USE OF TRIODE-CONNECTED TETRODES AS GROUNDED GRID AMPLIFIERS

The tetrode tube may be connected for hi-mu triode operation by placing the grid and screen elements at the same dc and signal potential (figure 1). Low-mu triode operation may be approximated by connecting the screen to the plate (figure 2). This connection is not recommended for grounded-grid operation, as the tube amplification factor is extremely low and screen dissipation is high.

Hi-mu triode connection, however, offers several advantages for SSB operation. No grid bias or screen power supplies are needed and the drive level of the grounded grid stage is compatable with the power output of the modern sideband exciters. Finally, neutralization is not required in a properly designed HF amplifier.

Certain tetrodes do not perform well when connected in the grounded grid circuit of figure 1. These tubes are characterized by high perveance, together with extremely small spacing between the grid bars, and between the grid structure and the cathode. Thus, while performing in excellent fashion in a grid driven circuit, this family of tubes is unsuited for grounded grid operation. Tubes of the 4-65A, 4X150 (which includes the 7609), 4CX250 (which includes the 8930), 4CX300, 4CX350, 4CX1000A, and 4CX1500 families are in this class.

For proper operation of a high-perveance tetrode the screen requires a much large voltage than the control grid. When the electrodes of the tubes are tied together the control grid tends to draw very high current and there is grave risk of destroying it. For example, in grounded grid configuration, the control grid current of the 4X150A is 1.3 amperes at the positive peak of the driving cycle and the peak screen current is 0.5 amperes. At the same instant, the peak plate current is only about 0.8 amperes. In other words, the plate is getting only a third of the current emitted by the cathode instead of nearly all the current! By any standards, such a triode is unsatisfactory. Under these conditions the grid dissipation is about one thousand times as great for the high-mu-connected configuration as it is for the tetrode-connected tube.

The best way to operate tetrodes such as the 4X150A/4CX250B family or the 4CX1000A in a cathode driven linear amplifier is to ground the grid and screen through bypass capacitors and to operate them at their rated dc voltages, as shown in figure 3. The grid dissipation drops to normal when this is done and stage gain is greatly increased. The screen dissipation is nearly the same as in the normal tetrode connection. Good stage gain can be obtained with this circuit because the driver does not have to supply large screen and grid losses. If it is desired to dissipate excess driving power, it should be expended in a resistive load (figure 4).

Tetrodes such as the 4-125A, 4-250A, 4-400A and the 4-1000A are suitable for connection as grounded grid triodes because of their favorable current division characteristic. In the case of the smaller tubes, maximum power capability is limited by maximum grid dissipation.

The following ratings apply to these tubes for triode connected, grounded grid service:

OPERATING CHARACTERISTICS, EIMAC TETRODES, GROUNDED GRID CONFIGURATION

4-125A (VOICE CONDITIONS)

Dc Plate Voltage	2000	2500	3000	Vdc
Zero-signal dc Plate Current *	10	15	20	mAdc
Single-Tone dc Plate Current	105	110	115	mAdc
Single-Tone dc Screen Current	30	30	30	mAdc
Single-Tone dc Grid Current	55	55	55	mAdc
Single-Tone Driving Power	16	16	16	W
Driving Impedance	340	340	340	Ohms
Load Impedance	10,500	13,500	15,700	Ohms
Plate Input Power	210	275	345	W
Plate Output Power	145	190	240	W

4-400A (VOICE CONDITIONS)

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

Dc Plate Voltage	2000	2500	3000	Vdc
Zero-Signal dc Plate Current *	60	65	70	mAdc
Single-Tone dc Plate Current	265	270	330	mAdc
Single-Tone dc Screen Current	55	55	55	mAdc
Single-Tone dc Grid Current	100	100	100	mAdc
Single-Tone Driving Power	38	39	40	W
Driving Impedance	160	150	140	Ohms
Load Impedance	3950	4500	5000	Ohms
Plate Input Power	530	675	990	W
Plate Output Power	325	435	600	W

4-1000A (VOICE CONDITIONS)

Dc Plate Voltage	3000	4000	5000	Vdc
Zero-Signal dc Plate Current *	60	80	110	mAdc
Single-Tone dc Plate Current	700	680	650	mAdc
Single-Tone dc Screen Current	105	80	55	mAdc
Single-Tone dc Grid Current	170	150	115	mAdc
Single-Tone Driving Power	120	110	90	W
Driving Impedance	104	106	110	Ohms
Load Impedance	2350	3200	4600	Ohms
Plate Input Power	2100	2700	3250	W
Useful Output Power #	1320	1790	2050	W

Useful output power is that which is delivered to the load. It is lower than plate output power because of the losses in the plate tank and amplifier output coupling circuits.

* Zero-signal dc plate current will vary significantly from tube to tube.

In all cases, grid current should be monitored. This may be accomplished by grounding the control grid through a 1-ohm composition resistor, bypassed by one or more .01 MFD disc ceramic capacitors (figure 5). The network serves to hold the control grid very near ground potential. Grid current is monitored by measuring the voltage drop across the 1-ohm resistor. The indicating meter is calibrated in terms of grid current. For example, to have a meter range of 100 milliamperes, the series meter resistor plus the internal meter resistance should equal 100 ohms.

For voice operation, plate or grid current (as read on the meter) will reach a peak value less than the single tone meter reading. Under average conditions, voice current peaks should be approximately one-half the indicated single tone current. For example, a single tone plate current of 300 ma is approximated by voice meter peaks of 150 ma. Driving the voice meter peaks to equal the value of single tone current will result in severe overload distortion.

Use of a high-C tuned cathode circuit in any grounded grid amplifier is mandatory if maximum amplifier efficiency, minimum TVI and lowest intermodulation distortion products are desired. The circuit need only have a Q of 2 or so.

For more information on grounded grid amplifiers and for amplifier design information, refer to the "Radio Handbook," 22nd edition, published by Howard W. Sams Co., 4300 W. 62nd St., Indianapolis, IN 46268.

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GROUNDED SCREEN OPERATION OF TETRODE AMPLIFIERS

One of the design problems encountered in tetrode amplifiers is ensuring that the screen element of the tube is at rf ground even though a dc potential is applied to it. The problem arises because the perfect screen bypass capacitor has not yet been invented. Even the best capacitor contains residual inductance which (when added to the inductance of the screen lead of the tube) inhibits neutralization and encourages VHF parasitics. One solution to this problem is to eliminate the screen bypass capacitor by rearranging the circuit.

Figure 1 shows the conventional dc return paths wherein all power supplies are returned to the grounded cathode of the stage. Meters are placed in the common return leads, and each meter reads only the current flowing in the particular circuit.

The dc ground connection is removed from the cathode in figure 2 and placed at the screen terminal of the tube. Circuit operation is still the same as all power supply returns are still made to the cathode of the tube. The only change is that the screen rf ground and dc ground are now the same. The cathode circuit is at a negative potential with respect to the chassis by an amount equal to the screen voltage. Also, the return of the high voltage plate supply and the grid bias supply are now negative with respect to ground by the screen potential. The cathode is bypassed to ground, as shown.

