amateur service newsletter
W6SAI

THE KW-2. AN ECONOMY GROUNDED GRID LINEAR AMPLIFIER

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The KW-2 sideband amplifier is designed for use with 4-400A, 4-250A, or 4-125A tubes, and will operate on the 80, 40, 20, 15 and 10 meter amateur bands. A pi-network output circuit is used, capable of matching 52 ohm or 75 ohm coaxial antenna circuits. Maximum power input is 2 kilowatts (p.e.p.), or 1 kilowatt, c.w. The amplifier may be driven by any of the popular SSB exciters having 70 to 100 watts output.

Full input may be achieved with the use of 4-400A tubes, but the unit may be run at reduced power rating with 4-250A or 4-125A tubes. No circuit alterations are necessary when tube types are changed.

The amplifier employs a passive (untuned) input circuit, and an adjustable pi-network output circuit. Air tuning capacitors are used in the network in the interest of economy and with no sacrifice in performance. The complete amplifier is housed in a TVI-suppressed perforated metal cabinet measuring 17¼" x 12" x 12½" - small enough to be placed on the operating table next to your receiver.

Amplifier Circuit

The schematic of the amplifier is shown in figure 2. Two tetrode tubes are operated in parallel, cathode driven, with grid and screen elements grounded. The sideband exciting signal is applied to the filament circuit of the tubes, which is isolated from ground by an r.f. choke. The resistance of the windings of the choke must be limited to .01 ohms or less, as filament current is 30 amperes for two 4-250A or 4-400A tubes. Neutralization is not required because of the excellent circuit isolation afforded by the grounded elements of the tubes.

The Input Circuit

The input signal is fed in a balanced manner to the filament circuit of the two tubes. Ceramic capacitors are placed between the filament pins of each tube socket, and excitation is applied to each tube through two 1250 volt, mica capacitors. The latter are employed because of the relatively high value of excitation current which may cause capacitor heating if ceramic units are employed at this point.

The filament circuit is wired with #10 stranded insulated wire to hold voltage drop to a minimum. The leads from the choke to the filament transformer are run in shielded loom which is grounded to the chassis at each end of the wire. The use of shielded leads for all low voltage d.c. and a.c. power wiring does much to reduce TVI-producing harmonics.

The Grid Circuit

The grid circuit of this amplifier is simplicity itself. Screen terminals of both sockets are grounded to the chassis of the amplifier. The best and easiest way to accomplish this is to bend the terminal lead of the socket down so that it touches the chassis. Chassis and lead are then drilled simultaneously for a 4-40 machine screw. Low inductance ground paths are necessary for the high order of stability required in grounded grid service.

It is helpful to monitor the control grid current for tuning purposes, and also to hold the maximum current within the limits given in the data chart. Maximum grid current for the 4-400A is 100 milliamperes. Under normal voice conditions this will approximate a peak meter reading of 50 milliamperes.

Grid current can be observed by grounding the control grid of each tube through a 1-ohm composition resistor, bypassed by a .01 μfd disc capacitor. The voltage drop across the resistor is measured by a simple voltmeter calibrated to read full scale when 100 milliamperes of grid current are flowing through the resistor monitoring grid current of either tube. With incorrect antenna loading, it is possible to exceed maximum grid current rating with some of the larger size SSB exciters. No circuit instability is introduced by this metering technique.

The Plate Circuit

Power is applied to the plate circuit via a heavy duty r.f. choke bypassed at the "cold" end by a 500 $\mu\mu$fd, 10 KV "TV-type" ceramic capacitor. In addition, a VHF choke and capacitor are used to suppress high frequency harmonics that might pass down the plate lead and be radiated through the power supply wiring. Two .001 μfd, 5 KV ceramic capacitors in parallel are used for the high voltage plate blocking capacitor, and are mounted atop the plate choke.

The pi-network coil is an Air-Dux #195-2S inductance, designed for service at a kilowatt level, and silver plated for minimum circuit loss. Use of the cheaper model having tinned wire is not recommended for continuous service at maximum power. The bandswitch is a Communications Products #88 high voltage, ceramic switch.

A circuit Q of 15 was chosen to permit a reasonable value of capacitance to be used at 80 meters. In this case, a 150 $\mu\mu$fd variable air capacitor is employed for operation above 80 meters, and an additional 50 $\mu\mu$fd parallel capacitance is switched in the circuit for 80 meter operation. The 50 $\mu\mu$fd padding capacitor is the small vacuum capacitor found in the "Command" set antenna relay boxes. These capacitors seem to be plentiful and inexpensive. A satisfactory substitute would be a 50 $\mu\mu$fd, 5 KV mica capacitor, also available on the surplus market.

The pi-network output capacitor is a 1500 $\mu\mu$fd unit. It is sufficiently large to permit operation at 80 meters into reasonable antenna loads. For operation into very low impedance antenna systems that are common on this band, the loading capacitor should be paralleled with a 1000 $\mu\mu$fd, 1250 volt mica capacitor. This capacitor may be connected to the unused 80 meter position of the bandswitch.

