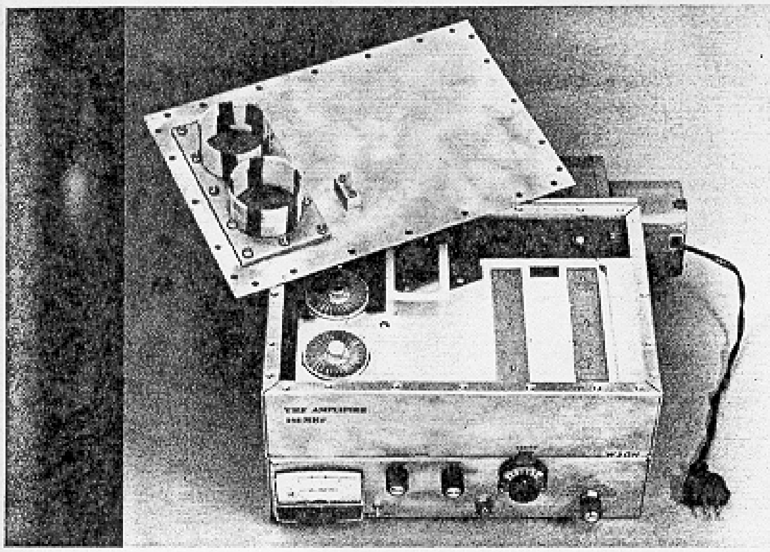


stripline kilowatt

for two meters

Complete layout and construction details for a compact two-meter kilowatt based on the popular K2RIW design for 432 MHz

The stripline rf power amplifier designed by K2RIW for 432 MHz and described in *QST* several years ago has gained wide acceptance and use.[1] At the present time it's estimated that 300 to 400 of these amplifiers are in use around the world. The techniques outlined by K2RIW — using a pair of inexpensive ceramic tetrodes in a parallel stripline configuration — were used in a two-meter power amplifier designed by W9OJI.[2] A number of other single-tube stripline power amplifiers for two meters have also appeared in the amateur magazines. In this article I will try to put all this background and experience into construction information for a two-meter power amplifier packaged in the same compact box as K2RIW's original design for 432 MHz. Such a unit could possibly become as popular on 144 MHz as the K2RIW amplifier has on 432.

Several stripline power amplifiers based on the layout described in this article have already been built and thoroughly tested on the air. When operated in the class AB1 linear mode, the amplifier provides 600 watts output with 6 to 8 watts drive. The all-mode two-meter transceivers now on the market have more than ample output to drive this amplifier to full output; the sharply tuned circuits in the amplifier help to attenuate any out-of-band products from the driver.

Any of the tubes from the 4CX250 series are suitable for the amplifier. However, the cooling problem is simplified by using 8930 tubes which are similar to 4CX250Rs except that they have a 2-inch (50mm) diameter anode. The dimensions for the plate line, chimneys, and top cover will be given for both tube types, but 8930s are the recommended choice.

Referring to the schematic, **fig. 1**, the plate line is a quarter wavelength long, with the plate blocking capacitor in the form of a Teflon sandwich at the cold end. Plate tuning is accomplished by a combination of fixed copper plate and beryllium copper flapper capacitor mounted below and near the plate end of the line, **fig. 2**. The capacitive loading to the output is adjusted by a flapper capacitor above the plate line which is also at the plate end of the line.

By Fred Merry, W2GN, 35 Highland Drive, East Greenbush, New York 12061

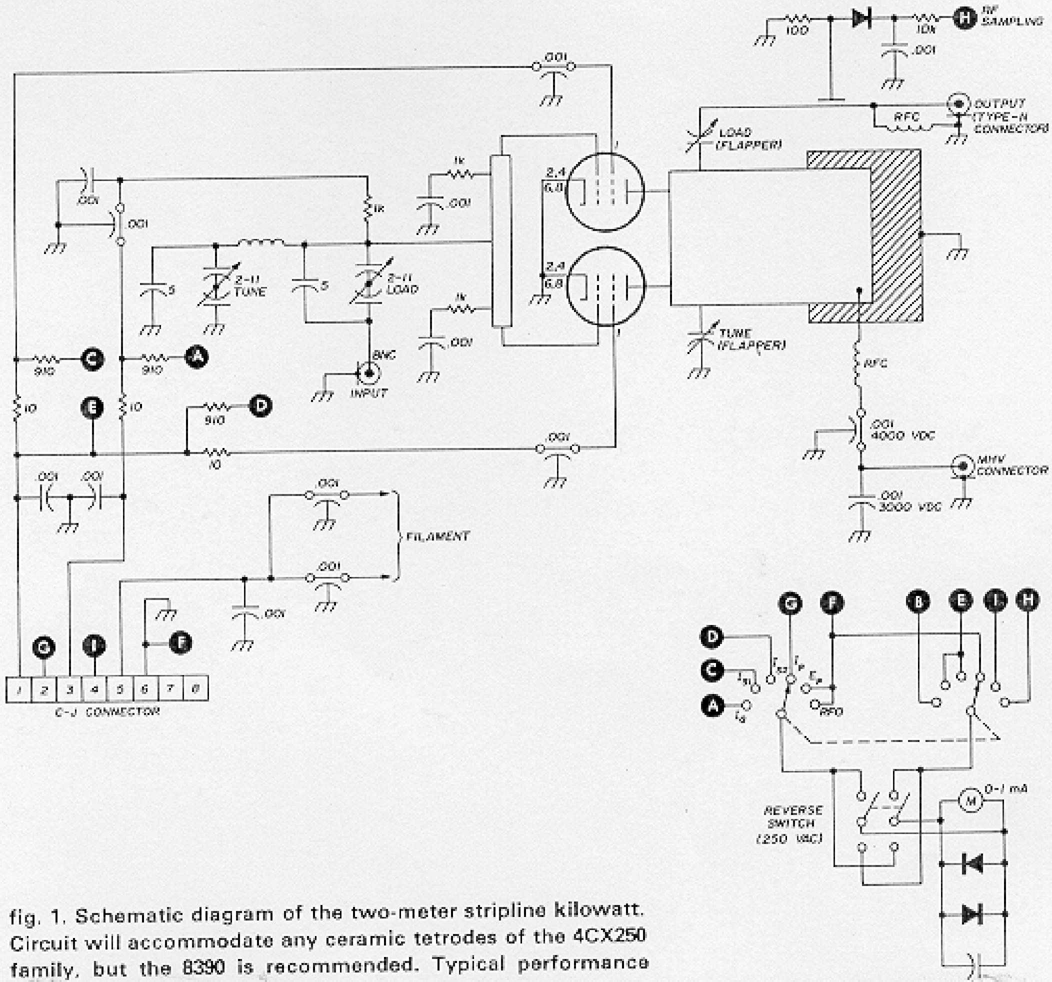
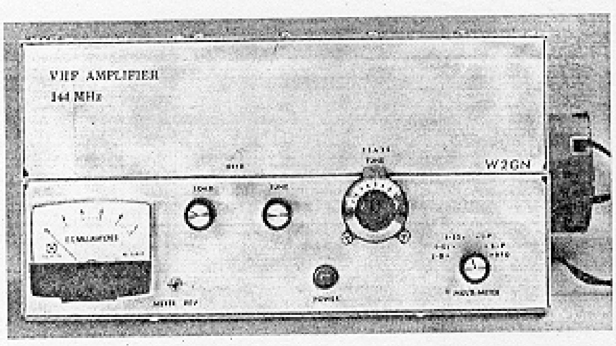


fig. 1. Schematic diagram of the two-meter stripline kilowatt. Circuit will accommodate any ceramic tetrodes of the 4CX250 family, but the 8390 is recommended. Typical performance data for this amplifier is listed in table 1.

The grid circuit consists of a 3-turn inductor tuned by a butterfly capacitor at the end away from the grids. Capacitive coupling is used for the input circuit. Eimac 620A or 630A sockets plus the construction and bypassing techniques used provide stability. Stability is further assured by loading the grid circuit down to approximately 300 ohms (derived from the grid bias resistor and two other 1000-ohm resistors mounted close to the grid socket connections of each tube, **fig. 1**).



Stripline kilowatt for two meters is compact, and measures only 6-inches (15cm) high, 12-inches (30.5cm) wide, and 8-inches (20cm) deep.

Chassis construction involves the use of three standard chassis: two 8 x 12 x 3 inches (20.3x30.5x7.6cm) and one 5 x 7 x 3 inches (12.7x17.8x7.6cm), plus a top plate and a bottom cover. The chassis preparation is covered by the illustrations accompanying this article which include complete drilling, punching, and cutting details. A good starting point is the top cover which is a piece of 3/32-inch (2.5mm) thick aluminum cut and drilled as shown in **fig. 3**. The large holes are made with a hole saw, 2-1/4 inches (5.7cm) for 8930 tubes, or 1-3/4 inches (4.5cm) for 4CX250s. The vent plate, which is 3/16-inches (4.5mm) thick can also be drilled and hole sawed at the same time. A piece of aluminum screening is cut to the size of the vent plate; the screen is fastened between the top plate and the vent plate with 1/2-inch (12.5mm) long screws, 6-32 (M3.5) lockwashers, and nuts.

The plate loading adjustment block is cut from a piece of 1/2-inch (12.5mm) square aluminum bar stock, drilled and tapped as shown in **fig. 3**. This block is fastened to the top plate with 3/4-inch (19mm) long 4-40 (M3) screws. The 8-32 (M4) nylon adjustment screw is cut to size and inserted in the block. This completes the top cover assembly.