A practical version of this circuit is shown in figure 3. The grid bias and screen supplies are incorporated in the amplifier and terminals are provided for positive and negative connections to the high voltage supply. A "tune-operate" switch is added which removes the screen potential for tune-up purposes. The negative of the plate supply "floats" below ground by the value of the screen voltage. A resistor is placed across the plate milliammeter as a safety device to prevent the circuit from being accidentally opened by chance failure of the meter. Note that the cathode bypass capacitor must be rated to withstand the full screen voltage.

Operation of this circuit is normal in all respects and it may be applied to any form of tetrode amplifier with good results.

Another version of this circuit is shown in figure 4. The screen supply is placed between the cathode and ground, and the supply must be capable of passing the dc plate current. The screen current is thus "swamped" by the plate current. Aside from the extra complication of high current screen supply, the advantage of an extremely stable screen voltage source is gained, plus the fact that the screen potential is added to that of the plate power supply. The plate voltage, therefore, is the sum of the plate and screen supply voltages.

Screen current and plate current should be monitored separately, because screen current is still the best indicator of loading in a tetrode amplifier stage, and also because the screen dissipation rating must be observed.

The resistors "R" serve to tie the plate and screen supplies to ground in the event of meter burn-out. The resistors are just large enough so that they do not materially affect the accuracy of the meters. The grid meter and power supply are "off ground" by the amount of the dc screen voltage and must be adequately insulated.