The Metering Circuits

It is always handy to have an output meter on any linear amplifier. A simple r.f. voltmeter can be made up of a germanium diode and a 0-1 d.c. milliammeter. The scale range is arbitrary, and may be set to any convenient value by adjusting the potentiometer mounted on the rear apron of the chassis. Once adjusted to provide a convenient reading at maximum output level of the amplifier, the control is left alone. Under proper operating conditions, maximum output meter reading will concur with resonant plate current dip.

It is dangerous practice to place the plate current meter in the B-plus lead to the amplifier unless the meter is insulated from ground, and is placed behind a protective panel so that the operator cannot accidentally touch it. If the meter is placed in the cathode return the meter will read the cathode current which is a combination of plate, screen and grid current. This is poor practice, as the reading is confusing and does not indicate the true plate current of the stage. A better idea is to place the meter in the B-minus lead between the amplifier chassis ground and the power supply. The negative of the power supply thus has to be "undergrounded", or the meter will not read properly (figure 5). A protective resistor is placed across the meter to ensure that the negative side of the power supply remains close to ground potential. Make sure that the negative lead between the power supply and the amplifier is connected at all times.

The Cooling System

It is necessary to provide a current of cool air about the base seals and plate seal of the 4-250A and 4-400A tubes. If small blowers are mounted beneath each tube socket it is possible to dispense with the special air sockets and chimneys, and use the inexpensive "garden variety" of socket. A Barber Coleman type DYAB motor and impeller is mounted in a vertical position centered on the socket, and about an inch below it. Cooling air is forced up through the socket and around the envelope of the tube. The perforated metal enclosure provides maximum ventilation, yet effectively "bottles up" the r.f. field about the amplifier. In order to permit air to be drawn into the bottom of the amplifier chassis, small rubber "feet" are placed at each corner of the amplifier cabinet, raising it about ½-inch above the surface upon which it sits.

Amplifier Construction

The amplifier is built upon an aluminum chassis measuring 13" x 17" x 3". Input circuit components, power circuits, and the blower motors are mounted below the chassis, and the plate circuit components are mounted above the deck. Placement of parts is not critical, except that the leads between the bandswitch and the plate coil must be short, heavy and direct. One-half inch, silver plated copper strap is used. The straps are bolted to the bandswitch with 4-40 nuts and bolts. Each lead is tinned and wrapped around the proper coil turn and soldered in place with a large iron. The operation should be done quickly to prevent softening of the insulating coil material. Low resistance joints are imperative at this point of the circuit. To play safe, you can submerge the coil in a can of water, with just the top of the turns showing above the surface. This will prevent the body of the coil from overheating during the soldering process. It is also helpful to depress a turn on each side of the tap in order to provide sufficient clearance for the soldering iron. This may be done by placing the blade of the screw driver on the wire, and hitting it with a smart tap.

The coil assembly is supported on four ceramic pillars, and placed immediately behind the band change switch, which is mounted on a sturdy aluminum bracket. The coil is positioned so that the taps come off on the side nearest the switch.

A set of auxiliary contacts are required to switch the padding capacitor into the circuit when the bandswitch is thrown to the 80 meter position. A simple switch may be made up from the metal portions of an insulated coupling and a block of insulating material, such as teflon, lucite, or micarta (figure 4). The insulated disc of the coupling is removed, and an oval of insulating material is substituted. This assembly is placed on the shaft of the bandswitch. A set of spring contacts are mounted on small standoff insulators attached to the side of the tuning capacitor and positioned so that the oval rotates between the contacts as the switch is turned. A hole is drilled in the oval, and a flat-head 8-32 brass machine screw is passed through it. A nut is run onto the screw, and screw end and nut head are filed flat. When the switch is rotated to the 80 meter position, contact is made between the two spring arms through the body of the screw, which completes the circuit between the switch contacts.

Amplifier Adjustment

Typical operating conditions for various tubes are tabulated in figure 8. For initial adjustment, four or five hundred volts plate potential is applied to the amplifier, and sufficient grid drive is supplied (five watts or so) to provide an indication on the plate meter. The loading capacitor is set at maximum capacitance, and the tuning capacitor is adjusted for resonance, which is indicated by the customary dip in plate current. After resonance is found full plate voltage should be applied to the amplifier, and resting plate current compared with the value shown in the table. If all is well, a carrier is applied to the amplifier for adjustment purposes. The signal may be generated by carrier injection, or by tone modulation of a sideband exciter.

Caution! Do not apply full excitation to any grounded grid amplifier without plate voltage on the stage, or with the stage improperly loaded. Under improper conditions, driving power normally fed to the output circuit becomes available to heat the control grid of the tube to excessive temperature, and such action can destroy the tube in short time. Adjustable control of the excitation level is mandatory.

The amplifier is now loaded to full, single tone input. (In the case of two 4-400A's this will be 3000 volts at 333 ma, 2500 volts at 400 ma, or 2000 volts at 500 ma). Driving power will be approximately 30 watts per tube. Under these conditions, power input will be 1000 watts p.e.p. for sideband operation.