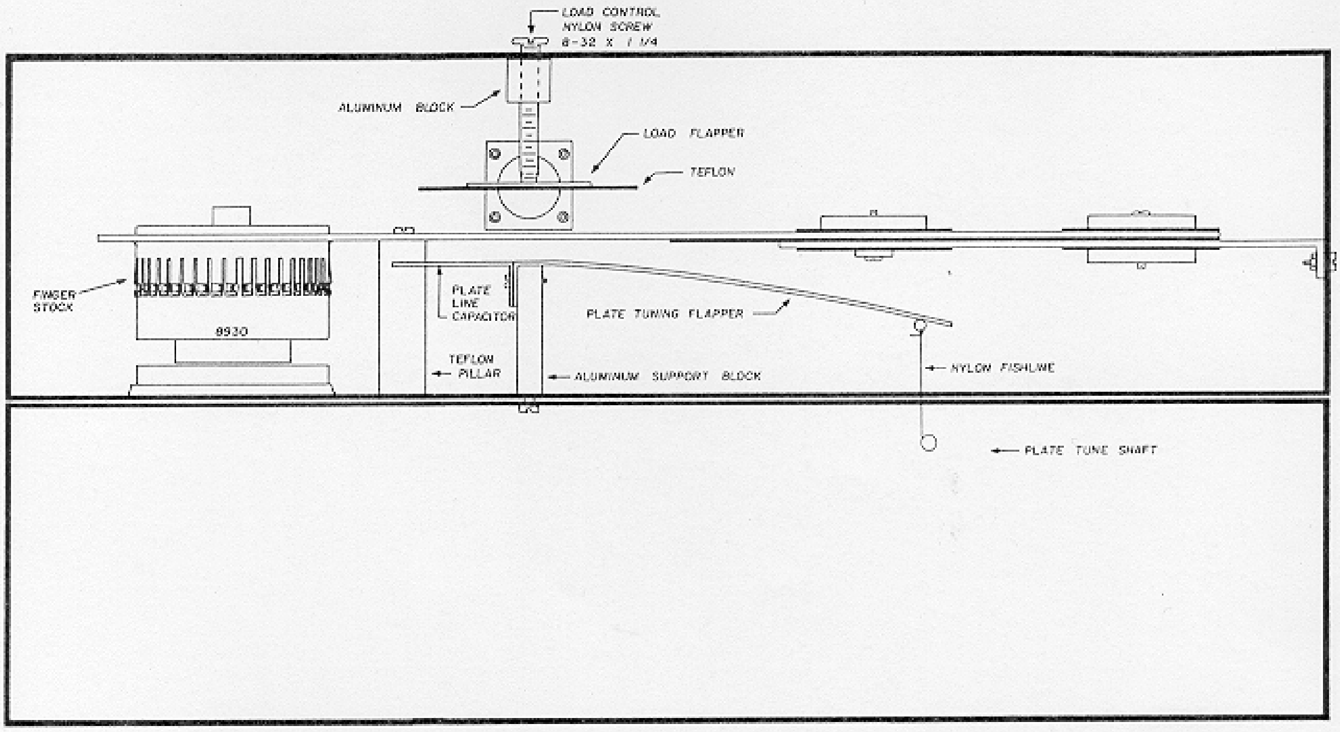


fig. 2. Cross-sectional view of the two-meter kilowatt showing the location of the plate circuit components.

The upper chassis is now prepared as shown in **figs. 4, 5,** and **6**. Chassis punches 2-1/4 and 1-3/4 inch (5.7 and 4.5cm) in diameter are required for the socket holes and the air intake. Note also that the plate with a 1-3/4-inch (4.5cm) hole requires the use of a hole saw to get through the 3/16 inch (4.5mm) thickness. This screened air intake plate must be chosen for either a hose-connected blower, or a blower mounted directly on the chassis. The drawing

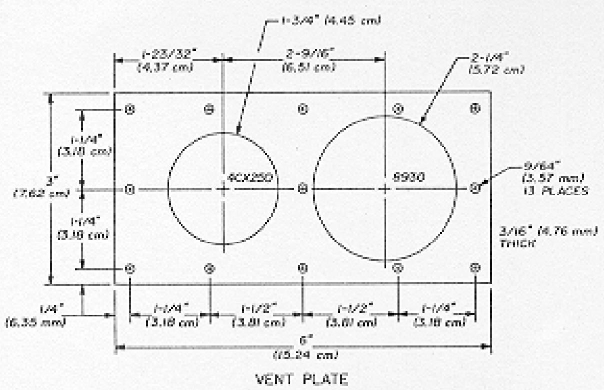
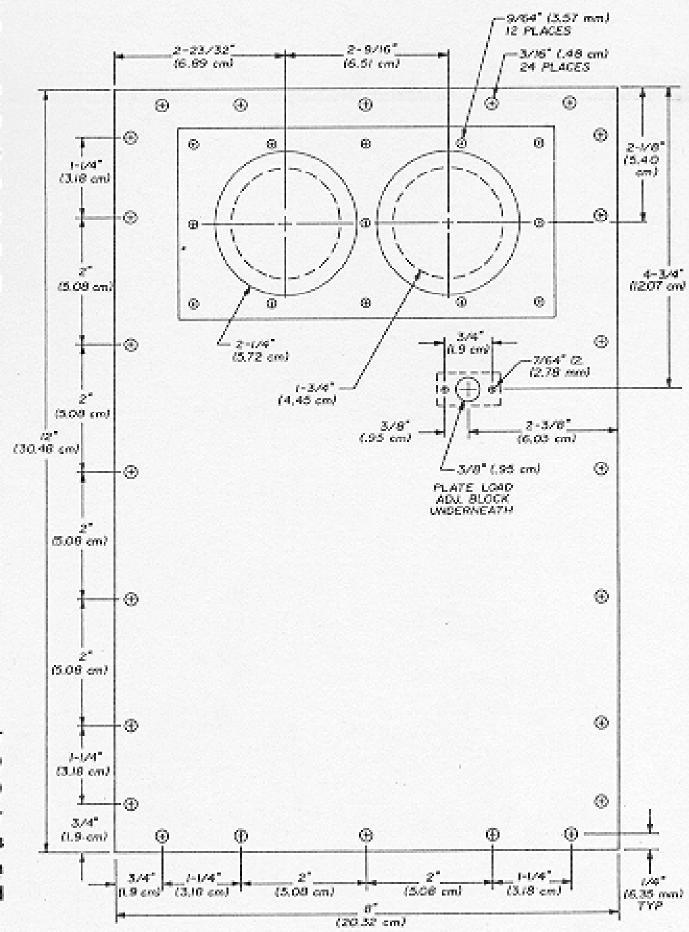


fig. 3. Bottom view of the top plate of the two-meter kilowatt. Top plate is made from 3/32-inch (2.5mm) aluminum sheet; vent plate is made from 3/16-inch (4.5mm) thick aluminum. The dashed 1-3/4-inch (4.5cm) circle is for 4CX250R and similar tubes; the 2-1/4-inch (5.7cm) circle is for the recommended 8390 tubes. A piece of aluminum screen is cut to the same dimensions as the vent plate and mounted between the top plate and the vent plate.



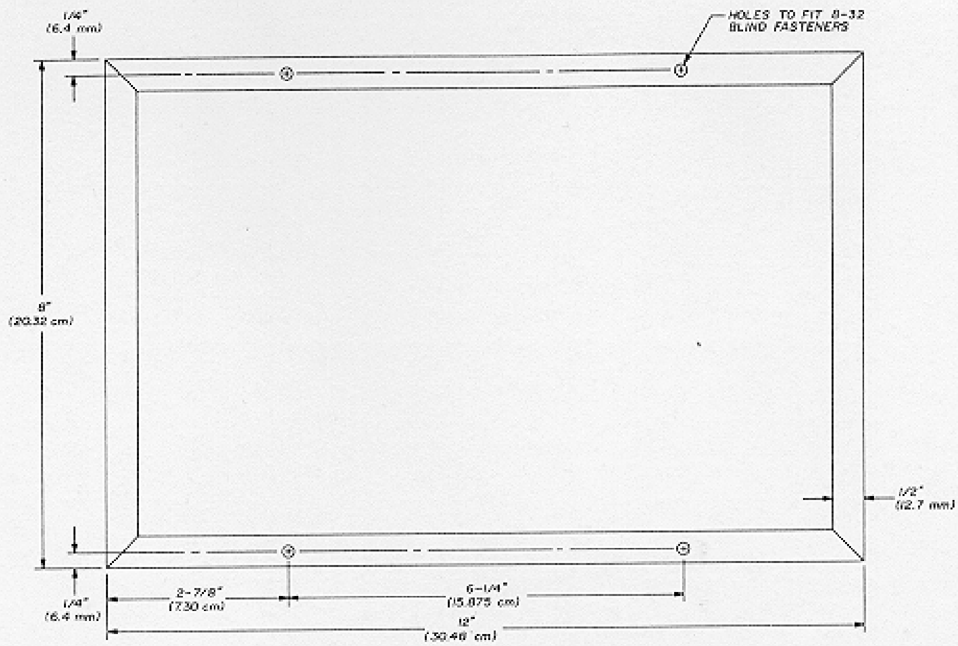


fig. 5. Top view of the upper chassis showing the top plate mounting holes. All holes are drilled to fit 8-32 (M4) blind fasteners.

for the chassis-mounted blower shows drilling and tapping for a Dayton 4C01 blower.

Although chassis-mounted blowers have been used successfully, vibration can be a problem. The intake plate for hose-connected blowers is drilled for a Nutone plastic fitting type 366. This fitting will accept a hose with a 2-1/4-inch (5.7cm) inside diameter. For hose-connected blowers, use a blower having 100 cfm free air rating into a 2-1/4-inch (5.7cm) aperture as a minimum. If 8930 tubes are used, the direct-mounted blower may be rated as low as 60 cfm into the same aperture.