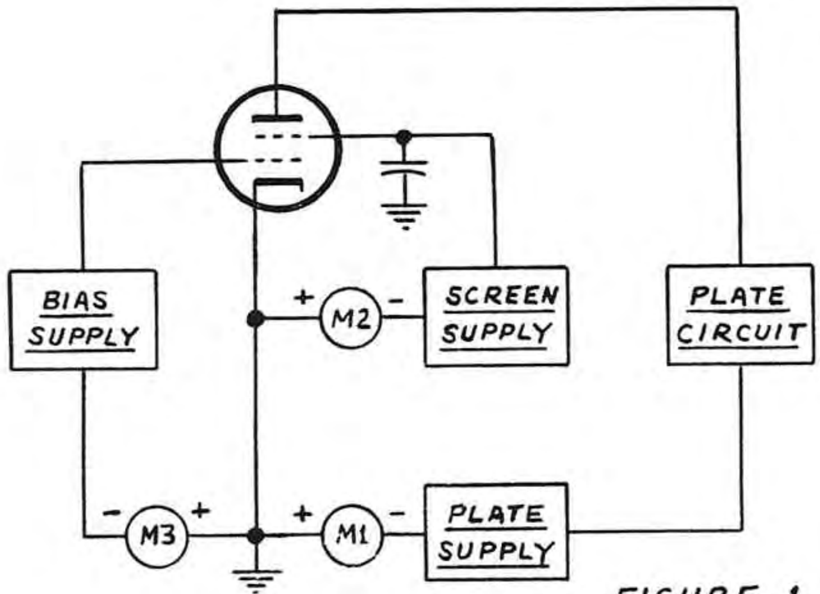

FIGURE 1

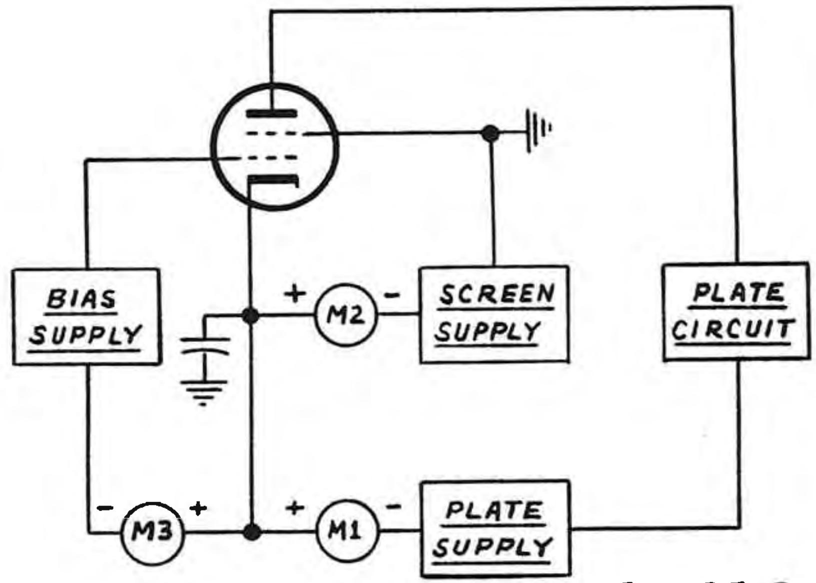

FIGURE 2

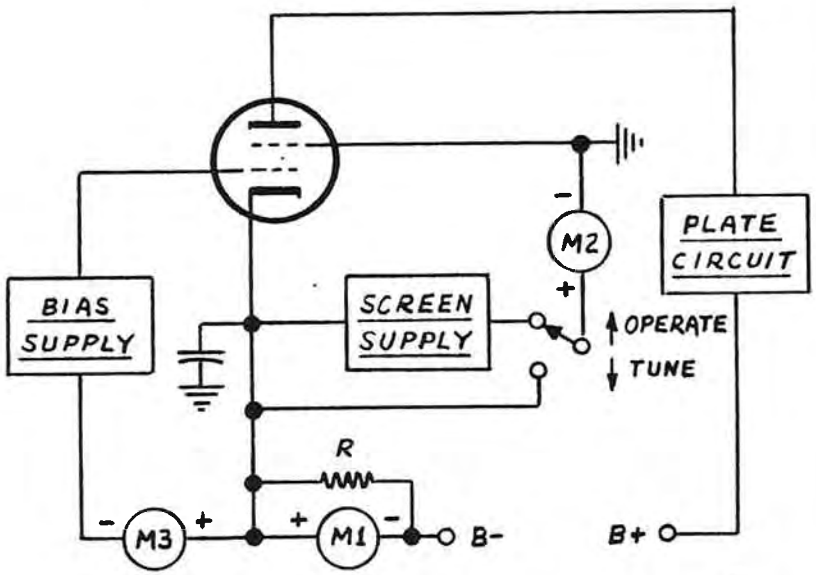

FIGURE 3

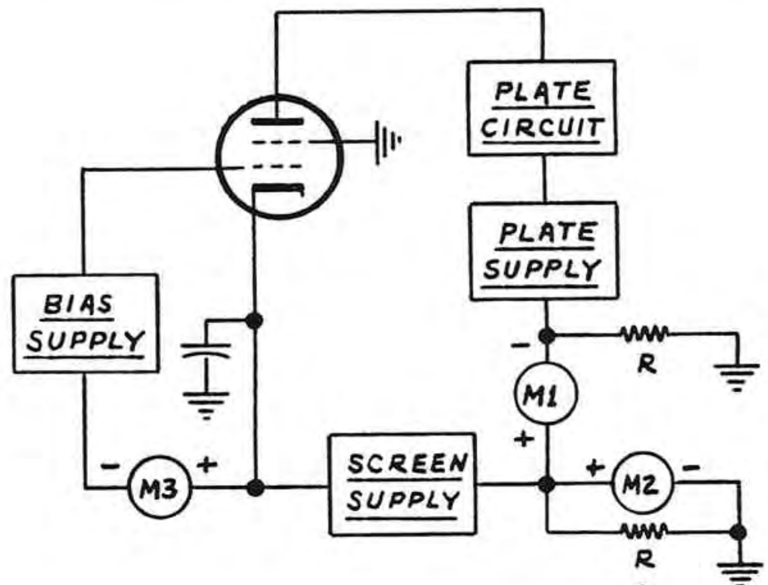

FIGURE 4

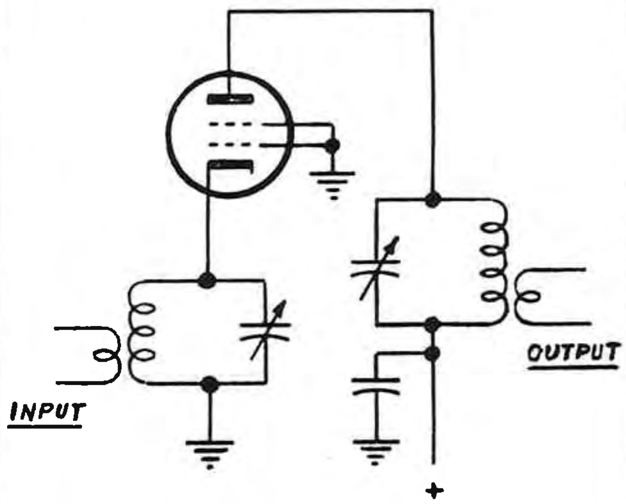

FIGURE 1

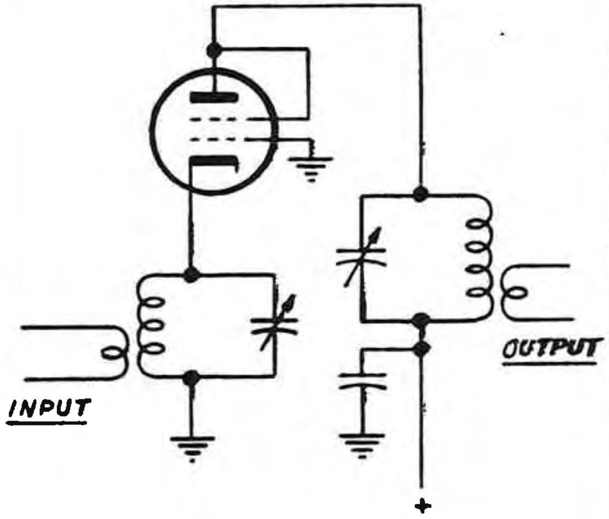

FIGURE 2

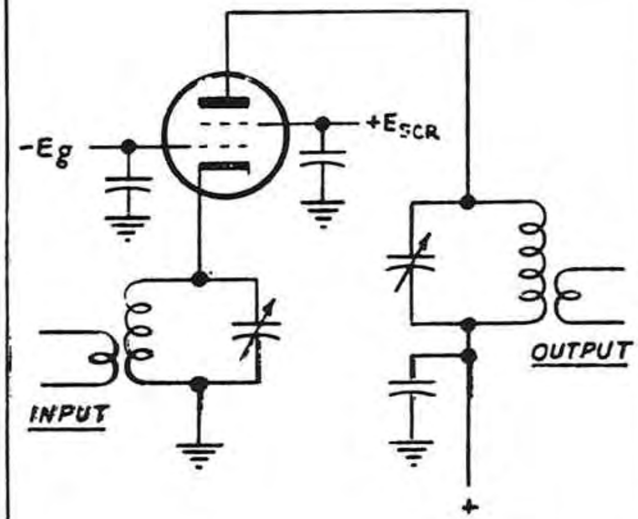

FIGURE 3

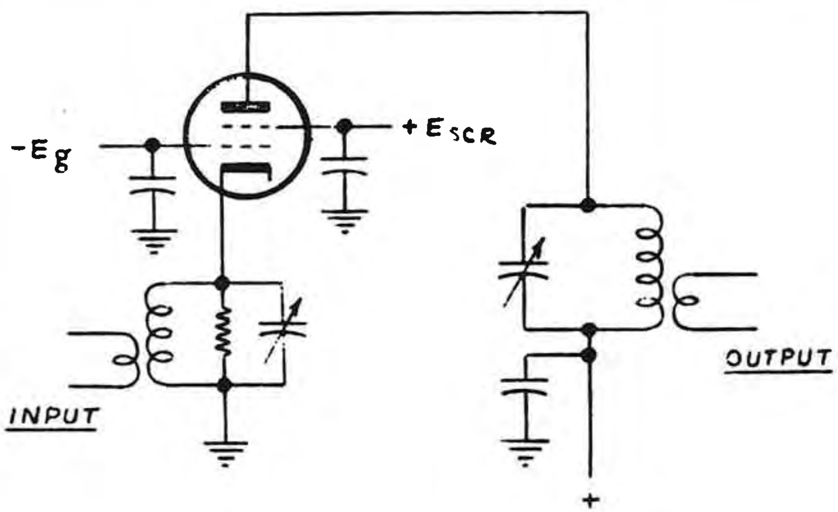

FIGURE 4

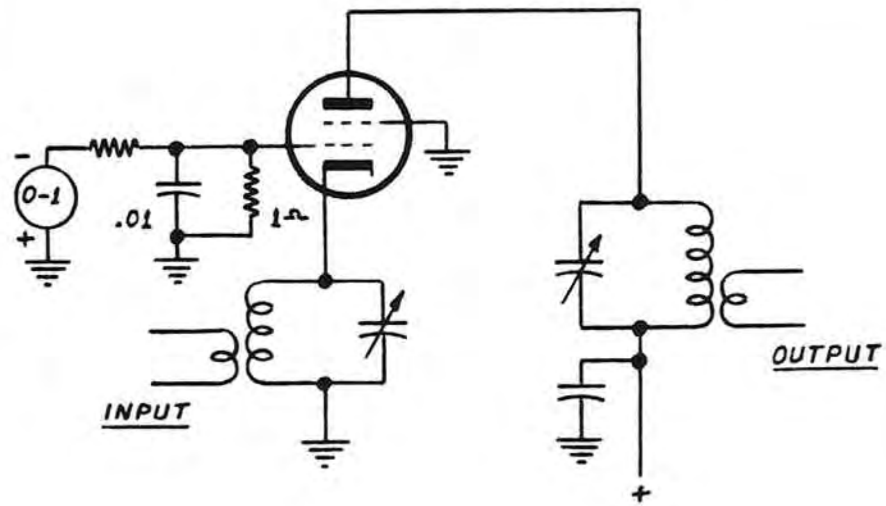

FIGURE 5

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THE 3-400Z and 3-1000Z FOR AMATEUR SERVICE

by William I. Orr, W6SAI

The EIMAC 3-400Z and 3-1000Z are zero bias triodes designed for grounded grid service in the high frequency spectrum. The tubes are rated at 400 and 1000 watts plate dissipation, respectively. No external bias supply is required over the plate potential operating range of 2000 to 3000 volts.