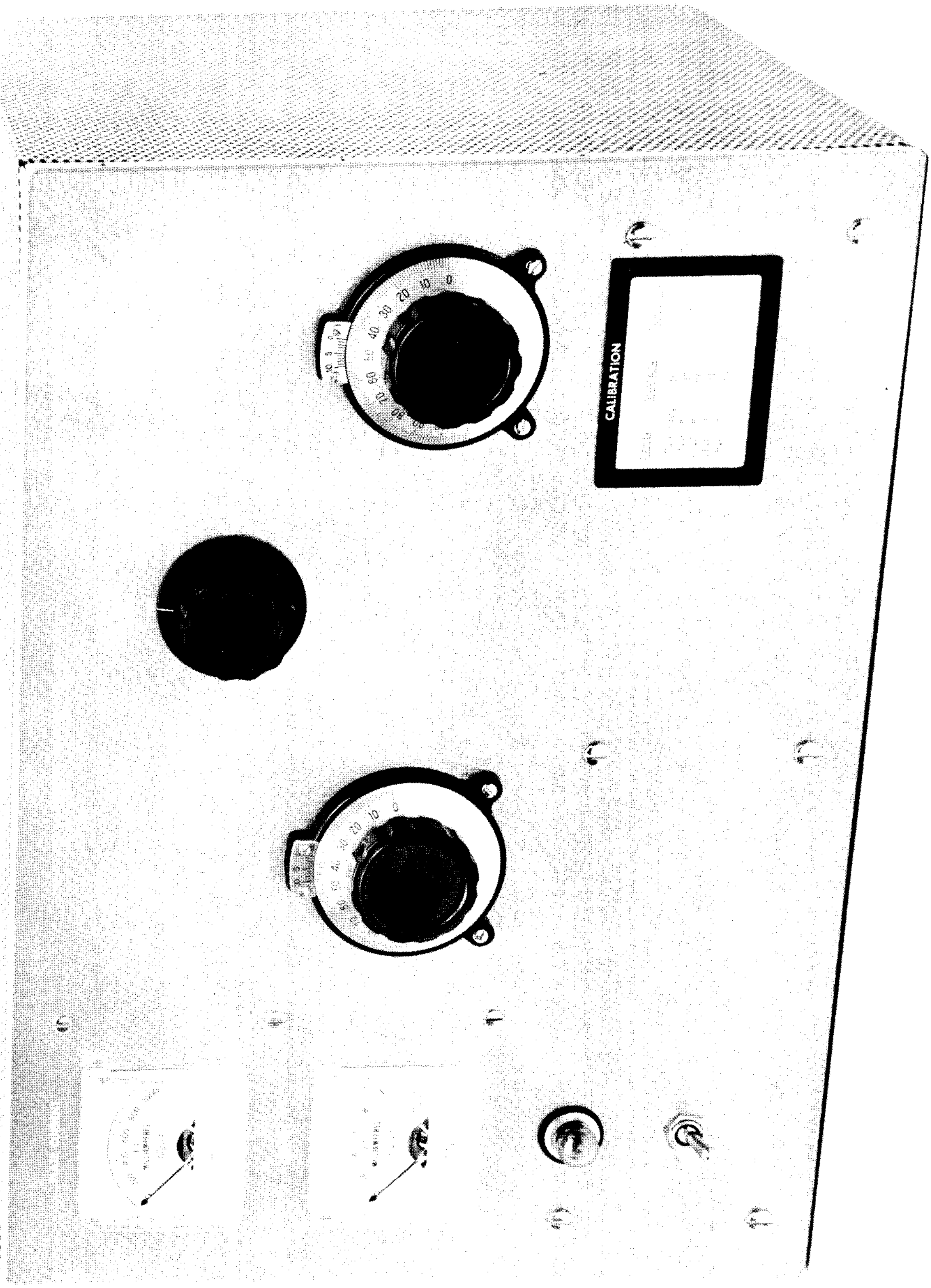
To properly load the amplifier for 2 kw p.e.p. operation it is necessary to have a special test signal. Tuning of this (or any other linear amplifier) is greatly facilitated by the use of an oscilloscope and envelope detectors. Even with two-tone or carrier input signal, however, it is difficult to establish the proper ratio of grid drive to output loading. In general, antenna coupling should be quite heavy: to the point where the power output of the amplifier has dropped about two percent. This point may be found by experiment for power levels up to 1 kw p.e.p. However, since neither this amplifier, nor most power supplies, are designed for continuous carrier service at two kilowatts and since this average power level is illegal, some means must be devised to tune and adjust a "legal" two kilowatt p.e.p. lineal amplifier without exceeding the limitations of the amplifier, and without breaking the law. A proper test signal having high peak to average power ratio will do the job, permitting the amplifier to run at less than a kilowatt d.c. input while allowing the 2 kw peak power level to be reached. This type of signal can be developed by an audio pulser, such as is described in QST magazine, August, 1947 (figure 9). The duty cycle of this simple pulser is about 0.44. This means when the amplifier is tuned up for a d.c. indicated meter reading 800 watts, using the pulser and single tone audio injection, the peak envelope power will just reach the 2 kw level. An oscilloscope and audio oscillator are necessary for this test, but these are required items in any well-equipped sideband station. Loading and drive adjustments for optimum linearity consistent with maximum power output may be conducted by this method.