Here are a couple of tricks to assure accurate drilling: lay the work out on masking tape which has been placed on the areas to be cut or drilled, and always use a 1/16-inch (1.5mm) pilot (starter) drill to

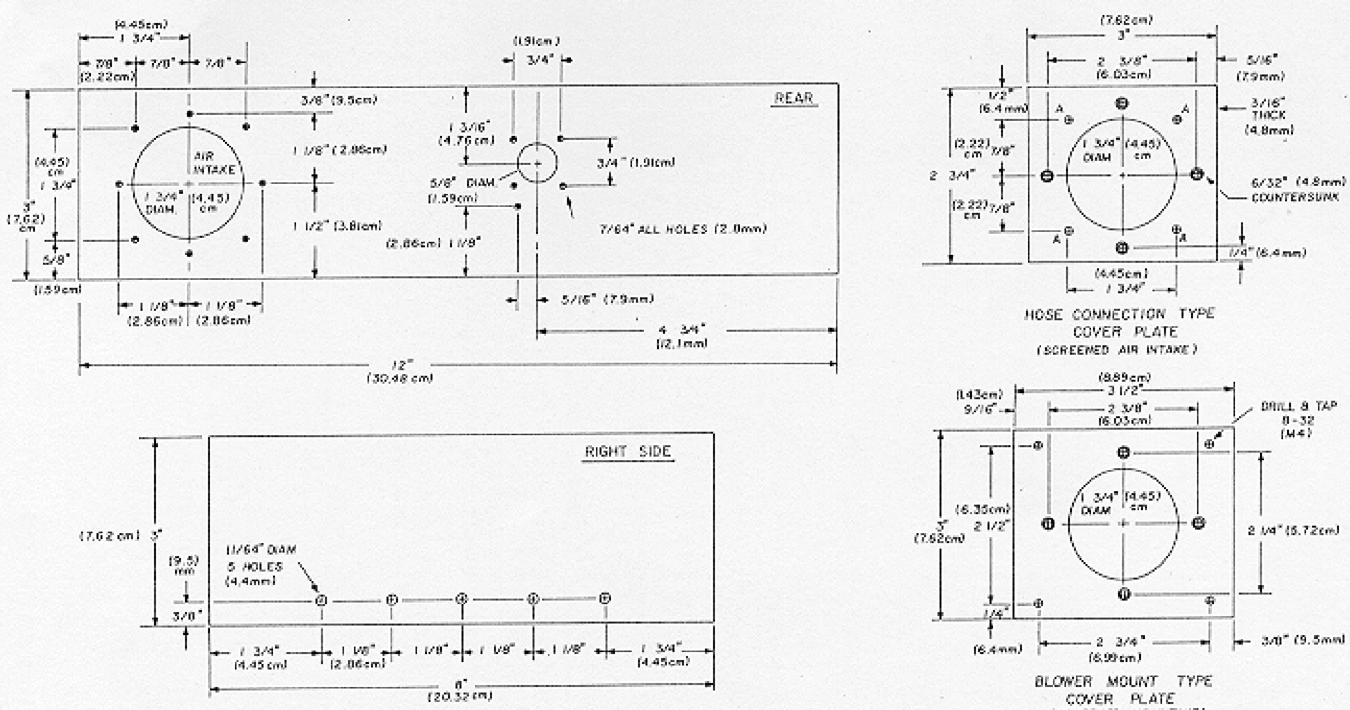


fig. 4. Top chassis for the two-meter kilowatt is made from 8 x 3 x 12-inch (20x7.6x30.5cm) aluminum chassis (Bud AC424 or equivalent). All holes not marked are 9/64 inch (3.5mm). Aluminum screening is mounted between vent cover plate and the air intake hole in the top chassis. Bottom view of the top chassis is shown in fig. 6.

center your holes. Although a drill press is convenient for all drilling operations, access to one is required only for the large holes through the 3/16-inch (4.5mm) thick material which requires the use of a hole saw.

To minimize alignment errors, one part with the 1/16-inch (1.5mm) pilot holes can be used as a drilling template for the matching parts. For example, use the top plate as a template for drilling the top of the upper chassis; use the vent plate as a template for the blower opening in the rear of the upper chassis.

Accuracy in drilling is essential, especially the socket holes, top plate vents, and plate line. These holes must line up nearly perfectly to assure alignment of the tubes, chimneys, and top vents.

It is best to use blind fasteners to secure the top plate to the upper chassis. Either 8-32 or 6-32 (M3.5 or M4) size is okay. The bottom plate may be fastened with self-tapping screws or blind fasteners with blind fasteners being the best choice. All other fastening is done with 6-32 or 4-40 (M3.5 or M3) screws, nuts, and lockwashers of suitable length.

The grid box is drilled and punched as shown in

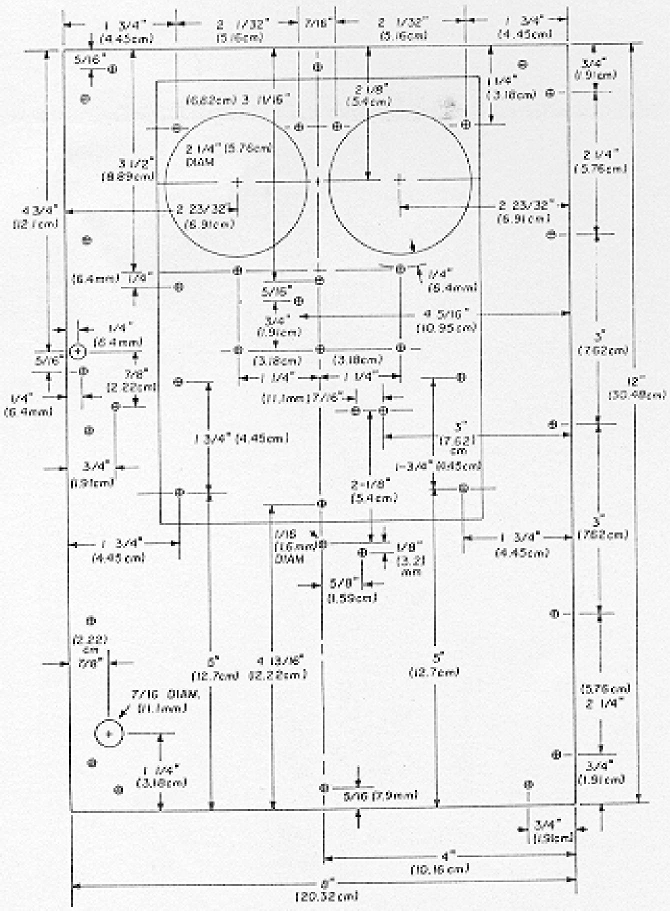
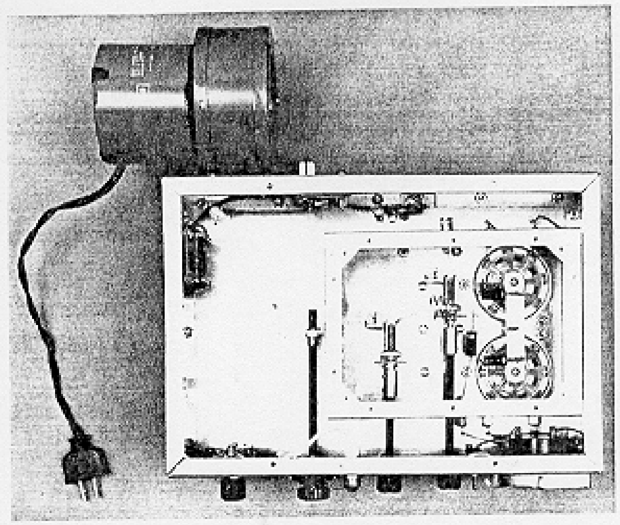


fig. 6. Bottom view of the upper chassis showing the layout of the tube cutouts and other mounting holes. All holes not marked are 9/64-inch (3.5mm) diameter.



Bottom view of the stripline two-meter kilowatt showing the wiring of the grid compartment.

figs. 7 and **8**. To ensure alignment of the socket holes with those in the upper chassis, the grid box pilot holes, including the pilot holes for the sockets, are drilled using the upper chassis as a template.

The top of the lower chassis is cut out as shown in **fig. 9**. This can be done with a nibbling tool, a small hand saw, or if you are very careful, on a table saw. The meter hole in **fig. 11** is for a Calectro D10912 — a 0-1 mA meter with 100 ohms resistance. Any 0-1 mA meter not more than 2-3/4-inches (7cm) high can be used; the clearance for the meter behind the front of the chassis is 1-1/4 inch (3cm).

The holes in the rear of the lower chassis may be changed to suit your choice of power connectors. The MHV high-voltage connector (Amphenol) is recommended for the B + lead.

The vent holes in both the grid box and the lower chassis can be covered with screening by using a 1-1/8 inch (2.9cm) punch to cut the center out of the pieces punched from the 2-1/4 inch (5.7cm) socket holes. This provides a ring-shaped clamp which is drilled to match the holes in the chassis.

The bottom plate shown in **fig. 8** does double duty as it is fastened to both the lower chassis and the grid box. First drill the pilot holes in the bottom plate and then, using it as a template, drill the pilot holes in the bottom of the lower chassis and the grid box. This completes the chassis work operations.

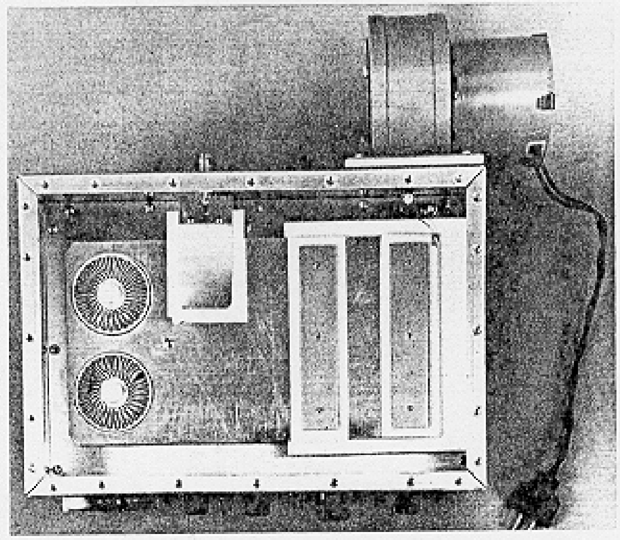
plate line

Before starting assembly and wiring, do the cutting and drilling for the plate line, the grid line, and the output flapper. The plate line consists of two pieces of copper clamped together in a Teflon sandwich by clamping bars (**fig. 12**). The cutting and drilling dimensions are shown in **fig. 13**. Note that only two of the clamping bars are drilled and tapped.

The third bar is drilled only 9/64 inch (3.5mm).

The finger stock is soldered on the under side of the plate line; this requires a soldering tool in the 200-watt range. The finger stock is held in place, flush with the upper side of the line, with a Pyrex beaker or some other cylinder of heat-resistant material about 2 inches (5cm) in diameter (1-5/8 inch or 4cm for 4CX250s) which is wrapped with Teflon tape to provide a squeeze fit which will hold the finger stock in place while soldering. Note that the smaller piece of the copper plate line is equipped with self clinching nuts; as an alternative, brass nuts may be soldered to the copper plate. The Teflon support for the plate line at the tube end is made from 1/2-inch (13mm) diameter Teflon rod, drilled and tapped 1/2-inch (13mm) deep on each end.

