high-performance grounded-grid 220-MHz kilowatt linear

The Eimac 8877 is a high-mu ceramic-metal triode rated for use up to 250-MHz and several successful amplifier designs using this tube have been constructed for hf through vhf.[1,2,3] The 220-MHz amplifier described here has proven to operate very well during the last year, including several successful Earth-Moon-Earth (EME) contacts.

This 220-MHz 8877 linear amplifier is designed for the serious vhf DXer who demands reliable service combined with good linearity and efficiency. The amplifier requires no neutralization, is completely stable and free of parasitics, and is very easy to operate.

The amplifier is designed for continuous duty operation at the 1000-watt dc input level, and can develop 2000-watts PEP input for SSB operation with ample reserve. For operation at 2000-watts PEP the plate supply should be between 2500 and 3000 volts; under these conditions the amplifier will deliver 1230 watts output. With the higher plate-voltage supply, up to 14-dB gain can be obtained with an amplifier efficiency of 61 per cent; see **table 1**.

The 8877 triode has very good current division; that is, the grid current is quite low in comparison to the plate current. The grid current is typically about 15 per cent of the value of the plate current. the 8877 also has good gain and intermodulation distortion characteristics. The plate dissipation rating is 1500-watts. The cathode is indirectly heated; filament requirements are 5.0-volts at 10.5 amperes. The tube base mates with a standard septar socket.

the circuit

In the amplifier circuit shown in **fig. 1** the 8877 grid is operated at dc ground. The grid ring at the base of the tube provides a low-inductance path between the grid element and the chassis. The plate and grid currents are measured in the cathode return lead. A 12-volt, 50-watt zener diode in series with the negative return sets the desired value of idling current. Two additional diodes are shunted across the meter circuit to protect the instruments in case plate voltage arcs over to ground, or if there is an internal tube arc.

Standby plate current of the 8877 is reduced to a very low value by a 10,000-ohm cathode resistor. This resistor is shorted out in the transmit mode by the station control circuit. The resistor must be in the cathode circuit when receiving to eliminate the noise generated in the station receiver if electron flow is permitted within the 8877 tube.

A 200-ohm safety resistor insures that the negative side of the power supply does not go below ground potential by an amount equal to the plate voltage if the positive side is accidentally grounded. A second safety resistor across the 1N3311 zener diode prevents the cathode potential from rising if the zener should accidentally burn open.

input circuit

The cathode matching circuit is a T-network which transforms the input impedance of the tube (about 54 ohms in parallel with 40 pF) to 50 ohms at the coaxial input connector; the network consists of two series inductors and a shunt variable capacitor. The inductors are fixed and have a very low value of inductance; in fact, the rf return path through the chassis has about the same inductance value. To design the input circuit, many values of circuit *Q* were tried in the calculations. When the design equations yielded physically realizeable inductance values, then several combinations were tried in the actual amplifier. Since the stray inductances in the chassis and connecting leads in the socket were not included in the calculations, the final inductors were smaller in value than the calculated size. The actual inductors which resonated and provided a reasonable input match are specified in fig. 1 and are shown in some of the photographs. For those who build this amplifier I would expect that some minor variations in these coils might be required to attain an adequate input match.