A Tuned Cathode Network

Use of a tuned cathode network is recommended for optimum linearity and ease of drive (figure 10). As the input impedance of the amplifier is in excess of 50 ohms, a moderate value of s.w.r. will exist on the coaxial line coupling the amplifier to the exciter. With certain lengths of line, it may be found difficult to properly load the amplifier to maximum input because of a lack of excitation. This is a common difficulty encountered in amplifiers employing an untuned cathode circuit. A slight change in line length will alleviate this difficulty somewhat. Unfortunately, some SSB exciters have a fixed pi-network output circuit designed for operation into 50 ohm loads and no adjustment of exciter loading is possible. A tuned cathode network in the amplifier is required in this case to achieve a proper match between the exciter and the amplifier.

The cathode network should be placed directly at the filament circuit terminals of the amplifier, keeping the lead between capacitor C3 of the network (figure 10) and coupling capacitors C3 and C4 (figure 2) very short. The amplifier plate circuit return to the cathode now passes through capacitor C3 of the network instead of returning via the coaxial line and exciter tank circuit. In any grounded grid amplifier, the condition of maximum linearity may only be achieved by the use of such a network.

The network may be adjusted by placing an SWR bridge in the coaxial line to the exciter. When properly tuned, maximum grid current to the amplifier will coincide with minimum SWR on the line.


CALIBRATION

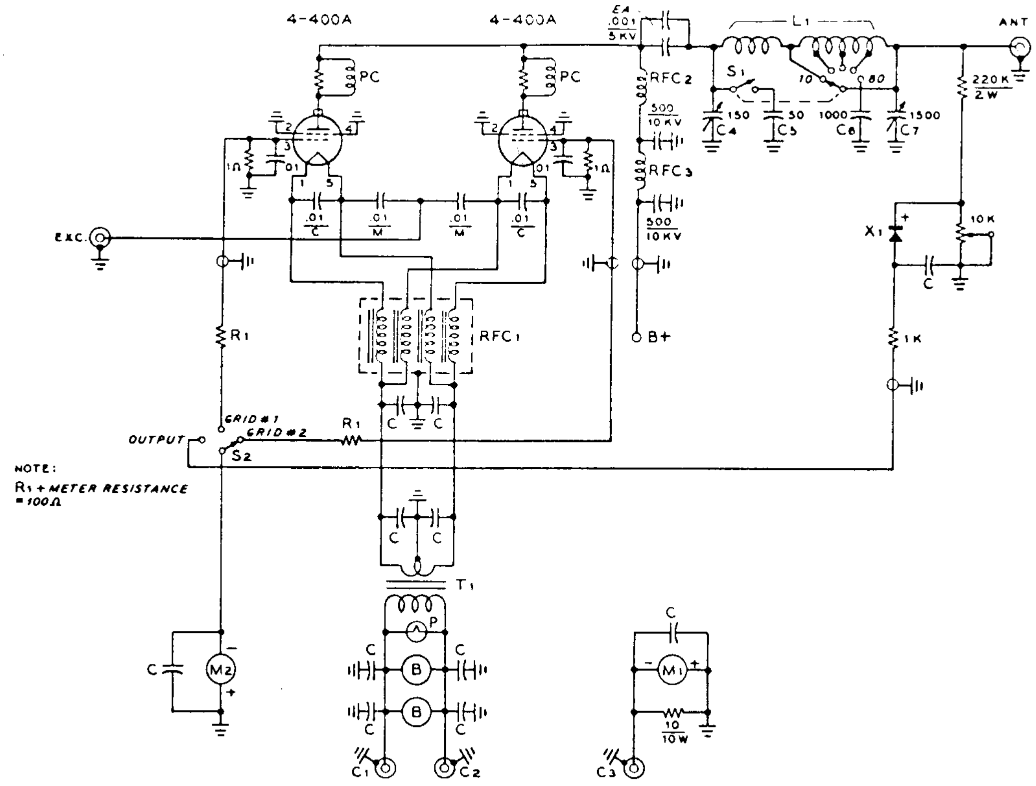


Fig. 2 Schematic, KW2

C--.001 µfd, 600 volt disc ceramic

C1-3, C8--0.1 µfd, 600 volt coaxial capacitor Sprague "Hypass" #80P3

C-4--150 µµfd, 4500 volt. Johnson #150D45

C-5--50 µµfd surplus vacuum capacitor (see text)

C-6--1000 µµfd, 1250 volt mica capacitor (see text)

C-7--1500 µµfd. Obtainable on special order from Barker & Williamson

Note: In drawing, C=ceramic, m=mica capacitor

L-1--Kilowatt pi-network coil. Air-dux #195-2S (silver plated). Modify as follows: Strap coil, 3 turns 1 3/4" diameter. Wire coil, remove turns from free end, leaving 11½ turns, counting from junction with tubing coil.