Fig. 14 shows the various components of the plate tuning and output flapper capacitors. The plate capacitor consists of two sections: the flapper and a piece of copper on the same mounting block which provides the additional capacitance needed to resonate the line. Semi-hard beryllium copper seems to make the best flapper material; it also has the advantage of taking silver plating which, while not essential, is desirable for all of the rf parts in both the plate and grid compartments of this amplifier.



Top view of the two-meter kilowatt showing the plate stripline, the output coupling flapper (upper center), and Teflon sandwich at the cold end of the line (right).

Note the details for the aluminum support block in

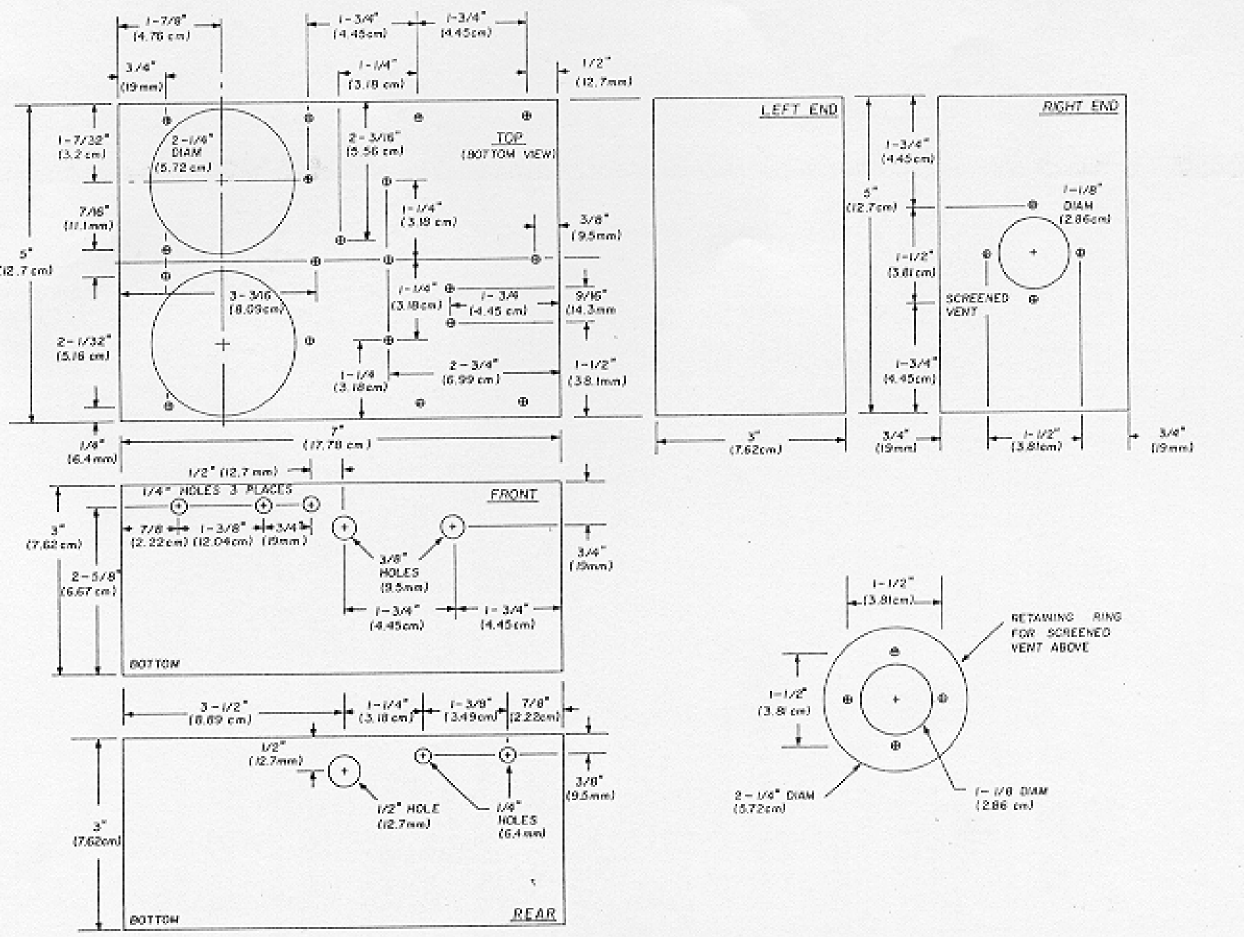
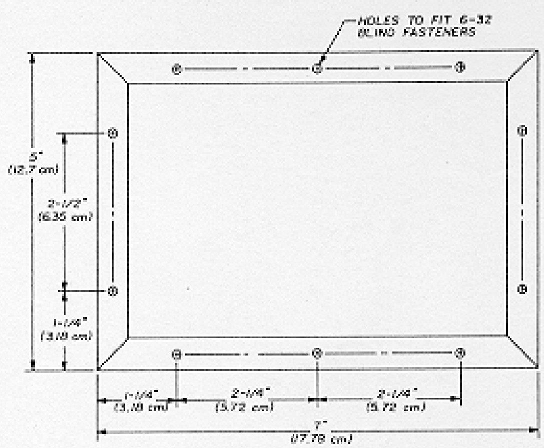


fig. 7. Construction of the grid box for the two-meter kilowatt. The aluminum chassis measures 5 x 7 x 3 inches (12.7x17.8x7.6cm) (Bud AC429 or equivalent). A piece of aluminum screen 2-1/4 inches (5.7cm) in diameter is clamped inside the box with the retaining ring. All holes not marked are 9/64 inch (3.5mm) in diameter.



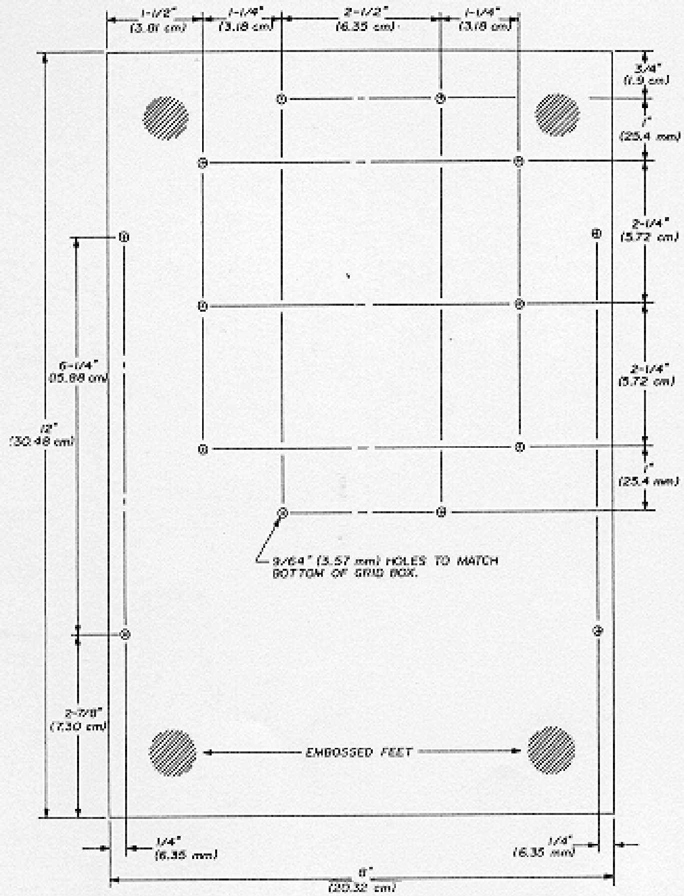


fig. 8. Bottom of the grid box and layout of the cover plate (Bud BPA 1519 or equivalent). The holes in the bottom of the grid box are drilled using the bottom plate as a template.

fig. 14; the flapper and fixed capacitor piece are mounted together with 8-32 (M4) hardware. The support itself is mounted to the chassis with 6-32 (M3.5) hardware. Dimensions for the bakelite shaft and bearing bracket for the plate flapper are also shown in **fig. 14.**

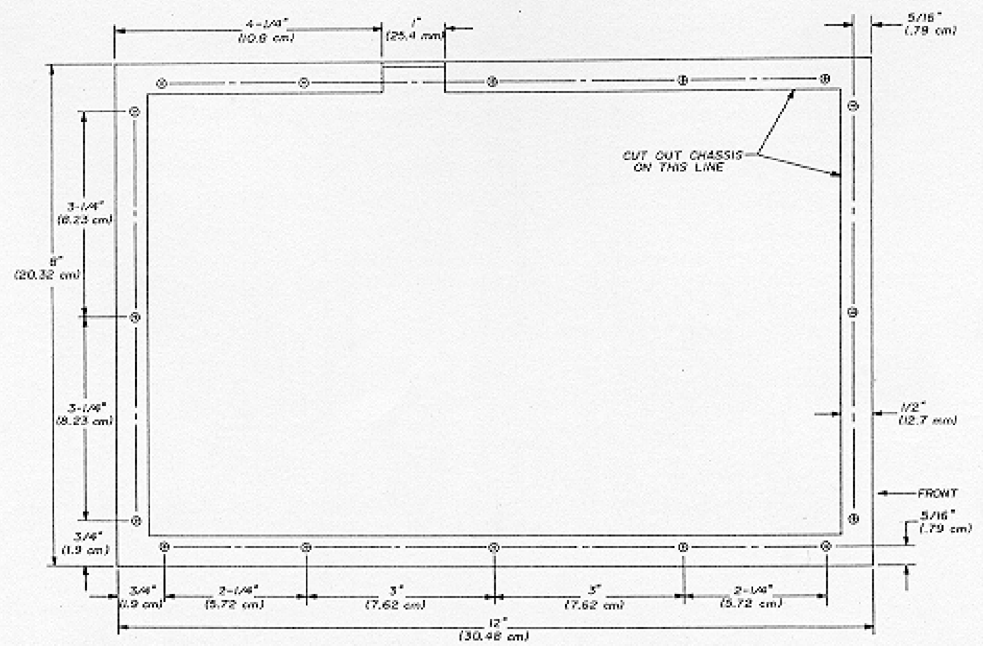


fig. 9. Top view of the lower chassis showing the large cutout made with a nibbling tool. Chassis is a Bud AC424 or equivalent. All holes are 9/64 inch (3.5mm).