These tubes are especially suited for single sideband operation in the amateur service. Costly and bulky screen and bias supplies are not required. The tubes are small and rugged, and are designed to fit into modern, compact transmitter design. Best of all, the 3-400Z and the 3-1000Z provide improved linearity and a reduction of bothersome intermodulation products when operated in an approved circuit.

The 3-400Z is rated to 1000 watts PEP input, and the 3-1000Z is rated to 2000 watts PEP input. These ratings are established at moderate plate potentials, and result in third-and high-order product distortion figures better than -35 decibels below maximum output!

Preliminary operating data for these tubes is given in figure 1, and suggested circuits are shown in figures 2 and 3.

Circuitry for the 3-400Z

A simple operational circuit for the 3-400Z is shown in figure 2. The input circuit comprises a high-C tank (L1-C1), with excitation applied at a point which matches a 52 ohm driving source. The coil is bifilar wound, with the filament voltage applied to the tube via the coil. The grid of the tube is at ground potential for both d-c and r-f The plate circuit consists of a pi-network (C5-L2-C6) with the output voltage monitored by a simple diode voltmeter.

The Cathode Circuit

Capacitors C3 and C4 form part of the cathode tuned circuit and comparatively high valves of r-f current flow through them. The specified capacitors are satisfactory for the 3-400Z tube in continuous service, and will serve for the 3-1000Z in intermittent duty. These two capacitors should be grounded to a common point at the rotor of capacitor C1. Capacitor C2 carried the full excitation current and should be a transmitting type, as specified.

Although specifically designed for class B service, the 3-400Z may be operated as a class C power amplifier or oscillator or as a plate-modulated radio-frequency power amplifier. One can take advantage of the zero bias characteristic of the 3-400Z in class C amplifiers operating at plate voltages below 3000 volts by employing only grid-leak bias. If driving power fails, plate dissipation is then kept to a low value because the tube will be operating at the normal static zero bias conditions. Operating conditions are listed below:

MAXIMUM RATINGS	Class C Amp. or Osc.	Class C Plate-Modulated
D C PLATE VOLTAGE	4000 VOLTS	3000 VOLTS
D C PLATE CURRENT	350 MA	275 MA
PLATE DISSIPATION	400 WATTS	270 WATTS
GRID DISSIPATION	20 WATTS	20 WATTS
TYPICAL OPERATION		
D C Plate Voltage	3000 volts	3000 volts
D C Plate Current	333 m A	245 m A
D C Grid Voltage	-75 volts	-90 volts
D C Grid Current	130 m A	100 m A
Grid Driving Power	25 watts	18 watts
Plate Output Power	730 watts	550 watts

Air Sockets and Chimneys for the 3-400Z and 3-1000Z

In order to properly cool the seals and envelope of the 3-400Z and 3-1000Z, use of the EIMAC Air System socket is recommended. The SK-400 and SK-500 sockets are satisfactory; however, the new series SK-410 and SK-510 sockets are recommended for new equipments. These modernized sockets feature low cost, lighter weight design and simplified mounting. Low lead inductance insures proper tube operation.

The SK-410 socket may be used with the 3-400Z, 4-250A, 4-400A series tubes, in conjunction with the SK-416 chimney (for the 3-400Z) or the SK-406 chimney (for the 4-250A or 4-400A). The SK-510 socket may be used with the 3-1000Z (with the SK-516 chimney) or the 4-1000A (with the SK-506 chimney). See tube data sheet for air flow and full cooling information.

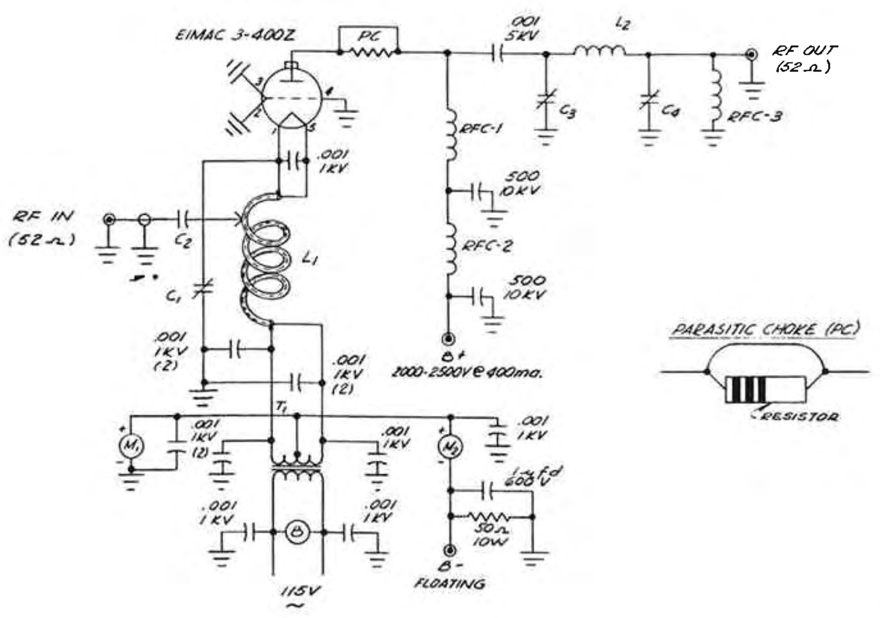


FIGURE 6

Using the 3-400Z on 50 MHz

The 3-400Z is rated for maximum service to over 100 MHz and makes an excellent grounded grid linear tube for 6 meter band. A suitable circuit for this service is shown in Figure 6. Neutralization is not required and the amplifier is stable and free of parasitics. A standard tuned cathode input and pi-network output circuit are used, with the grid and plate current meters placed in the d-c ground return. The power supply shown in Figure 3 can be used with this amplifier.

The amplifier may be built on a 10" x 14" x 3" aluminum chassis-box. Cathode circuit components are mounted within the box, with the plate circuit components placed atop the box. A complete cabinet, or enclosure should be built atop the chassis using perforated aluminum sheet. This will contain the various harmonics and reduce coupling between input and output circuits. The three grid pins of the 3-400Z socket (EIMAC type SK-410) are grounded directly to the chassis by means of wide copper straps passing through the adjacent socket slots. The straps (cut from flashing copper) are soldered to the socket pins, then bolted to the chassis directly next to the socket. Tuned cathode circuit L1/C1 is mounted close to the socket to insure short leads. The "cold" end of the bifilar filament coil (L1) is bypassed with two ceramic capacitors in parallel on each lead to bypass any r-f current flowing at this point. Input tuning capacitor C1 is mounted to the chassis in close proximity to the tube socket. All leads should be short and direct. Coupling capacitor C2 is placed near the tuned circuit and the lead from C2 to the input connector may be a length of 52 ohm coaxial cable.

The blower is mounted to the chassis, forcing air into the box which escapes via the tube socket and chimney.