Tap placements:

10 meters: 1 3/4 turns from junction of tubing coil and strap coil.

15 meters: 3¼ as above.

20 meters: 1½ turns of wire coil, counting from junction with tubing coil.

40 meters: 5¼ as above.

80 meters: Complete coil in use.

RFC-1--30 ampere filament choke. B&W #FC-30

RFC-2--Kilowatt r.f. choke. Raypar, or B&W #800

RFC-3--VHF choke. Ohmite #Z-50

T-1--5 volts at 30 amperes. Stancor P-6468

PC--3½ turns #12e, 7/8" diam. 2" long. Wound around three 220 ohm, 2 watt composition resistors connected in parallel.

R-1--10 ohms, 10 watt, wirewound.

M-1--0-1000 ma. Triplett

M-2--0-1 ma. Triplett

X-1--Diode, type 1N34

B-1, B-2--Blower motor and fan. Barber Coleman #DYAB

P-1, P-2--Coaxial receptacle, SO-239

Chassis & Cabinet--California Co., Type "LTC" 17¼" x 13¼" x 12"

Dials--"Cal-Rad" 3 inch

Plate Blocking Capacitors--.001 mf, 5KV Centralab #858-S (two used).

Plate Bypass Capacitors--500 µµfd, 20 KV "TV-type". Mallory HV-20035B

Tubes--4-400A by EIMAC.