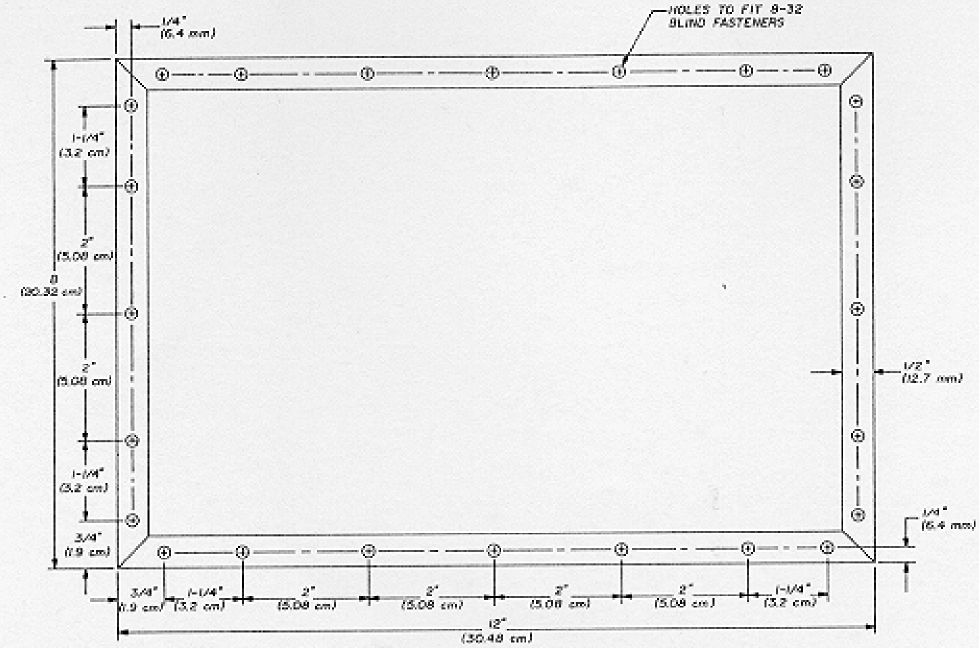


fig. 10. Bottom view of the lower chassis for the two-meter kilowatt.

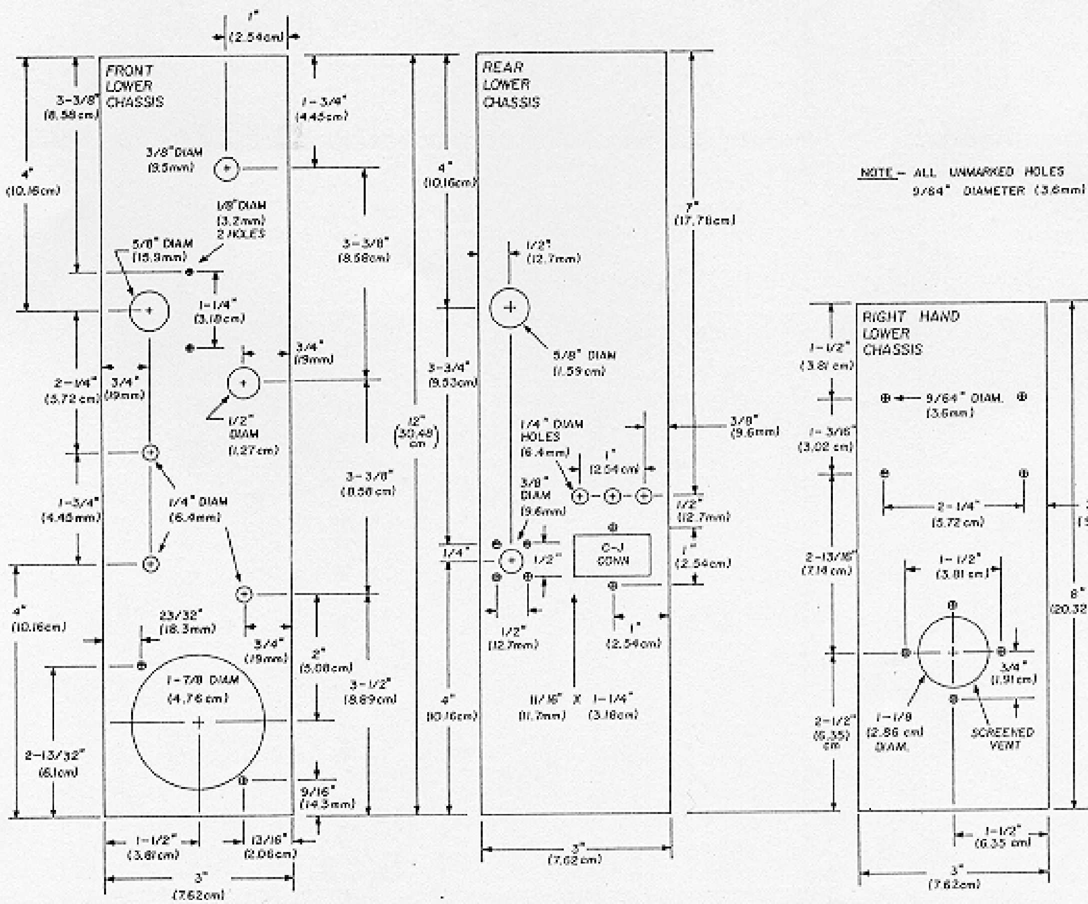


fig. 11. Layout of the front, rear, and right-hand side of the lower chassis (there are no holes in the left-hand side of the chassis). See fig. 7 for construction of the retaining ring for the screened vent. The meter hole in the front panel of the chassis is for a Calectro D10912 1 mA meter.

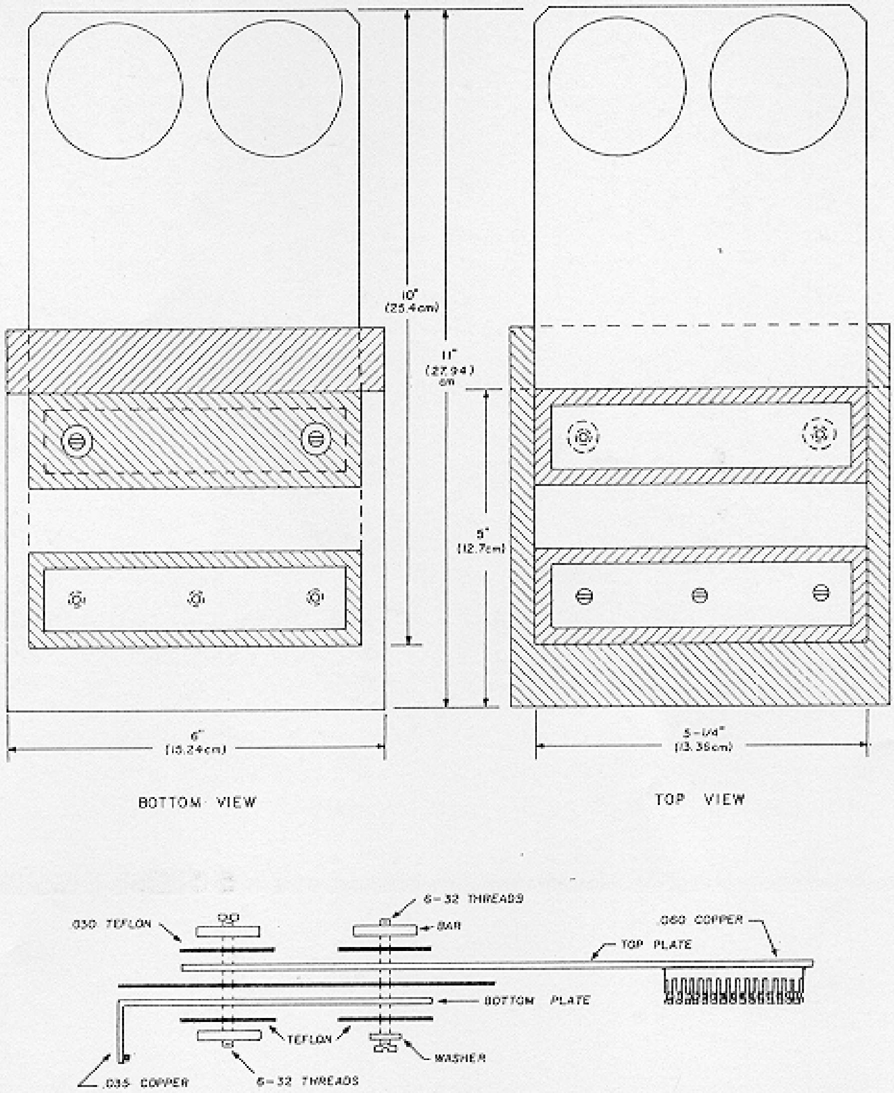


fig. 12. Construction of the plate line for the two-meter kilowatt. Material is .060 inch (1.5mm) copper (should be silver plated for best results). The shaded areas are 0.030-inch (0.8mm) Teflon sheet. Construction of the individual parts for the plate are shown in fig. 13.

A slot is sawed in the inner conductor of a type-N coaxial chassis connector to accept the output flapper (see **fig. 2**) which is soldered into the position shown. The two holes in the output flapper serve to mount a piece of Teflon underneath the flapper which prevents contact with the high voltage on the plate line. The dimensions of these items are shown in **fig. 14**.

Also prepare the short piece of 1/4-inch (6.5mm) diameter copper tubing for the rf sampling assembly and the piece of 1/4-inch (6.5mm) diameter Teflon rod for the rf choke form (**fig. 14**). A copper strap for connecting the grid terminals together, and mounting details for the grid butterfly capacitors and their respective shafts are shown in **fig. 15.***

assembly

Begin by mounting the parts and wiring the lower chassis. Connect all leads except the five leads from the grid box and the cable to the rf sampling assembly. Keep the wires formed into a bundle in the corner of the bottom of the chassis. Run in this manner, the wires will show only at the points of termination and can be laced into a cable with wire ties after they are all in place. Use a color scheme such as black for ground, green for filament, yellow for grid, and blue for screen.

*Many parts and assemblies for this two-meter amplifier are available from ARCOS, Post Office Box 546, East Greenbush, New York 12061; telephone (518) 477-4990. A price list will be furnished upon receipt of a self-addressed, stamped envelope.