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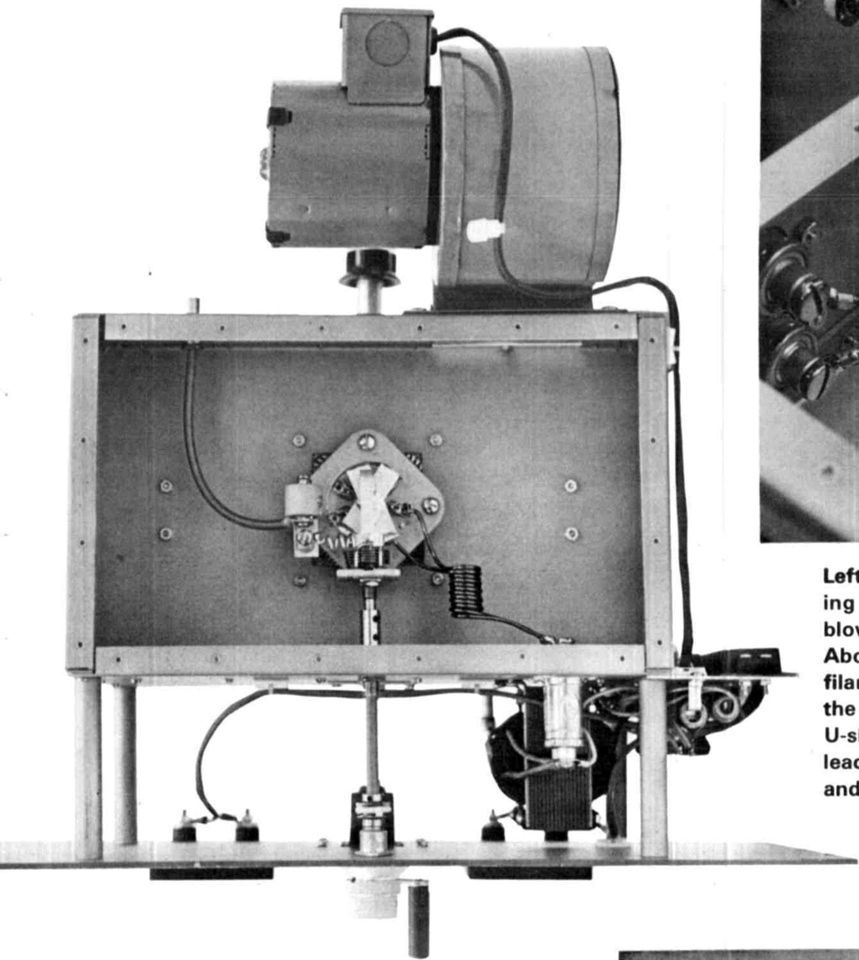
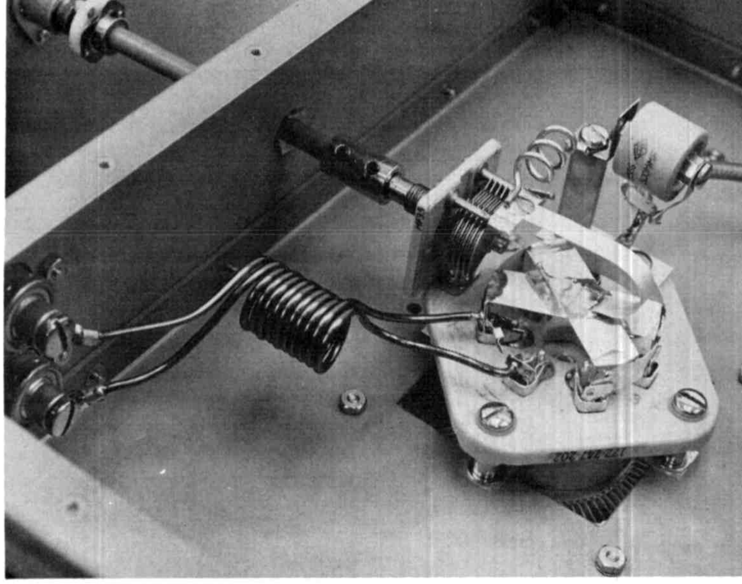
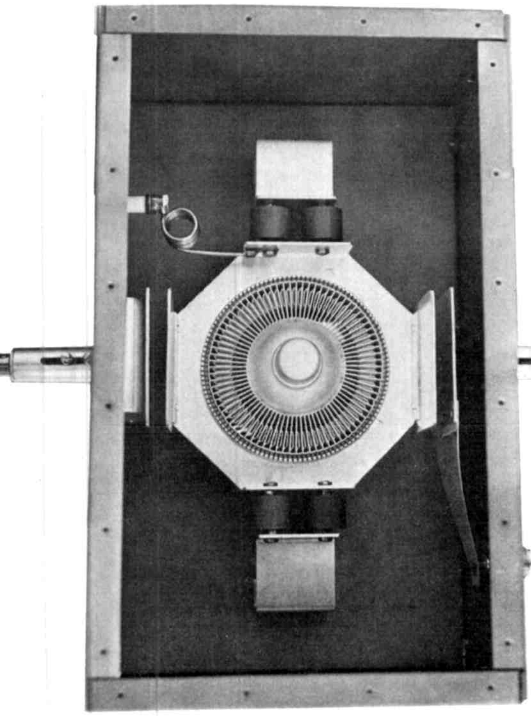
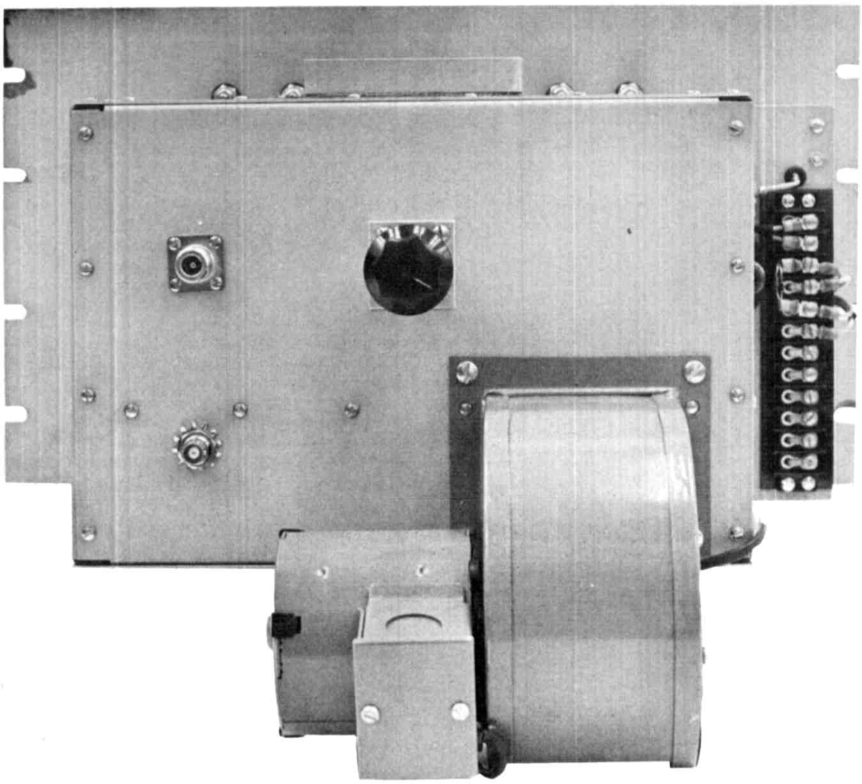




