level of this grounded-grid stage is compatible with the power-output level of modern sideband exciters. Finally, neutralization is not required.

### The Circuit

The circuit of the amplifier is shown in Fig. 2. Excitation is fed to the filament through a 0.01-μf. 1250-volt (working) mica capacitor. A ceramic capacitor is not suitable for coupling since it will not stand the current. The cathode coupler, consisting of C<sub>1</sub> and L<sub>1</sub>, does an excellent job of

struction time considerably, but it is not an absolute necessity. The meter holes can be cut with a bit brace, or with a hand drill and file. Best of all, every single component is standard merchandise and is readily available. Your favorite ham supplier may not have every item in stock, but he should be able to get any of them for you in a hurry.

### Triode Operation

The 4-1000A may be connected for high-μ triode operation by placing the grid and screen elements at the same d.c. and signal potentials; in this case, both are grounded. This connection



input matching.  $RFC_1$  is the new B & W FC-30A bifilar filament choke which is more efficient than the earlier type FC-30. With the center tap of the filament transformer returned to ground through an extra pair of contacts on the VOX or antenna relay, the no-signal resting current will be approximately 60 ma. with 3000 volts on the plate. With the relay contacts open on standby, the 25K bias resistor drops the plate current to a negligible value.

A B & W type 850-A coil-switching unit is used in the pi-network output circuit. The type 852, incidentally, is not suitable for use with the 4-1000A, since it is designed for a much lower plate load impedance. Its use would not only require much higher input and output capacitances, but would also result in an abnormally high- $Q$  circuit in this amplifier. Instead of an expensive vacuum variable for the tank capacitor,  $C_2$  is a split-stator air unit with 0.175-inch plate spacing. To reduce the minimum circuit capacitance on the higher-frequency bands, one section of the dual capacitor is used for 10, 15, and 20 meters; the second section is switched in parallel with the first for the lower frequencies.

The variable output capacitor  $C_3$  is a 1500-pf. unit with 0.03-inch plate spacing. This provides sufficient capacitance for the phone end of the 80-meter band. However, more capacitance will usually be required for the low-frequency end of this band, and this is provided by connecting a fixed 0.001- $\mu$ f. mica capacitor in parallel with  $C_3$  in the last position of  $S_{1C}$ .

#### Parasitic Suppression

Several different makes of chokes were tried at  $RFC_2$  in conjunction with many different resistance-inductance combinations in the v.h.f. suppressor  $Z_1$ . However, it was found practically impossible to completely eliminate parasitic oscillation on all bands until the B & W type 800 choke was tried.

#### Metering

Grid current is monitored very simply. The control grid is grounded through four 4.7-ohm  $\frac{1}{2}$ -watt composition resistors in parallel, bypassed by a 0.01- $\mu$ f. disk ceramic capacitor. The RC combination serves to hold the control grid

very close to ground potential. Grid current is monitored by measuring the voltage drop across the resistors with the 1-ma. grid meter, calibrated 0-300 ma. full scale, and a series resistor.

A simple way to determine the value of the series resistor  $R_1$  is to place a regular milliammeter with a scale of 200 ma. or more from the VOX relay terminal to ground. Apply excitation, and substitute resistors at  $R_1$  until both meters have the same deflection at 150 ma. As an example, the Weston Model 301, 1-ma. meter requires a 27-ohm series resistor.

Plate current is measured by a 0-1-amp. d.c. meter shunted across a 10-ohm resistor in the negative high-voltage lead. This resistor is incorporated in the power supply, not in the amplifier itself. The 50-watt rating gives an ample safety factor, since the power dissipation would not exceed a few watts should the ammeter open up. Notice that the negative terminal of the supply must not be grounded except through the 10-ohm resistor.