Turning now to the upper chassis, install the rf sampling assembly as shown in **fig. 17**. Also install the high-voltage feedthrough capacitor at this time. Fasten the upper and lower chassis together with 6-32 (M3.5) 1/4-inch (6.5mm) long screws.

Install the bulkhead BNC input connector and the five feedthrough capacitors on the grid box. Install the grid box and the sockets, making certain that socket terminals 1 and 3 are opposite their respective feedthrough capacitors. Run the five wires from the grid box to the resistor assembly board and the RG-174/U coaxial cable to the rf sampling assembly. This completes the wiring of the lower chassis.

Mount the butterfly capacitors (see **fig. 15**). Note that there are two holes in the area where the grid tuning capacitor mounts. The capacitor assembly is

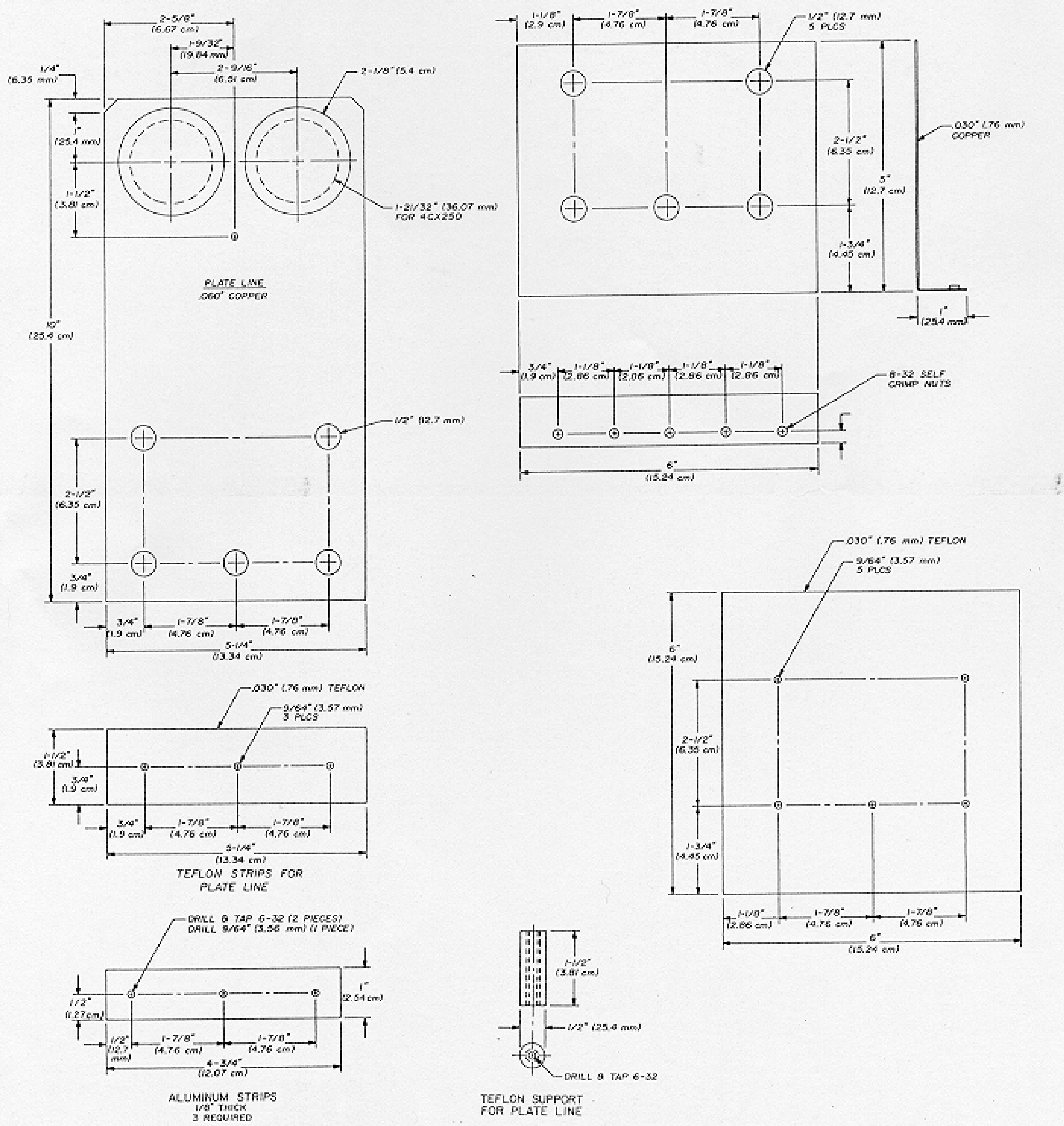


fig. 13. Plate line parts for the two-meter stripline kilowatt.

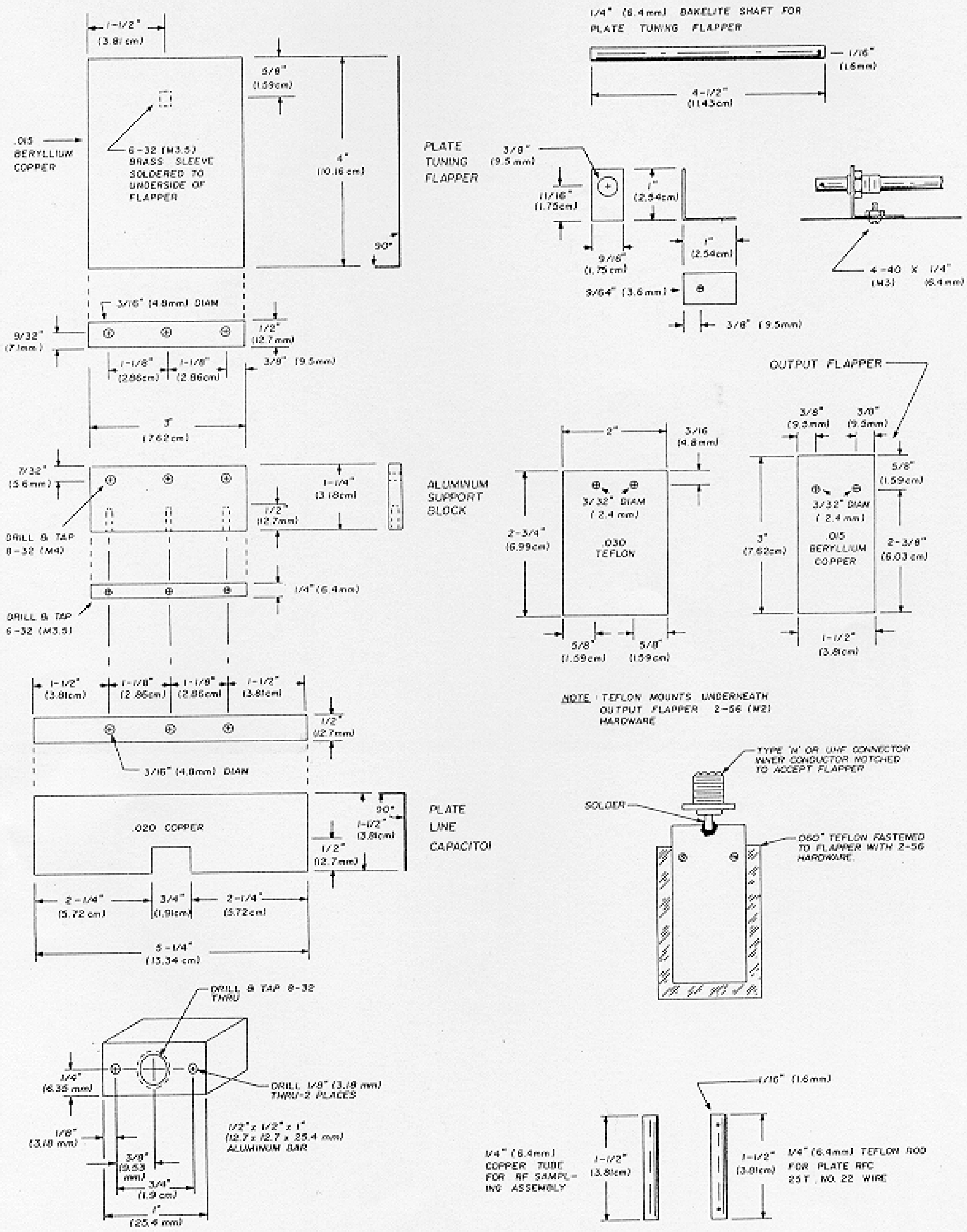


fig. 14. Construction of the plate line tuning and output flapper capacitors.

installed in the hole nearest the front of the chassis. Before mounting the tuning capacitor, put a spade bolt (with top cut off) in the rear hole. Tin the spade bolt. Now mount the capacitor assembly, adjusting the upper lug of the capacitor so it has some tension against the concave top of the spade bolt. Line up the coupling shaft and tighten the nut on the spade bolt holding the capacitor. Make sure the capacitor turns smoothly.