Left, underside view of the 220-MHz power amplifier showing the blower location as well as the input circuit. The blower is a Dayton 4C446.
Above, close-up view of the input circuit shows the bifilar filament choke L3 and L4 and the matching network. C2 is the 35-pF air variable mounted on the 8877 socket. L2 is the U-shaped strap connecting the capacitor to the cathode leads. L1 is the coil going between the variable capacitor and input line blocking capacitor C1.





Left, top view of the amplifier plate compartment. The 8877 tube is in the center with L5 and L6 to the left and right. The plate tuning capacitor C5 is at the bottom and the loading capacitor C6 is at the top.
Right, back view of the amplifier. The type-N connector is the rf power output; the BNC fitting is the connection for drive power. The knob is the loading adjustment. The terminal strip to the right is for the input voltage and control circuit connections. A Millen high-voltage connector is used for the plate voltage.

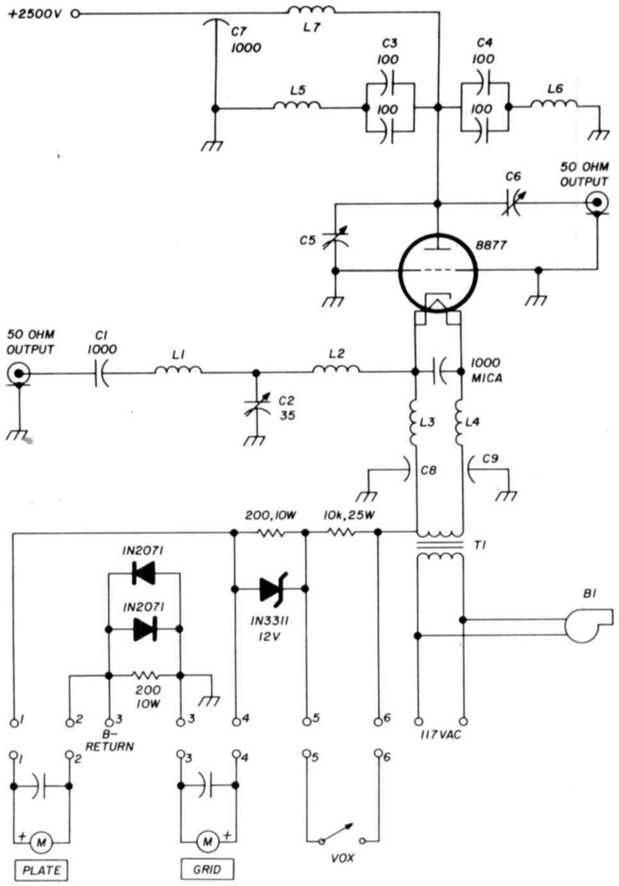


fig. 1. Schematic of the grounded-grid 220-MHz triode amplifier. Operating bias for the 8877 is supplied by a 12-volt zener diode in the cathode lead.

table 1. Performance of the 220-MHz grounded-grid 8877 rf power amplifier.