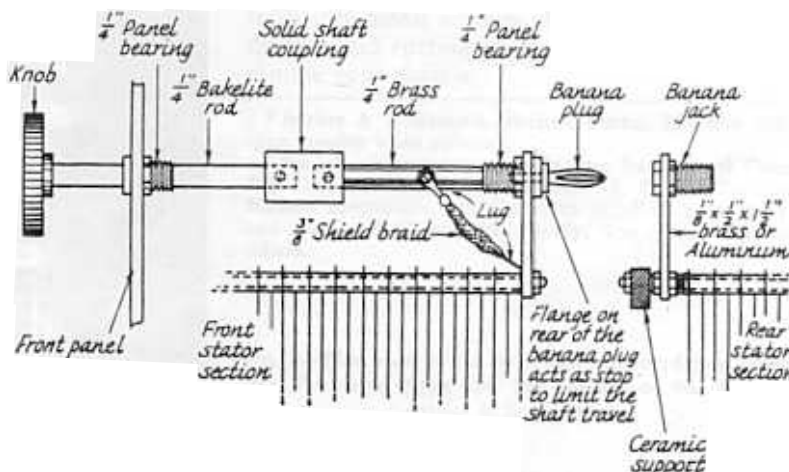
A plate voltmeter has a definite place in this amplifier, or in any other amplifier where the d.c. input runs 900 watts or more, since it is required by FCC regulations. Even if you run less than 900 watts, it is reassuring to know exactly what your input is at all times.

To continuously monitor the r.f. output level of the amplifier and to aid in efficient tuning, a simple r.f. voltmeter has been incorporated in the circuit. Absolute readings are not necessary, so provision has been made for varying the sensitivity by adjustment of  $R_3$ .

#### Component Modification

Some of the components require minor modification before mounting. The last rotor plate and the last stator plate of the rear section of the tank capacitor  $C_2$  are removed. This is section  $C_{2A}$  in the diagram, which is used alone on the higher frequencies. The operation is simple and requires no special tools. The alteration reduces the minimum capacitance to permit a more favorable  $Q$  on 10 meters. To further reduce the minimum circuit capacitance, the stators of  $C_2$  are moved farther away from the chassis by mounting the capacitor in an inverted position; that is,

Fig. 3—Sketch showing details of the tuning-capacitor switch,  $S_2$ . The stator sections are connected in parallel when the panel control knob is pushed to engage the plug in the jack.



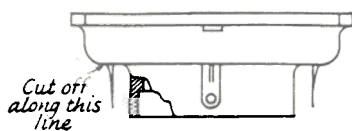


Fig. 4—Sketch showing how the lower portion of the tube socket is cut off.

with the stators on top. The mounting feet of the Johnson capacitor are easily moved to permit mounting in this manner, since the capacitor frame has duplicate mounting holes.

Fig. 3 shows the device used for  $S_2$ . Similar metal brackets are attached to adjacent ends of the stator-assembly rods of the dual capacitor. The bracket on the rear end of the front capacitor section ( $C_{2B}$ ) carries a  $\frac{1}{4}$ -inch panel bearing through which a 3-inch length of  $\frac{1}{4}$ -inch brass rod slides. One end of this rod is drilled and tapped to accept the threaded shank of a banana plug. The other end of the brass rod is coupled to a  $3\frac{1}{8}$ -inch length of  $\frac{1}{4}$ -inch bakelite rod which passes through another bearing in the panel to the control knob. The shaft coupler should be of the rigid type, either metal or ceramic. To assure good contact between the stator of  $C_{2B}$  and the banana plug, a piece of  $\frac{3}{8}$ -inch flexible copper braid is used to connect the two directly, rather than to depend on the sliding contact at the bearing.

The banana jack is mounted on the other bracket. Be sure that the two brackets are drilled identically so that the plug and jack may be lined up accurately.

One other slight modification was made in the capacitor before mounting. A small triangular bracket was mounted inside the rear frame plate, that is, between the capacitor sections. This was fastened in place using the same screws which hold the ceramic stator bar against the frame plate. The upper point of the triangle extends sufficiently above the frame plate to allow mounting a 1-inch ceramic pillar. After the components were mounted on the chassis, the open end of the 10-meter section of  $L_3$  was removed from the coil assembly, turned end for end, and fastened

between the ceramic end plate and the ceramic pillar. A short length of  $\frac{1}{4}$ -inch copper tubing, also fastened to the ceramic pillar, connects the coil to one side of the blocking capacitors. Another short length of tubing connects the rear stator terminal of  $C_{2A}$  to the same point.