FIGURE 1
Operating Data For
EIMAC 3-400Z and 3-1000Z

3-400Z

Filament: 5 volts @ 14.5 amperes

Socket: EIMAC SK-400 Air System Socket

Cooling: Radiation and forced air

Maximum Operating Temperatures: Base, 200° C; Plate seal, 225° C

Typical Operation for minimum distortion products with 1 kw PEP input

DC Plate Voltage	2500 volts
Zero Signal Plate Current	73 mA
Single Tone d-c Plate Current	400 mA
Single Tone d-c Grid Current	142 mA
Two Tone d-c Plate Current	274 mA
Two Tone d-c Grid Current	82 mA
Useful Power Output (PEP)	560 watts
Resonant Load Resistance	3450 ohms
Intermodulation Products	Typically more than -35 decibels below PEP level

.ament: 7.5 volts @ 21.3 amperes

Socket: EIMAC SK-500 Air System Socket

Cooling: Radiation and forced air

Maximum Operating Temperatures: Base, 200° C; Plate Seal, 225° C

Typical Operation for minimum distortion products with 2 kw PEP input

DC Plate Voltage	2500 volts
Zero Signal d-c Plate Current	162 mA
Single Tone d-c Plate Current	800 mA
Single Tone d-c Grid Current	254 mA
Two Tone d-c Plate Current	550 mA
Two Tone d-c Grid Current	147 mA
Useful Power Output (PEP)	1050 watts
Resonant Load Resistance	1700 ohms
Intermodulation Products	Typically more than -35 decibels below PEP level

Figure 2: Grounded grid circuitry eliminates expensive bias and screen supplies required with grid driven circuitry. Good tube linearity, plus use of tuned cathode circuit results in low distortion, high power sideband amplifier.

Parts List:

C1 -- 1000 pF (Three gang b-c variable, with sections connected in parallel. J.W. Miller #2113).

C2 -- .01 µF, mica. 1200 volt. Aerovox type 1446.

C3 -- .01 µF, mica. 500 volt. Aerovox type CM-30B-103.

C4 -- same as C3.

C5 -- 3500 volt rating. Effective tuning capacity; 2.5 pF per meter.

C6 -- 500 volt rating. Effective tuning capacity; 25 pF per meter.

L1 -- See text. Resonates to operating frequency with C1 setting of approximately 13 pF per meter. Approximate dimensions are: 80 meters, 10 turns, 1-5/8" i.d., 3-1/4" long, tap 6 turns from ground. 40 meters, 6 turns, as above, 2" long, tap 3-1/2 turns from ground. 20 meters, 4 turns, as above, 1-1/4" long, tap 2 turns from ground. 15 meters, 3 turns, as above, 1" long, tap 2 turns from ground. 10 meters, 1 turn, as above, tap 1/2 turn from ground. Make of 1/4-inch copper tubing, threaded with #12 insulated wire.

L2 -- Make of 1/4-inch copper tubing, 3" i.d. To resonate to frequency with settings of C5 and C6 as specified above.

M1 -- 0-750 mA M2 -- 0-1 mA M3 -- 0-1 mA

R1 -- Internal resistance of meter M3 plus R1 totals 550 ohms. Meter reads 0-500 mA, full scale.

T1 -- 5 volts at 14.5 amperes. Chicago type F-516.

RFC1 -- HF choke. B & W type 800.

RFC2 -- VHF choke. Ohmite Z-144.

PC -- Three 100 ohm, 2 watt composition resistors in parallel; shunt coil is 3 turns, 1" diameter, length of resistors.

B -- 115 volt blower. Minimum of 15 cubic feet per minute. Ripley #82.

FIGURE 3

T1 - 2900-0-2900 volts @ 500 mA CCS. 115-230 volt primary. 1600 VA capacity. Chicago #P-2126.

T2 - For 866A tubes: 2.5 volts @ 10 amp. 9 kV insulation. Chicago #F-210H.
For 872A tubes: 5 volts @ 15 amp. 10 kV insulation. Chicago #F-520HB.

CH1 - 10 Henries @ 500 mA. Resistance 40 ohms. Chicago #R-105

RYL - DPST relay. Potter & Brumfield PR7AY, with 115 volt a-c coil.

Note: 866A rectifier tubes may be used with 3-400Z. Use 872A rectifier tubes for 3-1000Z. Xenon type 3B28 may be substituted for 866A, and 4B32 for 872A.

FIGURE 4

Pi-network circuit for 3-1000Z

C1 - 1250 volt, transmitting-type mica capacitor. Aerovox type 1446 or 1651-L. Two capacitors may be connected in parallel to obtain odd values of capacitance.

80 meters:	1000 pF	15 meters:	150 pF
40 meters:	450 pF	10 meters:	100 pF
20 meters:	220 pF		

C2 - Same as C1. Capacitance as follows:

80 meters:	900 pF	15 meters:	90 pF
40 meters:	375 pF	10 meters:	30 pF
20 meters:	150 pF		

C3 - Same as C1. 0.02 μF

L1 - May be made of B & W Miniductor coil stock, as follows:

80 meters:	2.5 μH 15 turns, 1" diameter, 8 turns per inch. (B & W #3014).
40 meters:	1.1 μH 8 turns, same as above.
20 meters:	0.55 μH 7 turns, 3/4" diameter, 8 turns per inch. (B & W #3010).
15 meters:	0.37 μH 6 turns, same as above.
10 meters:	0.3 μH 6 turns, 1/2" diameter, 8 turns per inch. (B & W #3002).

Network may be adjusted by shorting capacitor C2 and trimming coil L1 until L1-C1 resonates to center of band of operation, or by making C2 variable and adjusting for maximum grid drive.

B - 115 volt, 60 cycle blower. Ripley #81. 45 cubic feet per minute.

RFC1 - 30 ampere bifilar filament choke. Barker & Williamson FC-30

Note: An alternative arrangement is to eliminate the bifilar filament choke and substitute a low-capacity filament transformer. (7.5 volts at 21.3 amperes). A suitable transformer is made by Transformer Technicians, Inc., 2608 No. Cicero Avenue, Chicago, Ill. (Type #TTI-4173).