Plate voltage	3000 V	2500 V	2500 V
Plate current (single tone)	667 mA	800 mA	400 mA
Plate current (idling)	54 mA	44 mA	44 mA
Grid voltage	− 12 V	− 12 V	− 12 V
Grid current (single tone)	48 mA	50 mA	29 mA
Power input	2000 W	2000 W	1000 W
Power output	1230 W	1225 W	621 W
Efficiency (apparent)	61%	61%	62%
Drive power	48 W	69 W	20 W
Power gain	14 dB	12.4 dB	15 dB

C1	1000 pF ceramic transmitting type (Centralab 858S-1000)
C2	35 pF air variable (Hammarlund HF35 or Millen 22035)
C3,C4	Each consists of two parallel connected 100 pF, 5000 volt ceramic transmitting capacitors (Centralab 850S-100)
C5	Plate tuning capacitor (see **fig. 2**)
C6	Output loading capacitor (see **fig. 7**)
C7	1000 pF, 4000 volt feedthrough (Erie 2498)
C8,C9	0.1 uF, 600 volt feedthrough capacitor (Sprague 80P3)
L1	3 turns no. 14 (1.6 mm) wire, 1/4 inch (6.5 mm) inside diameter, 5/8 inch (16 mm) long
L2	Copper strap 1/4 inch (6.5 mm) wide, 2-1/2 inches (64 mm) long, bent into a U 5/8 inch (16 mm) wide
L3,L4	7 bifilar turns no. 12 (2 mm) enamelled wire, bifilar wound on 1/2 inch (12 mm) inside diameter
L5,L6	Plate resonators (see **fig. 5**)
L7	6 turns no. 14 (1.6 mm) wire, 1/2 inch (12 mm) diameter, 1 inch (25 mm) long
T1	Filament transforrmer rated at 5 volts, 10 amps (Stacor P-6433)

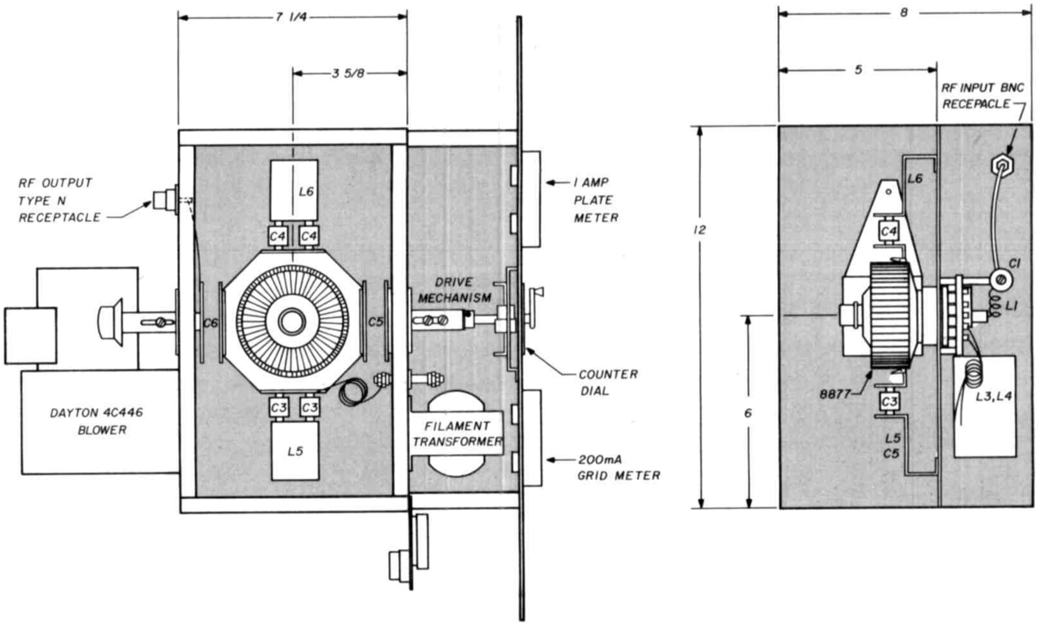


fig. 2. Structural details of the amplifier showing relative size and position of the various components. Assembly is made of aluminum panels.