It will be noted that the 0.001- $\mu$ f. fixed output capacitor requires an additional switch position. Fortunately, this is not difficult to provide, since there is already a hole for an extra stationary contact in the ceramic end plate of the B & W coil unit. All that is necessary is to obtain a switch contact from B & W<sup>2</sup> for one dollar (or make a reasonable facsimile) and mount it in the spare hole.

The socket for the 4-1000A is Eimac's new plastic type SK-510 (amateur net \$6.50). It is designed primarily for duct connection to a blower. For the pressurized-chassis ventilating system used here, you can improve the air flow by cutting off the "nose" of the socket with a hacksaw, as shown in Fig. 4. Remove the socket contacts while this operation is performed, to avoid damaging them. Use extreme care in sawing. Although the socket is made of a tough plastic, unusual stress or strain may cause it to break.

You will note that the socket has slots next to the pins, right in the side of the molded fixture. To ground the two screen leads, pass a  $\frac{1}{4}$ -inch copper ground strap through the slot and solder it to the bottom of the screen contact inside the socket; then ground the strap to the chassis at the point where it emerges from the socket. The grid bypass capacitor should be installed in the same manner. One lead passes through the slot and is soldered to the bottom of the grid contact, while the other lead is grounded to the chassis. The leads should be only  $\frac{1}{4}$ -inch long.

### Construction

The 14 × 17 × 4-inch chassis is made up of a pair of SeeZak<sup>3</sup> R414 rails (4 by 14 inches), a pair of R417 rails (4 by 17 inches), and two P1417 panels (14 by 17 inches). Standard 13 × 17 × 4-inch chassis are readily available, of course, but the extra inch of depth provided by the SeeZak units is necessary to accommodate  $C_2$  which has a length of  $13\frac{1}{16}$  inches. Machining of the front and rear chassis walls and the top deck is greatly simplified by using these handy rails and panels. No more trying to get big fingers and tools into small corners. You can do all of the drilling and cutting on flat plates, and then assemble your chassis.

<sup>2</sup> Barker & Williamson, Bristol, Penna. Mention 850A type number when ordering.

<sup>3</sup> SeeZak products are available from Radio Shack Corp., 730 Commonwealth Ave., Boston 17, Mass., Terminal Hudson Electronics, 236 West 17th St., New York, N. Y., and California Electronics Supply, Los Angeles, among others.

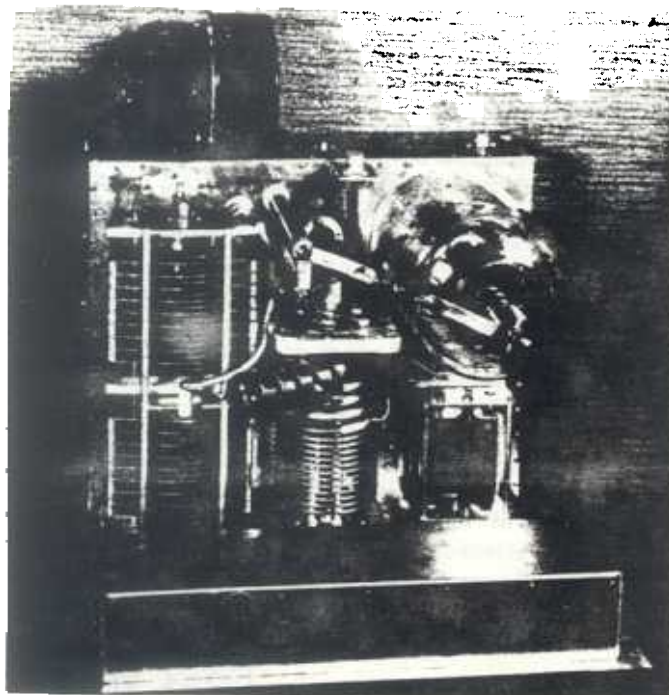


Fig. 5—Plan view of the 4-1000A grounded-grid amplifier. This view shows how the position of the 10-meter section of  $L_2$  is changed.