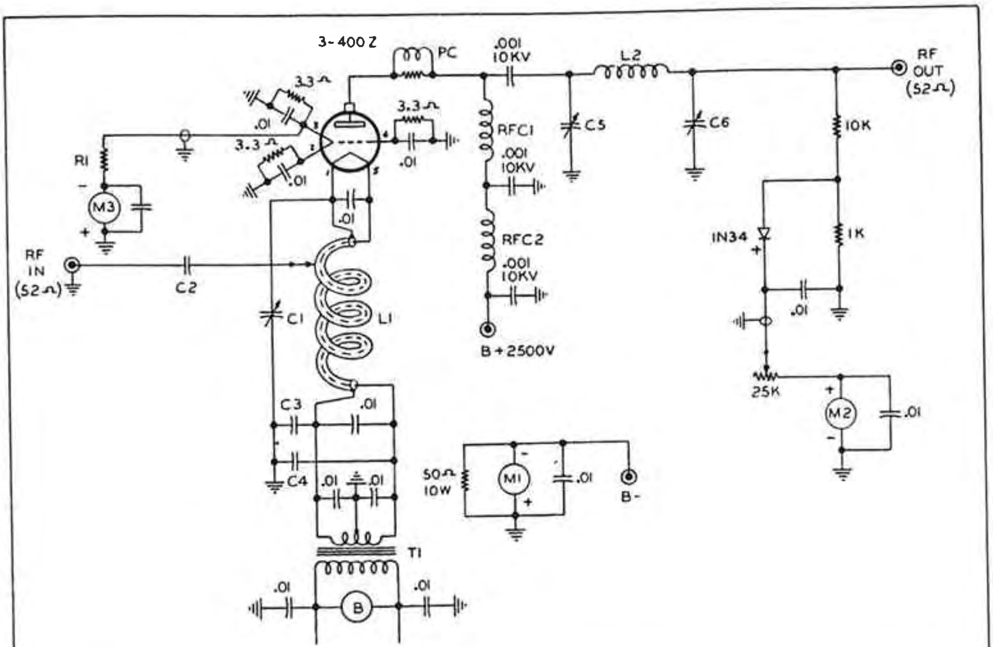


FIGURE 2

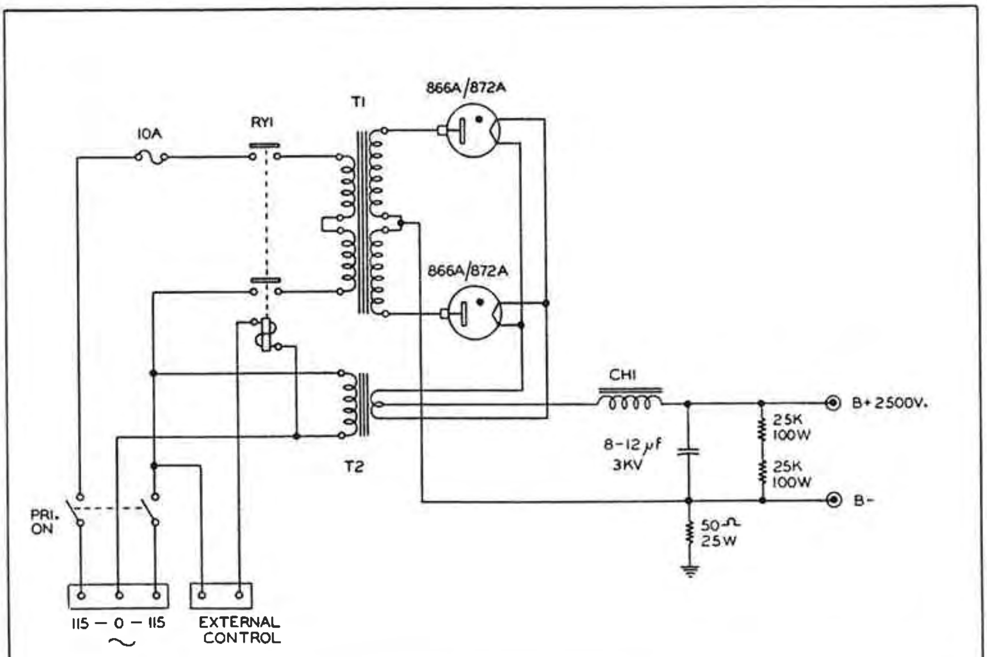


FIGURE 3

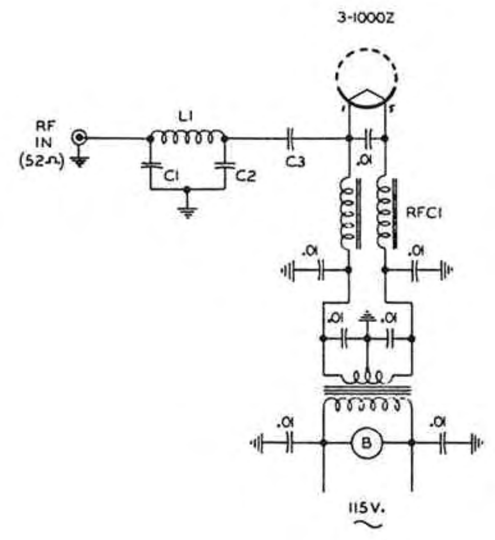
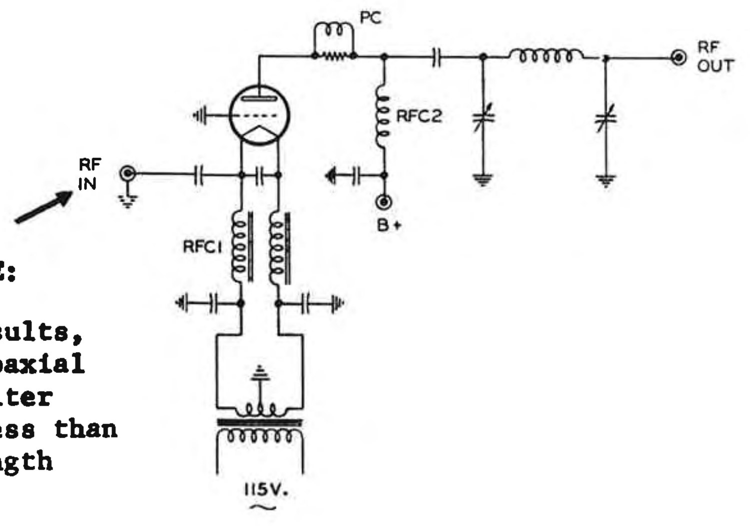


FIGURE 4



NOTE:

For best results, length of coaxial line to exciter should be less than 1/10 wavelength

FIGURE 5

The Untuned Cathode Circuit

hown in figure 5 is a simple grounded grid amplifier circuit employing r-f chokes in the cathode in place of a tuned circuit. This circuit is very popular, and may be employed with the 3-400Z or 3-1000Z provided the limitations of the circuit are understood by the user.

Any single-ended Class B stage (regardless of the tube used) draws grid and plate current over only a portion of the operating cycle (approximately 180°). The input impedance of such a stage, therefore, does not represent a constant load. The waveform delivered by the exciter to the grounded grid stage is greatly distorted over the portion of the cycle that the amplifier draws grid and plate current. Although published "input impedance" values may look attractive, they actually represent only the fundamental component of input impedance (useful for tank circuit "Q" calculation). Since the input load impedance of the class B grounded grid stage is not a constant value, it is necessary to transform it to a **constant impedance** which will resemble 50 ohms over the complete operating cycle. This is best done by a high C tuned circuit placed directly at the cathode of the grounded grid stage.