Using a 200-watt iron, carefully solder the upper lug of the butterfly capacitor to the spade lug. This is a very important connection and becomes inacces-

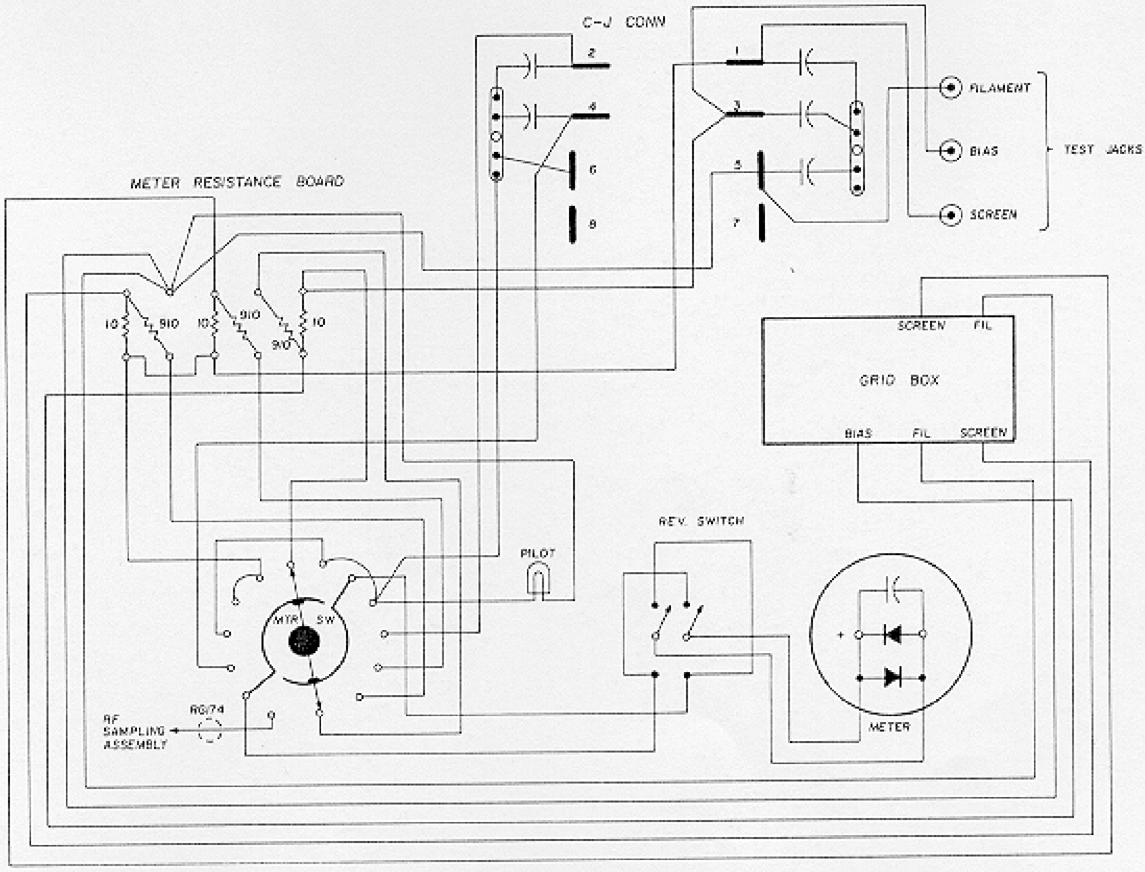


fig. 16. Wiring diagram for the two-meter kilowatt. Details of the rf sampling assembly are shown in fig. 17.

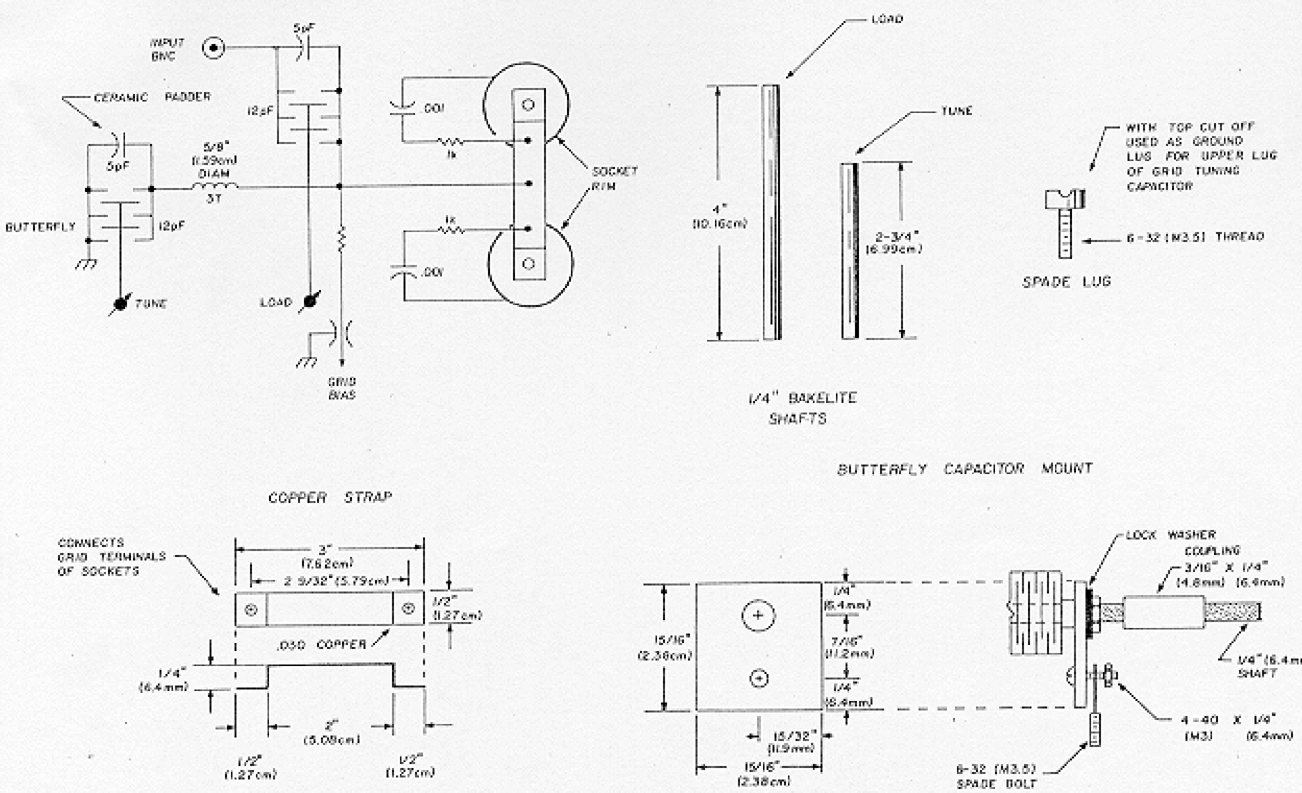


fig. 15. Grid circuit details for the two-meter stripline kilowatt.

sible later, so make sure it's a good solder joint. The other butterfly capacitor (loading) is not grounded so it is just a matter of making sure it operates freely. The balance of the grid circuit may now be installed.

Now mount the shaft bearing bracket and the bearing for the plate flapper tuning control. Install the plate tuning dial and the shaft. Make sure the shaft turns freely in the dial hub; this will facilitate placing the flapper tuning in the proper range. Install the Teflon support at the plate end of the plate line.

Assemble the two parts of the plate tuning capacitor to the aluminum support block and bolt the support block to the chassis. (The fishline control should be made fast to the plate tuning flapper before mounting the flapper assembly to the chassis, and the plate flapper positioned to about 1-3/4 inch (4.5cm) above the chassis.) Assemble the plate line (see **fig. 12**) and mount it to the chassis. Before tightening up the Teflon sandwich make sure that the large piece of Teflon between the plates is centered in the mounting holes.

Install the rf choke and the output flapper (which should be bent up to within 1/4 inch or 6.5mm of the top of the chassis). Position the rf sampling capacitor about 1/8 inch (3mm) away from the output flapper

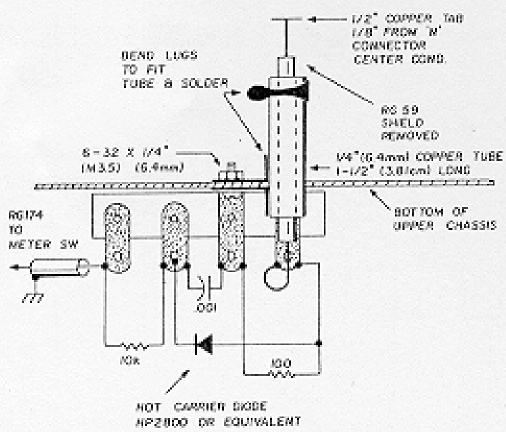
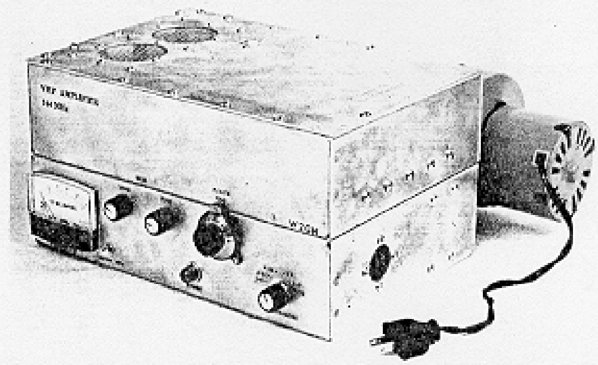


fig. 17. Side view of the rf sampling assembly. Adjust the position of the copper tab for approximately 0.6 mA on the meter at 600 watts output.

and type-N connector. Now assemble the top plate vent and the loading adjustment block. Fasten the top plate and bottom cover to complete the assembly of the amplifier.

power supply

A power supply suitable for this amplifier is shown in **fig. 21.** The voltage-doubling circuit offers a 1000 volt source for the screen dropping resistor. Since no grid current will flow with linear operation, the bias supply can be the simple zener regulated type



The entire amplifier is assembled in two mated chassis.

shown. The protective features of this supply include a high voltage fuse and a diode protective resistor in the transformer secondary lead. A delay tube maintains cutoff bias until the tubes warm up. The filament voltage is 8 volts at the transformer winding and offers ample control of the voltage at the sockets with the adjustable 1/2-ohm series resistor.

This power supply will deliver 2000 volts at 500 mA with a no-load voltage of 2200 volts. At 1 ampere the output voltage drops to 1850 volts. With a transformer weight of 30 pounds (13kg) the total weight of the unit is only 45 pounds (20kg). This is quite a relief from the 80 to 100 pound (35-45kg) power supplies of the past.

test and check out

An inexpensive dummy load for a high power vhf amplifier can be set up with 100 feet or 30 meters (or more) of RG-8/U with a Heath Cantenna at the end. This will stand up on 144 MHz for about ten minutes or so at 600 watts output before the cooling oil in the dummy load starts to boil. The driver for this amplifier *must* have a adjustable output control unless it is capable of less than 5 watts maximum output because the amplifier is very power sensitive; it is not possible to adjust it properly if it is overdriven.

After connecting the amplifier to the power supply

table 1. Typical operation of the two-meter stripline kilowatt using 8930 ceramic power tetrodes (grid bias = −77 volts, screen supply = 409 volts, idling current = 100 mA).

drive power	grid current	screen 1 current	screen 2 current	power input	power output
2 W	0	− 6 mA	− 6 mA	800 W	200 W
4 W	0	− 8 mA	− 10 mA	1000 W	400 W
8 W	− 1 mA	+ 1 mA	+ 2 mA	1360 W	830 W

Plate voltage during these tests ranged from 2100 volts at 200 mA idling current, to 1700 volts at 830 watts output.