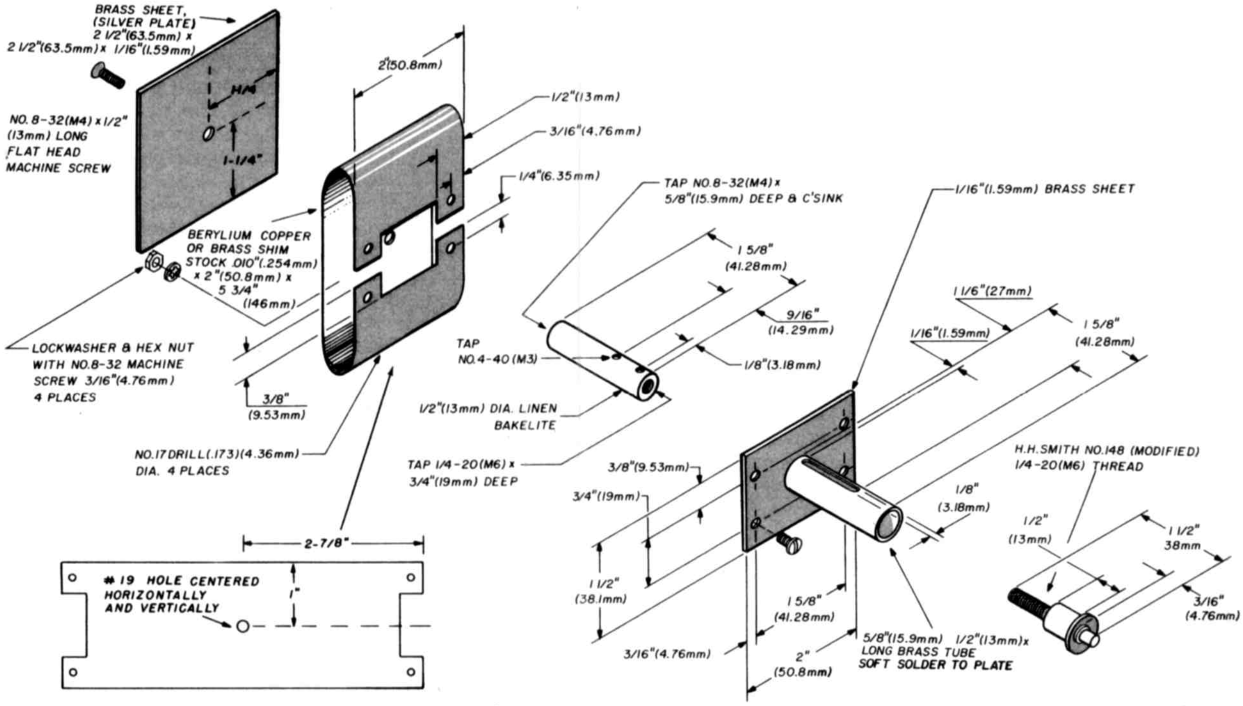


fig. 3. Variable plate portion of plate-tuning capacitor C5. Since there are no moving or sliding contacts which carry heavy rf current, this arrangement permits the capacitor to be adjusted under full power without erratic tuning.