The 3-400Z and 3-1000Z are not unique in requiring a tuned cathode circuit. Good engineering practice requires it for **any** grounded grid amplifier to achieve best linearity unless the amplifier is operating class A. In short, grounded grid amplifiers may be built **without** the cathode tank circuit, but the fullest capabilities of the equipment will not be realized. Power output will be sacrificed, and poorer values of odd-order product distortion will be observed when the cathode tank circuit is omitted. The degree of degradation will vary with the particular driver/amplifier combination used, and with the length of interconnecting coaxial line. Typical measurements made with a class A driver stage (well swamped) and a short length of interconnecting coaxial line between the driver and a grounded grid amplifier showed that when the amplifier cathode tank was removed, the power output of the amplifier stage dropped about 5%, the third order products increased approximately 3-5 decibels, and the fifth order products increased 5-7 decibels. The higher order products also rose accordingly. It is possible that with an exciter having poorer output circuit Q, and with other lengths of interconnecting coaxial line that a greater degradation might have been noticed in performance when the tuned tank was removed.

The tuned cathode tank can be thought of as a refinement necessary for best performance of a grounded grid class B linear amplifier. Its use is highly recommended.

Filament coil L1 is made of a section of ¼-inch diameter copper tubing with a length of #12 insulated wire passed through the center hole. Heavy conductors are soldered to each end of the coil to serve as filament circuit leads. After the correct position of the excitation tap has been found, it may be soldered in position.

It is necessary to use some form of tuned circuit at this point and to resist the temptation to substitute untuned filament chokes. Use of the latter by themselves will result in degradation of linearity to a marked degree, and will make the amplifier more difficult to drive properly.

Circuit Details

Plate meter M1 is placed in the B-minus lead to the amplifier in order to register plate current instead of cathode current (a combination of grid and plate current). The negative return of the power supply, therefore, should be "floating" as shown in figure 3.

Since a great deal of power is produced in a small package, an EIMAC air system socket and blower are recommended for use with these tubes in order to maintain the envelope and seals at a low temperature. An alternative arrangement may be two separate blowers, one directed at the envelope of the tube, and the other at the bottom of the tube socket.

Amplifier Construction and Adjustment

In order to complement the excellent internal shielding of the grounded grid tubes it is necessary to isolate the input and output circuits. The cathode circuit should be placed below the metal chassis, enclosed in a metal box. Plate circuit components should be mounted above the chassis. As a TVI preventive measure, the complete amplifier should be enclosed within a metal shield made of perforated material. The grid terminals are bypassed to ground by means of three .01 μF ceramic capacitors mounted (one at each socket terminal) by the shortest possible leads. Also placed at each grid terminal is a 3.3 ohm, 1-watt composition resistor. These resistors "de-Q" the capacitors and provide a short, direct ground return for the r-f and d-c currents in the grid circuit. Meter M3 measures the slight voltage drop across the resistors and is calibrated in terms of grid current for tuning purposes.

Before the amplifier is adjusted, the filament voltage at the tube socket should be checked to ensure that excessive voltage drop does not exist in the tuned circuit. Approximate setting for the tap of L1 is given in figure 2. The exact point may be found by loading the amplifier to full input and varying tap placement until maximum grid current is obtained at the same setting of capacitor C1 that provides minimum SWR on the exciter coaxial line. At incorrect tap settings, minimum SWR figure and maximum grid current settings of capacitor C1 do not coincide.

When properly loaded and tuned, grid current runs about 1/3 the value of plate current. Plate loading and tuning and the excitation level adjustments should be conducted to adhere closely to this ratio of grid/plate current. After the amplifier is loaded to maximum input in this fashion, the pi-network should then be overcoupled (C6 reduced in capacitance) slightly until the r-f output measured on M2 drops about 3%. This will approximate a condition of maximum linearity. **Do not** apply full excitation to the tube without plate voltage and proper loading as grid dissipation will be exceeded.

In sideband service, for voice waveforms, the indicated plate current measured on M1 will be approximately one-half the peak d-c plate current. One kilowatt PEP input to the 3-400Z, for example, may be achieved on voice by plate current meter peaks of 200 milliamperes at a plate potential of 2500 volts.

Notes on the 3-1000Z tube

The circuit of figure 2 may be used for the 3-1000Z. However, the higher filament current of this tube requires that a heavier bifilar coil be used having a length of #10 insulated wire for the center conductor. Also, as the input impedance of this tube is close to 52 ohms, the filament tap point for C2 occurs near to the top (filament end) of the coil. Adjustment of the tap point may not be required.

It may be somewhat easier from a mechanical point of view to substitute a pi-network input circuit for the parallel L-C circuit, as shown in figure 4. Untuned filament chokes are used to supply filament voltage to the tube, and a simple fixed tuned pi-network circuit is employed to couple the exciter to the filament circuit of the 3-1000Z. The transformation ratio of the network is 1:1, matching the line to the tube, yet providing the "Q" necessary for proper circuit operation. The pi-network circuit and filament choke may be used for the 3-400Z tube, if desired.

To assist in proper adjustment of the amplifier, an output tuning device should be placed in the coaxial lead to the antenna. A SWR power meter or r-f ammeter may be used. The amplifier is adjusted for maximum power output at the proper plate and grid current values. Carrier injection may be used for the tuning process, and antenna loading and grid drive adjusted to provide the current data given in figure 1 for 3-400Z.

FIGURE 6

50 MHz Linear Amplifier for 3-400Z

C1 - 100 pF. Bud MC-1855 (double bearing)

C2 - .001 mica capacitor

C3 - 15 pF. 3 kV (.075" spacing). Johnson 155-8 capacitor may be used, with every other rotor plate removed.

C4 - 200 pF. Bud MC-1858 (double bearing)

L1 - 2 turns of 1/4-inch copper tubing, 1 inch inside diameter, 1-1/2 inches long. Pass #12 insulated wire through center before winding coil. Tap for C2 placed at center of coil. Connections between L1 and C1 should be made with 1/8-inch copper strap.

L2 - 3-1/2 turns of 1/4 inch copper tubing, 2 inch inside diameter, 3 inches long. Mount between stator terminals of C3 and C4 with short leads.

PC - Plate lead to 3-400Z is made of 1/4-inch copper strap. The parasitic choke (PC) is made of a section of this lead with three 47 ohm, 2 watt resistors in parallel placed across the lead, as shown in Figure 6. Resistors are mounted side by side.

RFC1 - 8.3 µH. Space-wound on 1/2-inch diameter ceramic insulator, 2-1/2 inches long (Birnbach 447). Wind #28 double silk covered wire spacewound about wire diameter. Winding 1-3/4 inches long. Teflon rod may be used. (Avoid polystyrene as it may melt or deform from heat of tube).

RFC-2,3 - VHF choke. Ohmite Z-50.

M1 - 0-200 mA(grid current)

M2 - 0-500 mA(plate current)

B - 115 volt blower. Minimum of 15 cubic feet per minute. Ripley #82 or Dayton 2C782

T1 - 5 volts at 14.5 amperes. Chicago-Standard F-516

Socket: EIMAC SK-410 Chimney: EIMAC SK-616

Note: 500 pF, 10 kV capacitors are TV "door-knob" type. Aluminum chassis box 10" x 14" x 3" is used.

amateur service newsletter
W6SAI

THE KW-2. AN ECONOMY GROUNDED GRID LINEAR AMPLIFIER

by William I. Orr, W6SAI

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 µµfd, 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 µµfd variable air capacitor is employed for operation above 80 meters, and an additional 50 µµfd parallel capacitance is switched in the circuit for 80 meter operation. The 50 µµfd 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 µµfd, 5 KV mica capacitor, also available on the surplus market.