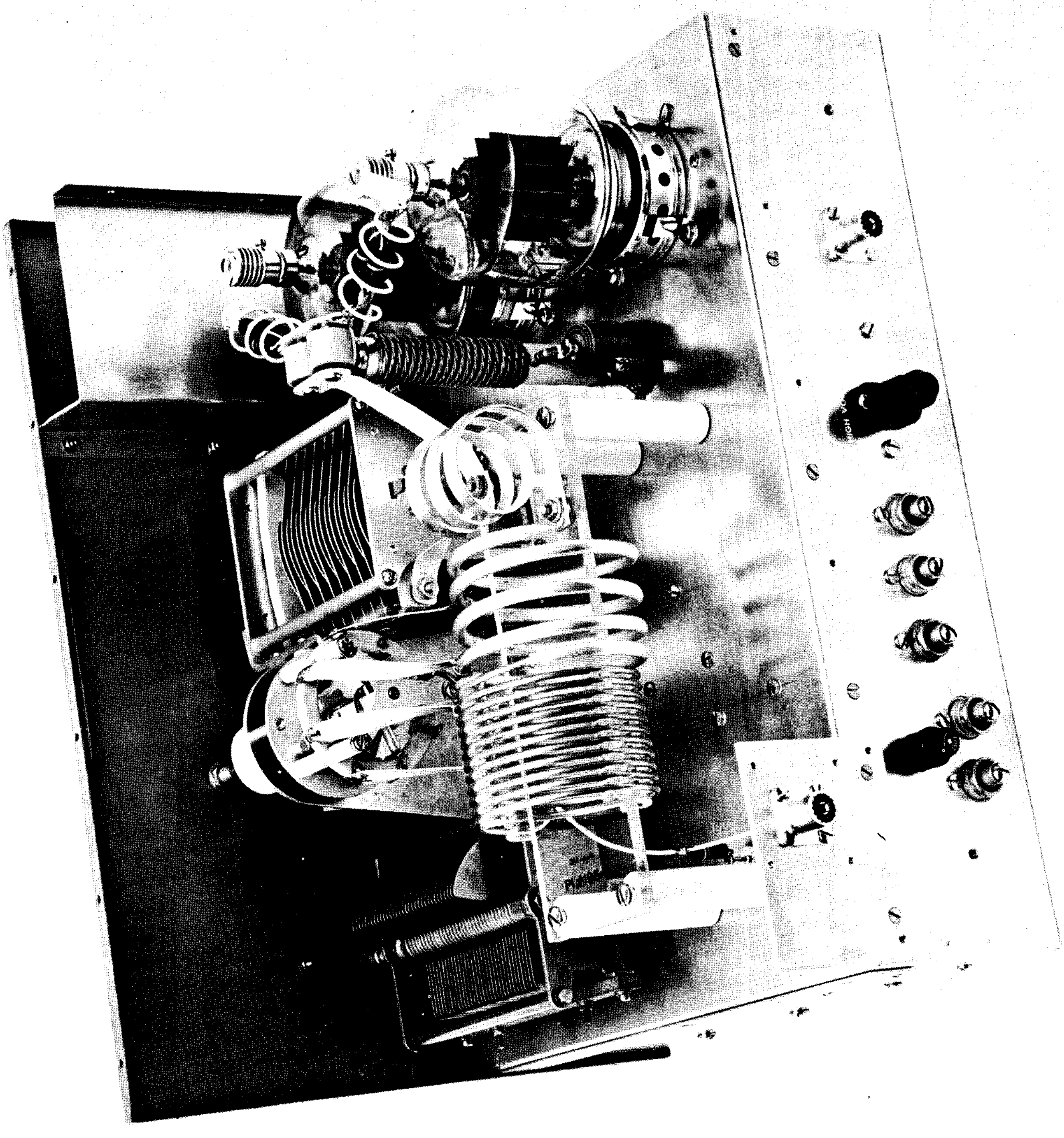


Fig. 8

OPERATING CHARACTERISTICS, EIMAC TETRODES, GROUNDED-GRID CONFIGURATION

4-125A

D-C Plate Voltage	2000	2500	3000	volts
Zero-Signal Plate Current	10	15	20	ma
Single-Tone Plate Current	105	110	115	ma
Single-Tone Screen Current	30	30	30	ma
Single-Tone Grid Current	55	55	55	ma
Single-Tone Driving Power	16	16	16	watts
Driving Impedance	340	340	340	ohms
Load Impedance	10,500	13,500	15,700	ohms
Plate Input Power	210	275	345	watts
Plate Output Power	145	190	240	watts

4-400A

(Ratings apply to 4-250A, within plate dissipation rating of 4-250A)

D-C Plate Voltage	2000	2500	3000	volts
Zero-Signal Plate Current	70	80	90	ma
Single-Tone Plate Current	265	270	330	ma
Single-Tone Screen Current	55	55	55	ma
Single-Tone Grid Current	100	100	100	ma
Single-Tone Driving Power	38	39	40	watts
Driving Impedance	160	150	140	ohms
Load Impedance	3950	4500	5000	ohms
Plate Input Power	530	675	990	watts
Plate Output Power	325	435	600	watts

4-1000A

D-C Plate Voltage	3000	4000	5000	volts
Zero-Signal Plate Current	100	120	150	ma
Signal-Tone Plate Current	700	675	540	ma
Signal-Tone Screen Current	105	80	55	ma
Single-Tone Grid Current	170	150	115	ma
Single-Tone Driving Power	130	105	70	watts
Driving Impedance	104	106	110	ohms
Load Impedance	2450	3450	5550	ohms
Plate Input Power	2100	2700	2700	watts
Plate Output Power	1475	1870	1900	watts