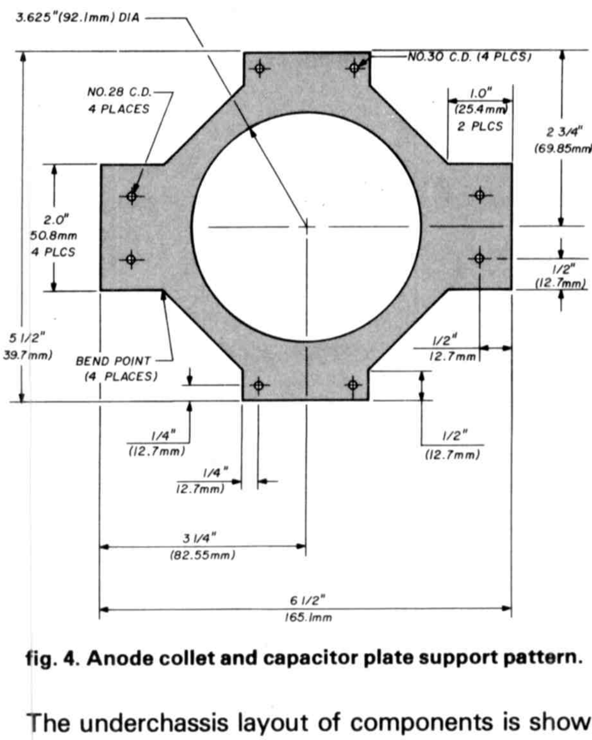
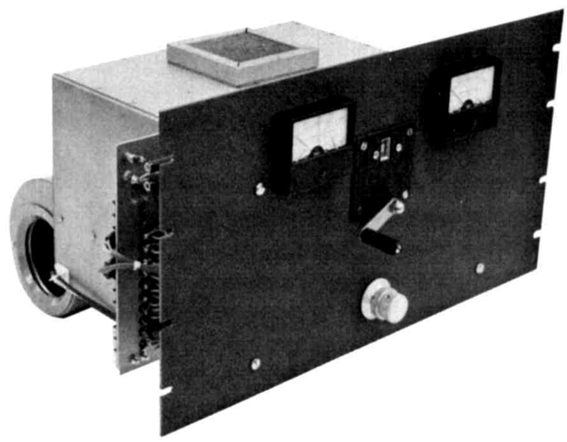


fig. 4. Anode collet and capacitor plate support pattern.

The underchassis layout of components is shown in the photographs. In the close-up view the bifilar wound coil in the foreground is the filament choke. The variable capacitor is C2, and L2 is the U-shaped strap connecting C2 with the cathode terminal. All the cathode leads and one filament lead are connected together with low inductance copper straps. Note that L2 is connected to the center point of all the cathode leads in an effort to equally balance rf drive to all sides of the cathode. At the frequency of 220-MHz, lead length and residual inductance are very important.

The inductor L1 connects capacitor C2 with the input blocking capacitor C1 at the top of an insulating piller. A section of RG-142B/U teflon-insulated coax connects the other side of C1 to the BNC coax input connector. It is difficult to see in the picture, but there is a 1000-pF chip ceramic capacitor connected from one heater pin to the other on the socket.

The socket for the 8877 is the Eimac SK-2210, the version with the grounded grid clips. The filament transformer is located between the aluminum enclosure and the panel. The filament voltage is fed



through the enclosure wall using 0.1 μF Sprague *Hy-Pass* feedthrough capacitors.

plate circuit

The plate circuit of the amplifier is a transmission-line type resonator. The line (L5 plus L6) is one half-wavelength long with the tube placed at the center. This type of circuit is actually two quarter-wave-length lines in parallel. One of the advantages is that each of the quarter-wavelength lines is physically longer than if only one is used. This is because only half of the tube output capacitance loads each quarter-wavelength section. Another advantage to this layout is a better distribution of rf currents around the tube seals.

The dc blocking capacitors are surplus Centralab 100-pF, 5000-volt ceramic capacitors. Two are used on each line to handle the rf current. The homemade variable capacitor C5 tunes the plate circuit. Note that this type of capacitor structure has no wiping contacts. All the rf currents flow through a fixed path which provides very smooth tuning with no jumping meter readings. The load capacitor C6 is constructed in a similar manner.

The plate choke L7 is visible in the photograph of the plate compartment. It is connected to the plate collet assembly with the Erie high voltage feed-through capacitor C7.

construction

The 220-MHz power amplifier is built in an enclosure measuring 8 × 12 × 7-1/4 inches (20 × 30 × 18 cm). The 8877 socket is centered on an aluminum deck 5 inches (12.7 cm) from the top of the enclosure. A centrifugal blower* forces cooling air into the under chassis area; the air escapes through the air-system socket, the teflon chimney (SK-2216), and then the tube. The warm air is exhausted through a "waveguide beyond cut-off" air outlet. This is an assembly which has expanded metal about 1/2 inch (12 mm) thick, mounted in a frame. A perforated aluminum cover may suffice in most cases, although restricts air flow slightly more and is not a very good rf shield at 220 MHz.

The plate tuning mechanism is shown in **fig. 3**. This simple apparatus will operate with any variable plate capacitor, providing a back-and-forth movement of about one-half inch. It is driven by a counter dial and provides a quick, inexpensive, and easy means of driving a vhf capacitor. The ground return path for the grounded capacitor plate is through a wide, low inductance beryllium-copper or brass shim stock which provides spring tension for the drive mechanism.