### Cathode Coupler

Place  $S_1$ ,  $L_1$ , and  $C_1$  close to the tube socket, as shown in Fig. 6. In this amplifier, Millen type 39005 universal-joint couplings were used between the shaft of  $C_1$  and the front panel to allow the control to be placed symmetrically in respect to others on the panel. Even though the shaft and rotor of  $C_1$  are at ground potential, use an insulated shaft coupling to couple the indicator dial to avoid the possibility of setting up a spurious tuned circuit. If you don't gang the input and output band switches, as described presently, use an extension shaft on the input switch so that the switch can be placed close to the tube socket.

### Ganging the Switches

It is not difficult to gang  $S_{1A-B}$  and  $S_{1C}$  to provide single control. This can be accomplished by means of a National type RAD geared right-angle shaft coupler. A Johnson rigid ceramic shaft coupler (type 104-252) is attached to the tail shaft of the B & W coil unit. A short length of  $\frac{1}{4}$ -inch brass rod couples the gear end of the right-angle drive to the ceramic coupler.  $S_{1A-B}$  is mounted below deck with its shaft extending through a clearance hole in the chassis so that the shaft can be lined up with the shaft of the right-angle drive. The two shafts are coupled together by means of a ceramic semiflexible coupler (Johnson 104-262). Since the switch on the B & W coil unit has 60-degree indexing,  $S_{1A-B}$  must have the same indexing, rather than the more common 30-degree indexing. The 60-degree switch is, however, a standard item in the manufacturer's catalog. A 30-degree switch may be used, of course, if ganging is dispensed with.

### Wiring

As the photographs indicate, very little actual wiring is required. The positive high-voltage lead enters the rear of the chassis through a Millen high-voltage connector where it immediately connects to the first 500-pf. bypass capacitor.  $RFC_3$  is mounted between this capacitor and a feedthrough insulator which is connected to one side of the voltmeter multiplying resistor. The feedthrough carries the high voltage through to the top of the chassis where it connects to the second 500-pf. capacitor mounted on the chassis, and to the bottom end of  $RFC_2$ . A tapped ceramic pillar insulator threads onto the top terminal of this capacitor. The two blocking capacitors are suspended from a short copper strap fastened across the top end of the insulator, and a second strap connects them to the top of the r.f. choke. The parasitic suppressor  $Z_1$  is inserted at the center of a copper strap connecting the top of  $RFC_2$  to the plate cap of the tube.

Since the high- $C$  input circuit carries considerable current, the r.f. wiring should be done with reasonably heavy wire (I used No. 10). This includes the short between the 80-meter contacts of  $S_{1A}$ .