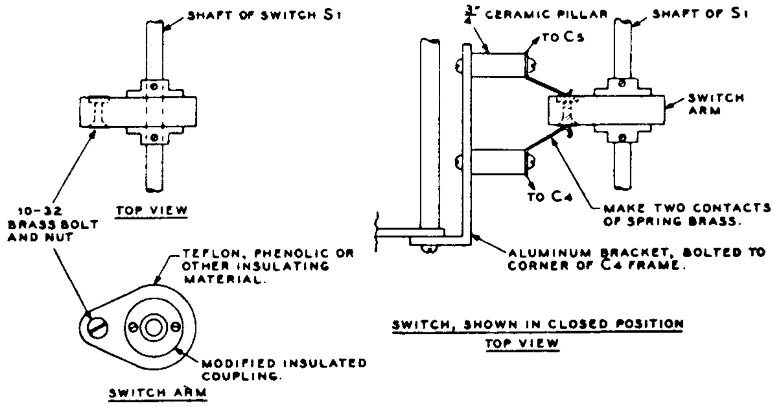


Fig. 4

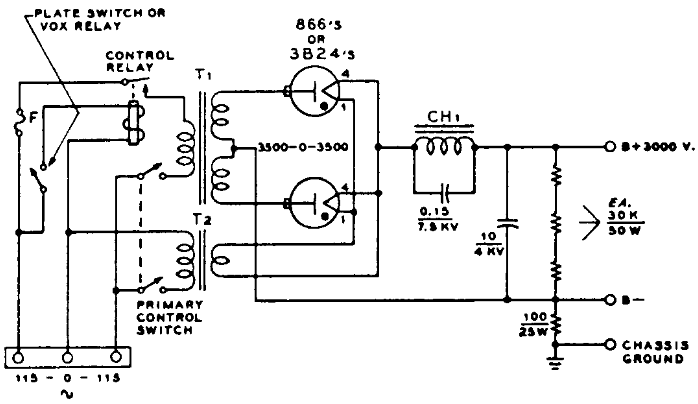


Fig. 5

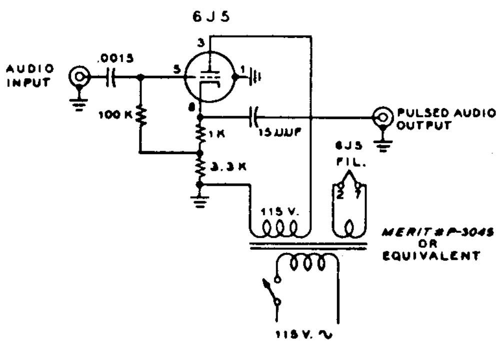
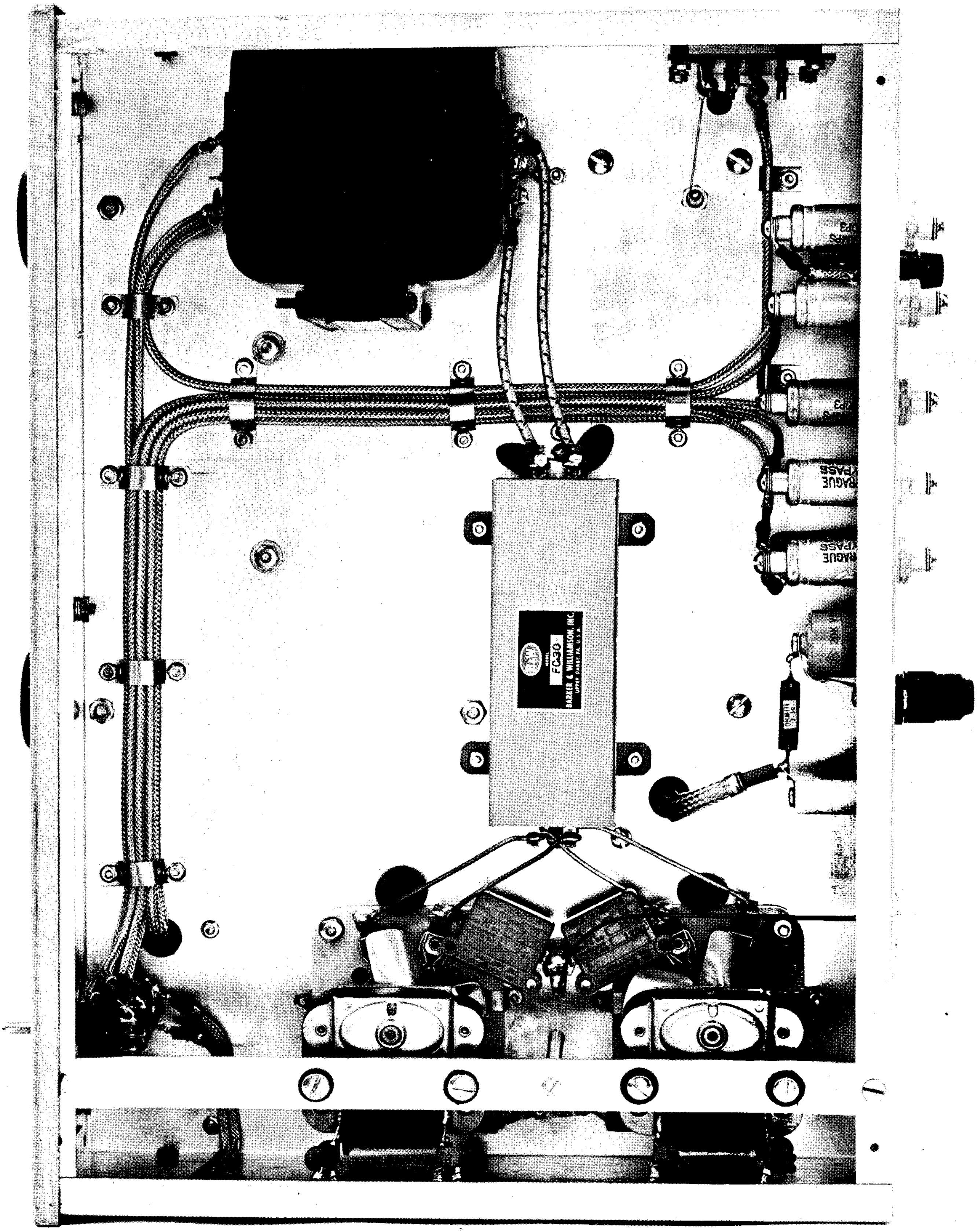