The variable output coupling capacitor is located at the side of the 8877 anode. The type-N coaxial

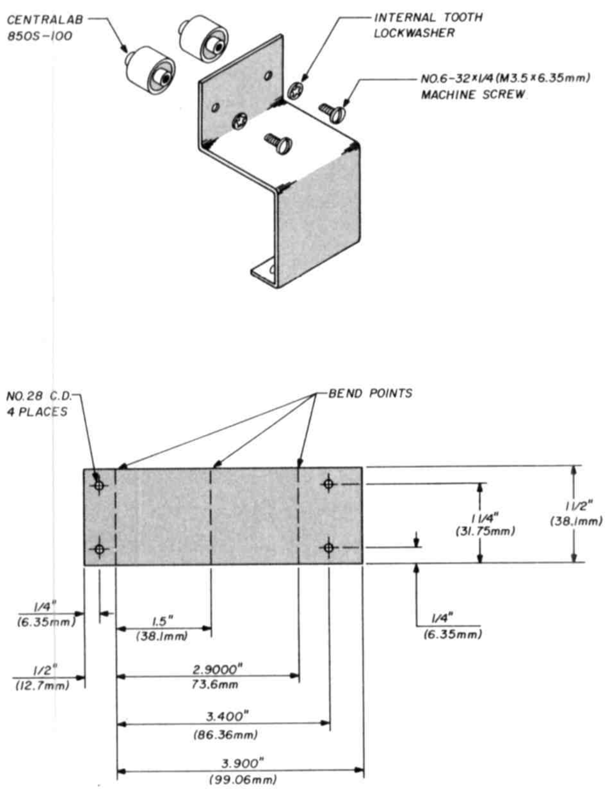


fig. 5. Plate line inductor pattern and bending layout for L5 and L6. Two assemblies are needed for the plate circuit.

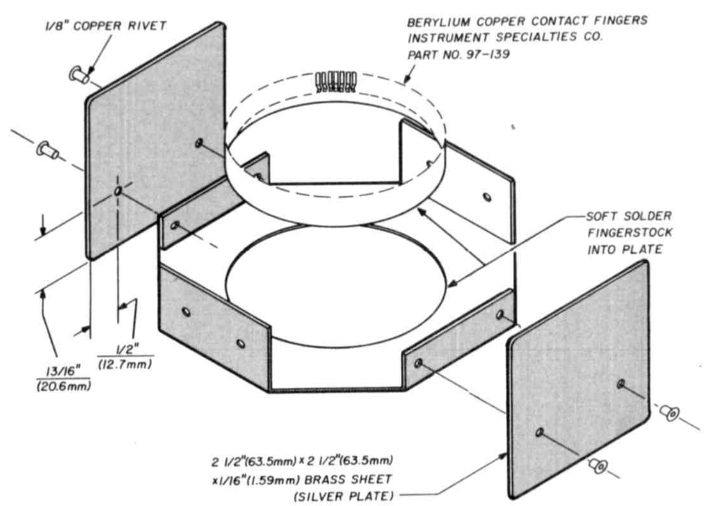


fig. 6. Anode collet and capacitor plate support assembly. The two fixed capacitor plates for C5 and C6 are mounted to the assembly using copper pop-rivets and then soldered. The two remaining bent-up edges are for mounting the blocking capacitors C3 and C4. The finger-stock is soft-soldered into the large hole in the center. A tight fitting aluminum disc helps to hold the finger stock in place while soft soldering with a hot plate.

*Recommended blower is the Dayton 4C446, a 115-Vac unit rated to deliver cooling air at 135 cubic feet per minute (3.8 cubic meters) with a static pressure equivalent to 0.2 inch (5 mm) of water.