A lead attached to the stator of  $C_3$  passes down

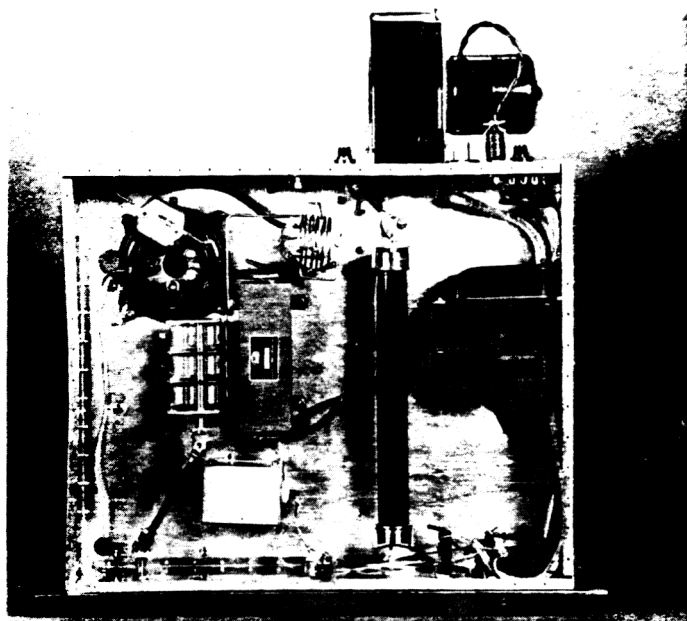


Fig. 6—Bottom view of the 4-1000A amplifier. The filament transformer and voltmeter multiplier resistor are to the right. The input coil,  $L_1$ , is at top center, supported on  $S_{1AB}$  by its leads. Input capacitor  $C_1$  is operated through a pair of universal-joint shaft couplers so that the capacitor may be placed close to the tube socket without upsetting panel-layout symmetry. The small shielding box ( $2\frac{1}{4} \times 2\frac{1}{4} \times 1\frac{1}{2}$ -inch Minibox), below the bifilar filament choke, houses the r.f. output-indicator diode and associated components.

through the chassis via a second feed-through insulator to the box below containing the r.f. output-indicator components. A short section of RB-8 U connects the stator of  $C_3$  to  $J_2$ . Be sure to ground both ends of the outer conductor.

### Blower Mounting

Don't compromise on the blower. The 4-1000A requires 60 c.f.m. at 0.6 inch of static pressure. Some so-called 60-c.f.m. blowers aren't worth their salt when you try to pressurize the chassis. The blower suggested does an excellent job in this respect, and is priced quite reasonably.

Be sure to place the blower well away from the tube socket. If it is placed too close, it will create a pressure wall across the bottom of the socket which will tend to restrict the flow of air through the base and chimney.

An a.c. receptacle is set in the rear apron of the chassis and a short cord from the blower motor plugs into it.

### The Panel

The panel is a standard  $15\frac{3}{4} \times 19 \times \frac{1}{8}$ -inch unit of aluminum. The four meters are in line across the top. A  $4 \times 17 \times 3$ -inch aluminum chassis fits over the back of the line of meters to shield them from r.f. fields. It is held in place by eight No. 6 sheet-metal screws inserted from the front. Shielded meter leads (Belden 8882 wire) are brought up from below chassis through rubber grommets in the chassis and in notches filed in the bottom front corners of the meter enclosure.

The panel is fitted with chrome handles (Bud type H9113) for lifting the amplifier in and out

of the rack mounting. They also serve to protect the controls if it becomes necessary to place the unit face down on your workbench for service.

The lettering was done with Tekni-Cals, and the engraved plates are obtainable from Central Engravers <sup>4</sup> at 5 cents per letter.

#### ***The Shielding Enclosure***

The two ends and the back of the shielding enclosure are made of 0.51-inch solid sheet aluminum, while the top is made of perforated sheet of the same weight. One of the SeeZak P1417 panels is used for the bottom cover. Aluminum angle stock, 1/2 inch by 1/2 inch, is used to join the pieces with the help of 1/4-inch No. 6 sheet-metal screws spaced every two inches. All of the above pieces, including the angle stock, may be obtained cut to size if desired.<sup>5</sup>

#### ***Adjustment***

After checking out the filament circuit and grounding the center tap of  $T_1$ , reduce the sensi-

<sup>4</sup> 529 South State, Belvidere, Illinois.

<sup>5</sup> From Dick's, 62 Cherry Ave., Tiffin, Ohio.

tivity control of the r.f. voltmeter to near minimum. Select the proper band with  $S_1$  and apply excitation. Adjust  $C_1$  for a grid current of approximately 150 ma. Apply plate voltage and load, and resonate the output circuit with  $C_2$ . With a plate voltage of 3000 and grid current of 160 to 170 ma., alternately adjust  $C_3$  and  $C_2$  to increase the plate current to 300 ma. or slightly over. In observing the r.f. voltmeter, you will note that maximum output does not always occur at the point of resonance as indicated by the dip in the plate current.

The amplifier may be checked for linearity as described in the *Radio Amateur's Handbook*.

I am very grateful for the technical advice and suggestions of Bill Orr, W6SAI, and George Stinson, W9KDK. Their analysis of the problems encountered, as well as their suggestions for changes during construction, made this a much better amplifier, and a pleasure to build. Operating at an input of 1 kw. or less, this amplifier actually "coasts" and will give you years of trouble-free service.

**QST**

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*Reprinted from July 1963 QST*