Fig. 9



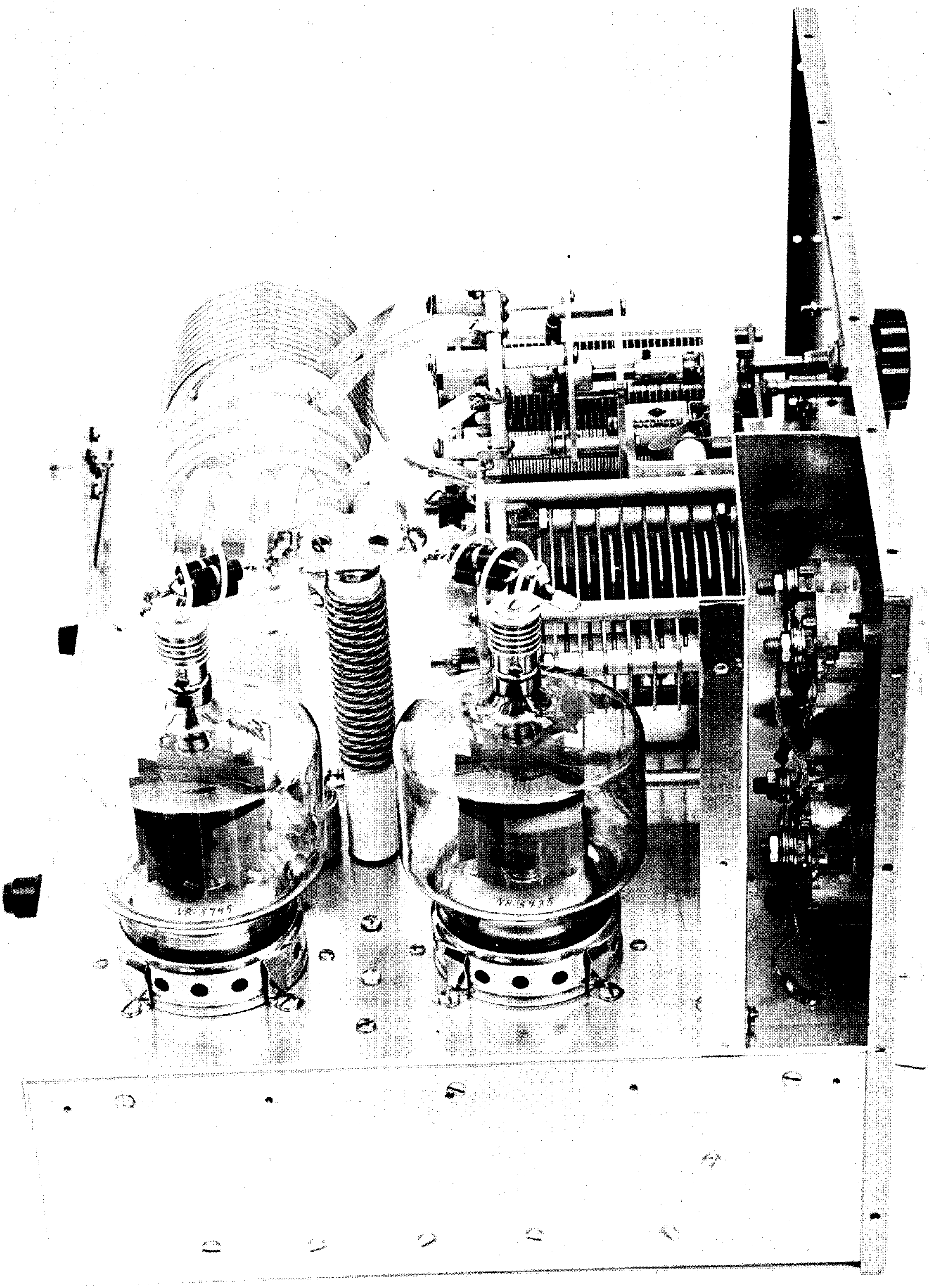
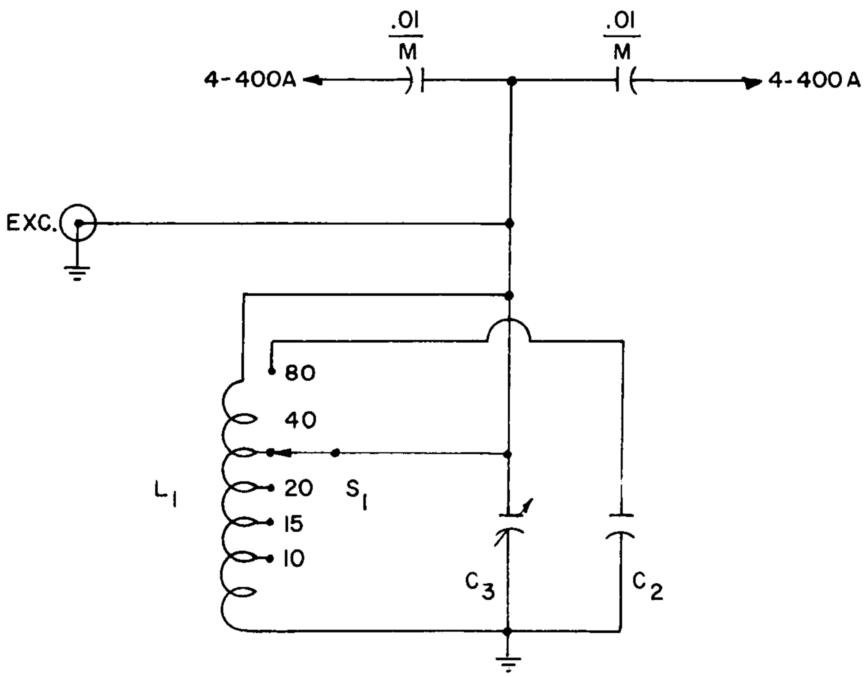


FIGURE 10



C_2 - 800 mmf mica, 1200v test

C_3 - Three gang b.c. capacitor. 1100 mmf. J.W. Miller #2113

L_1 - 9 turns #10e, 1" diam., 1-½" long. 40 meter tap 4-½ turns, 20 meter tap 2-½ turns, 15 meter tap 1-¾ turns, 10 meter tap 1/2 turn plus 2" lead, (all taps measured from the ground end).

Taps adjusted so circuit resonates with tubes in socket with following tuning capacitance:

80 meters - 1660 mmf
40 meters - 830 mmf
20 meters - 415 mmf
15 meters - 240 mmf
10 meters - 210 mmf