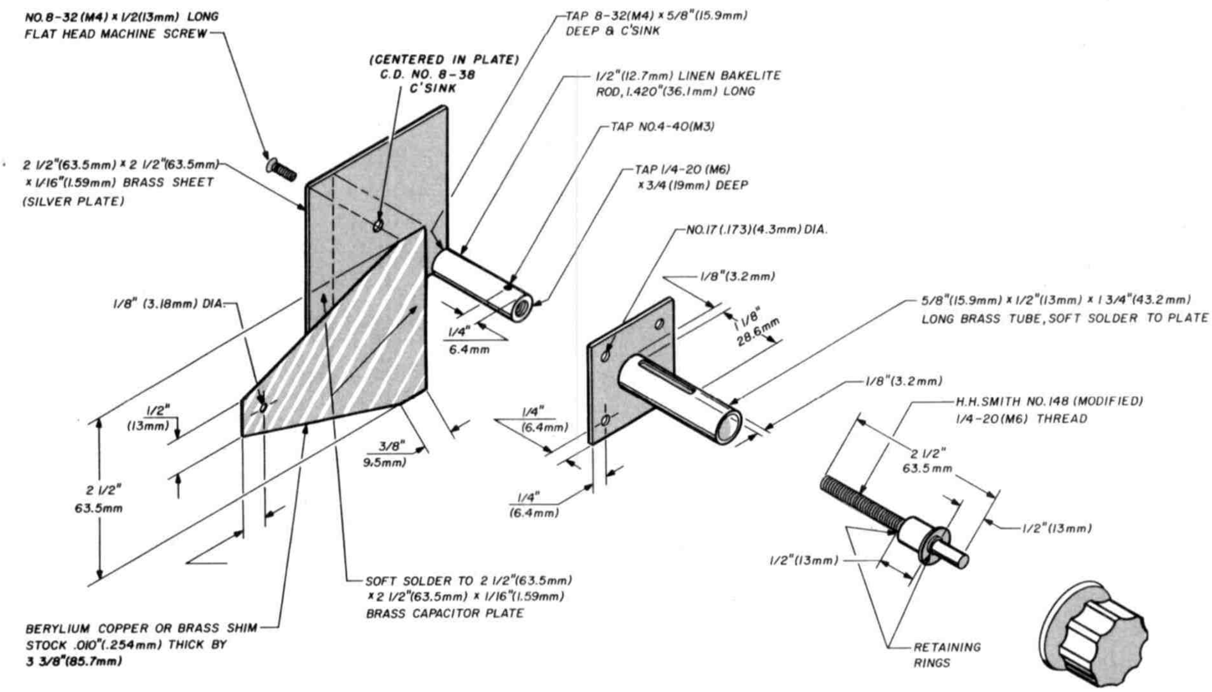


fig. 7. Variable plate portion of the loading capacitor C6. The beryllium-copper portion carries the rf current to the type-N coaxial connector as well as providing spring tension on the tuning mechanism. Because of the constant rf conducting path, the loading is very smooth with no jumpiness.

output connector is connected to the moveable capacitor plate by a wide beryllium-copper strap. The capacitor plate is driven in a manner similar to the tuning capacitor as shown in **fig. 7.**

The plate line is made up of two inductors L5 and L6 (see **fig. 5**) and the anode collet and capacitor assembly shown in **fig. 6**. With the inductor sizes given, the amplifier can be tuned from 220 to 222.5-MHz; no tests were run above 222.5-MHz.

The plate rf choke is mounted between the junction of the anode collet and a pair of the dual blocking capacitors. The high-voltage feedthrough capacitor is mounted on the front wall of the plate compartment. The blocking capacitors are rated for rf service, and inexpensive television-type capacitors are not recommended for this amplifier.

operation

Amplifier operation is completely stable with no parasitics. The unit tunes up exactly as if it were on the hf bands. As with all grounded-grip amplifiers, excitation should never be applied unless the plate voltage is on the amplifier.

The first step is to grid-dip the input and output circuits to near-resonance with the 8877 in the socket. An SWR meter should also be placed in series with the input line so the input network may be adjusted for lowest SWR.

Tuning and loading follows the same sequence as any standard grounded-grip amplifier. Connect an SWR indicator at the output and apply a small amount of rf drive. Quickly tune the plate circuit to resonance; the cathode circuit should now be resonated. The SWR between the exciter and the amplifier will not necessarily be optimum. Final adjustment of the cathode circuit for minimum SWR should be done at full power because the input impedance of a cathode-driven amplifier is a function of the plate current of the tube.

Increase the rf drive in small increments along with the output coupling until the desired power level is reached. By adjusting the drive and loading together it will be possible to attain the operating conditions given in the performance chart in **table 1**. Always tune for maximum plate efficiency: maximum output power combined with minimum input power. It is easy to load heavily and underdrive to get the desired power input but power output will be reduced if this is done.

references

1. R. Sutherland, W6UOV, "Two Kilowatt Linear Amplifier for Six Meters," *ham radio*, February, 1971, page 16.
2. R. Sutherland, W6UOV, "High Performance 144-MHz Power Amplifier," *ham radio*, August, 1971, page 22.
3. M. Partin, K6DC, "Custom Design and Construction Techniques for Linear Amplifiers," *QST*, September, 1971, page 24.

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