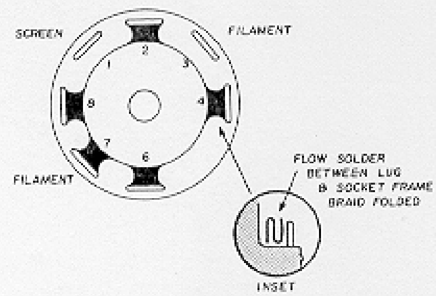


fig. 18. Grounding for the Eimac 620A socket. The 630A socket requires this modification only on terminal 7.

and making the usual checks of filament voltage, bias, screen voltage, and blower operation, establish an idling current of about 150 mA for initial tests. Applying a watt or so of excitation, adjust the grid circuit controls for a rise in plate current. Then resonate the plate circuit by observing power output. If the plate circuit will not resonate, change the range of the plate tuning flapper controls until the dial is midrange for your chosen operating frequency.

The next step is to increase drive until the amplifier is at about 400 watts or so output with the loading screw about 1/8 inch (3mm) above the top plate. Now the grid circuit controls should be set for minimum swr toward the driving source. The reverse power will drop to an unreadable value. Once grid tuning is established, adjust the load control on the top of the amplifier for a compromise between maximum output and minimum plate current at an output level of 600 watts. Keep the loading on the heavy side.

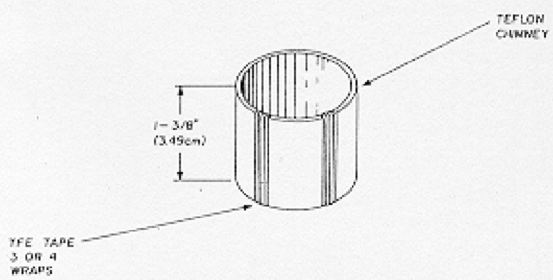


fig. 20. Tube chimneys for the two-meter kilowatt are made from 0.010-inch (0.25mm) Teflon, 1-3/8-inches (35mm) wide. Roll the Teflon for a tight fit in the top vent plate; secure with 1/4-inch (6.5mm) Teflon tape wrapped vertically around the roll. 12 inches (30cm) of Teflon is required for 4CX250s; 24 inches (60cm) is required for 8390s.

Once the proper setting for the load control is found, there should be no reason to change it unless you wish to operate the amplifier at a lower-power level or with different voltatges. Having set up the initial operating conditions, further tests and adjustments can be made for best linearity.

Check for blower operation each time the amplifier is turned on. If the air supply should fail, the solder on the plate line will melt and the finger stock usually springs out, grounding the plate supply and operating the breaker within about 30 seconds. The tubes survive but it is a messy job to repair the plate line.

safety

Like any other piece of radio equipment operating at high voltages, this innocent looking aluminum box can be a killer — it is absolutely unforgiving of careless moves. Just to repeat the safety rules, disconnect the B+ line before taking covers off. Don't operate the amplifier with the covers off. If you must take a reading inside with the cover off, disconnect the power, connect the meter with well-insulated leads, stand back and take the reading *after* you have put the power plug back in. One hand in the pocket while you are testing is the time-tested rule

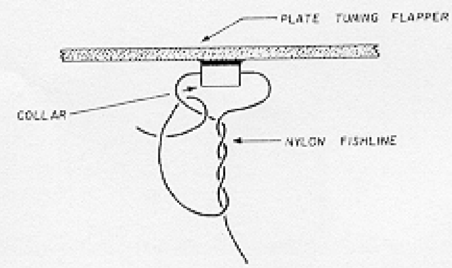


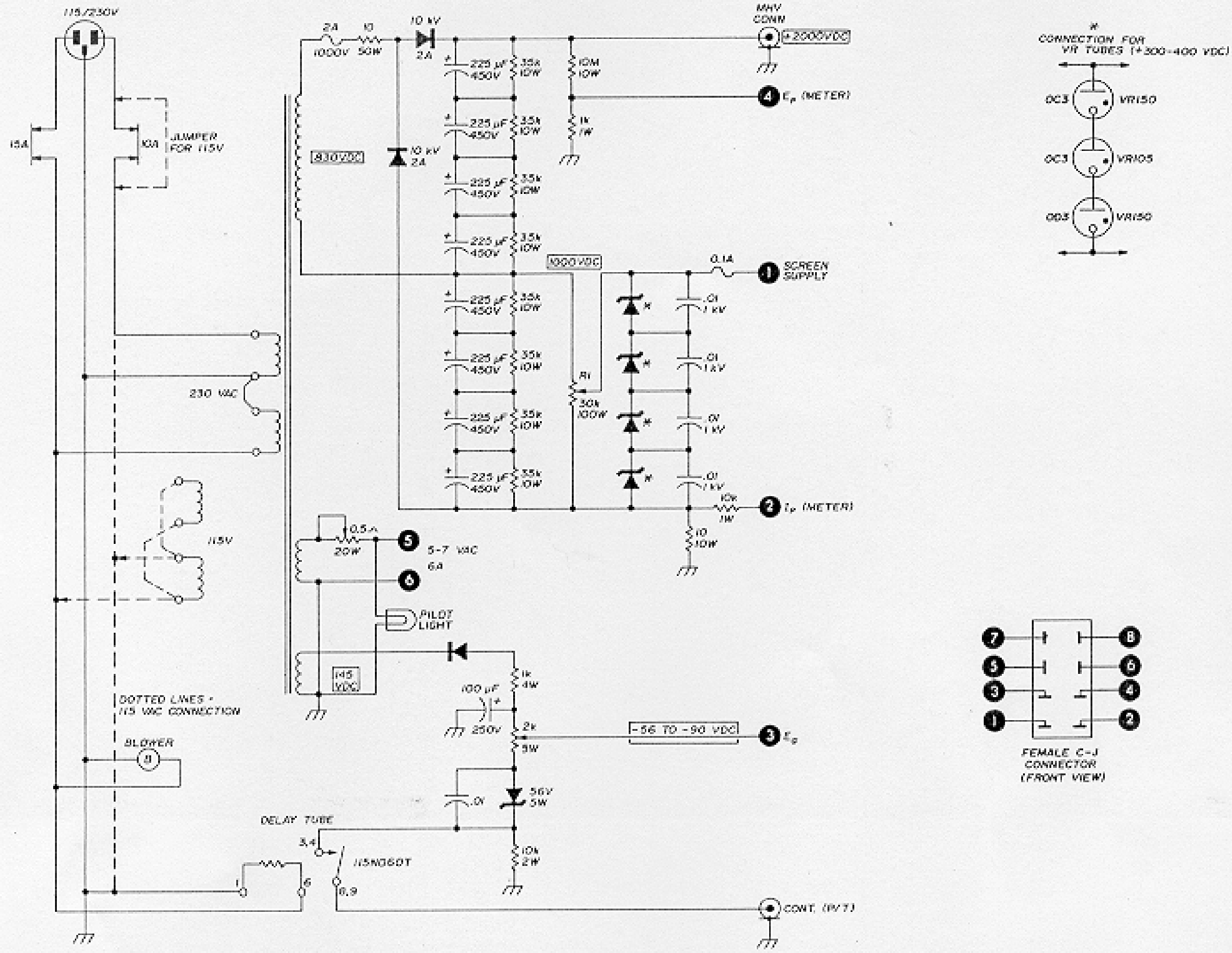
fig. 19. Knot for fastening nylon fishline to the collar on the plate tuning flapper, and to the tuning shaft. Pull the knot tight to prevent unraveling.

for staying alive. Another precaution in dealing with this level of rf power is to stay out of the path of the rf radiated from the antenna.

operation

To adjust the amplifier for linear operation, perhaps the simplest setup is to use a directional wattmeter at both the input and the output. Set the idling current at 200 mA. Using the test values of 2, 4, and 8 watts drive, (see **table 1**)adjust the loading control and the plate tuning control for best linearity at the lowest value of peak plate current. When the proper adjustment is reached the power output will be approximately 200, 400, and 800 watts, respectively. These tests can be made at the bench and the adjustments will be valid for a 50-ohm antenna system with low swr.

For CW operation the bias can be set higher for an idling current of 100 mA or less, and the loading control and plate tuning optimized for best output at the least plate current. At 1 kilowatt input, 600 watts output is the objective. About 5 watts drive is required.



Voltage: no load, 2300 V; 500 mA, 2000 V; 1 A, 1900 V
Bias: −55 to −95 volts (no grid current)
Standby bias: −150 volts (P/T contacts open)
Weight: 45 pounds (20 kg)

fig. 21. Recommended power supply for the two-meter stripline kilowatt is rated at 1 kilowatt continuous duty, 2 kW PEP. Adjust R1 (30k, 100W) for 500 volts at the screen terminal with the zener diodes (or VR tubes) disconnected. Readings in boxes were taken at 1 kilowatt output.

The temperature of the exhaust ports can be checked by setting a candy thermometer on top of the amplifier in a nearly vertical position (put a pair of stiff wire legs on it). This does not give a reading of the temperatures at the tube seals, but is a relative indicator. Based on many hours of testing these amplifiers, a suggested limit for the exhaust air temperature read in this manner is 200°F (95°C). The tubes will not fail under continuous operation at this temperature limit. The 8930s will stay well within this level but the 4CX250s will tend to exceed it.

The filament voltage for the two-meter amplifier has been set at 6 volts on the assumption that the effects requiring 5.5 volts on the filaments at 432 MHz are not as significant at 144 MHz.

The grid current should be at zero or barely negative for AB1 operation. Screen current will go negative (read with the meter reverse switch) to 10 mA more or less. It may become barely positive on modulation peaks. The screen voltage is regulated at 350 to 400 volts.

Once you have this amplifier on the air, properly adjusted, you will find that no further attention is required except perhaps an occasional tweaking of the plate tuning to match the antenna.

references

1. Richard T. Knadle, Jr., K2RIW, "A Stripline Kilowatt for 432 MHz," *QST*, April, 1972, page 49; May, 1972, page 59.
2. Steve Gross, W9OJI, "A Parallel 4CX250B Amplifier for 144 MHz," *QST*, May, 1975, page 11.

ham radio