The pi-network output capacitor is a 1500 µµfd 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 µµfd, 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.

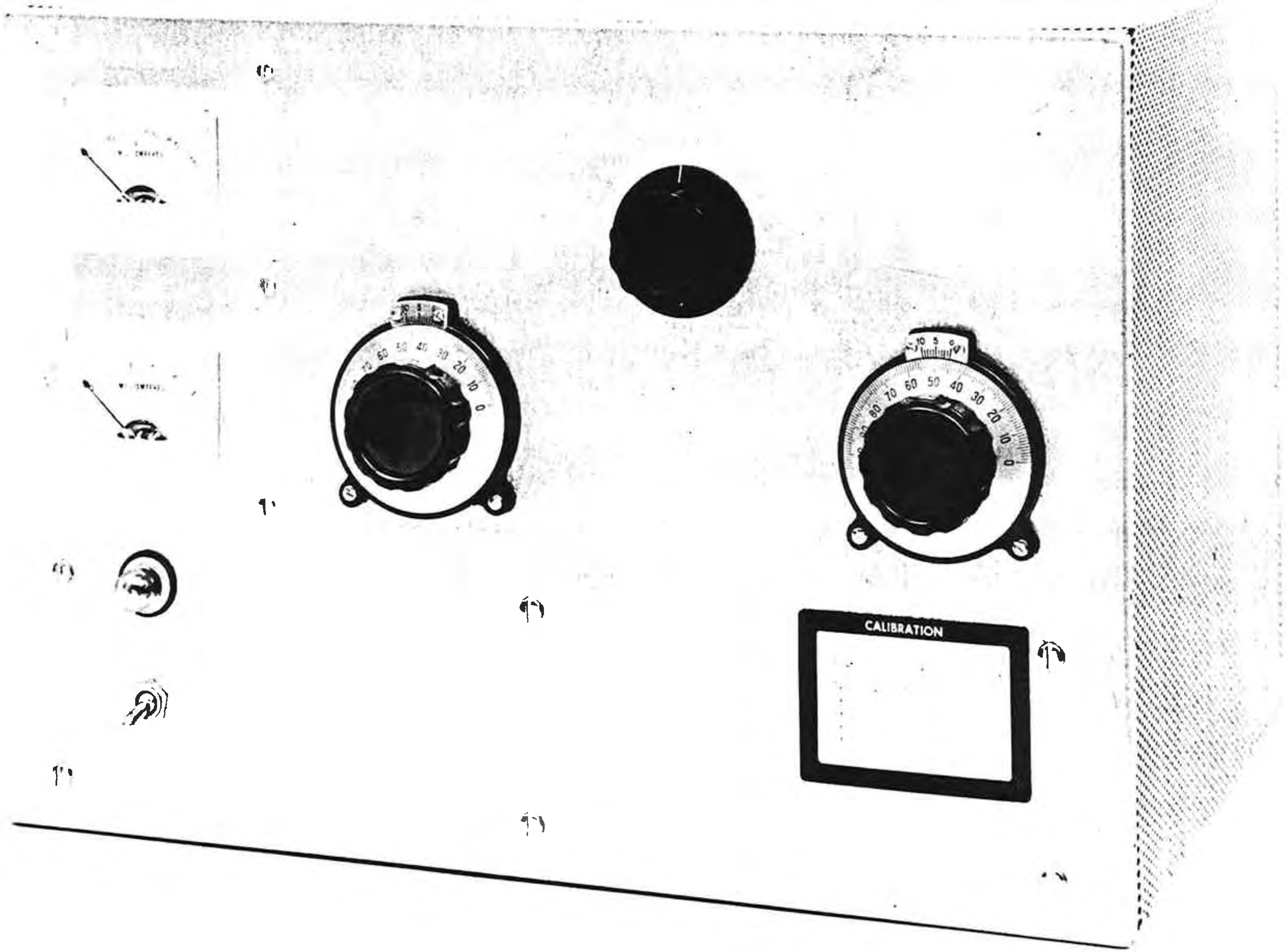
To properly load the amplifier for 2 kw p.e.p. operation it is necessary to have a special test signal. Tuning of this (or any other linear amplifier) is greatly facilitated by the use of an oscilloscope and envelope detectors. Even with two-tone or carrier input signal, however, it is difficult to establish 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

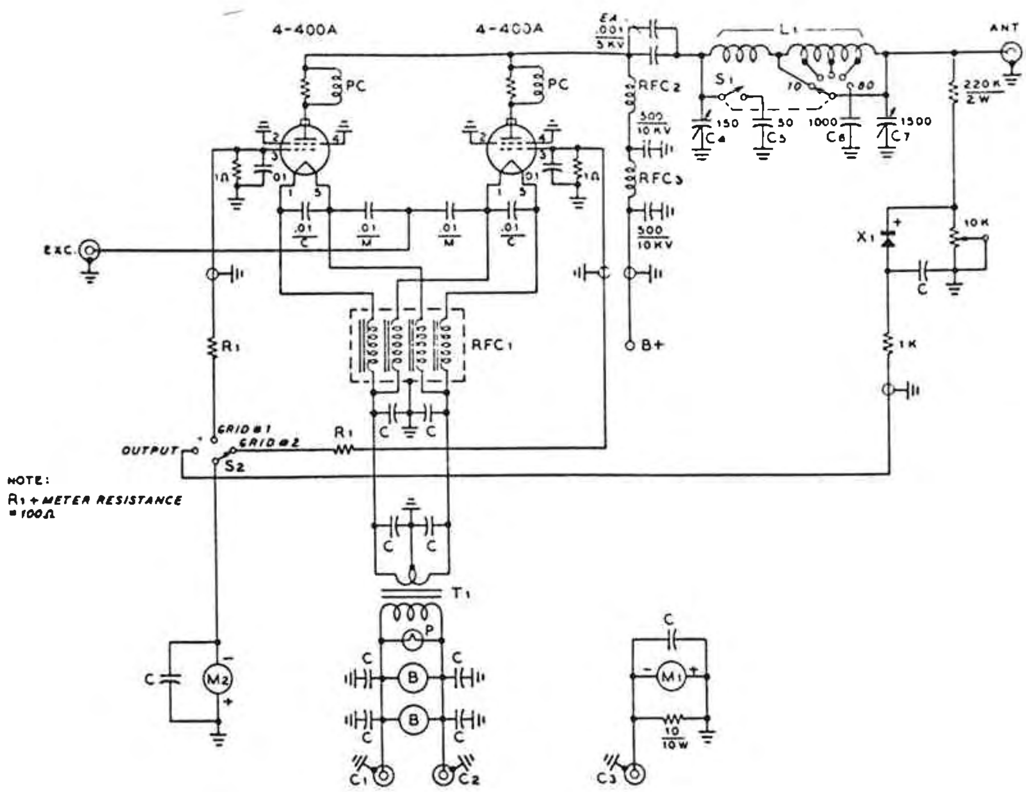


Fig. 2 Schematic, KW2

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.

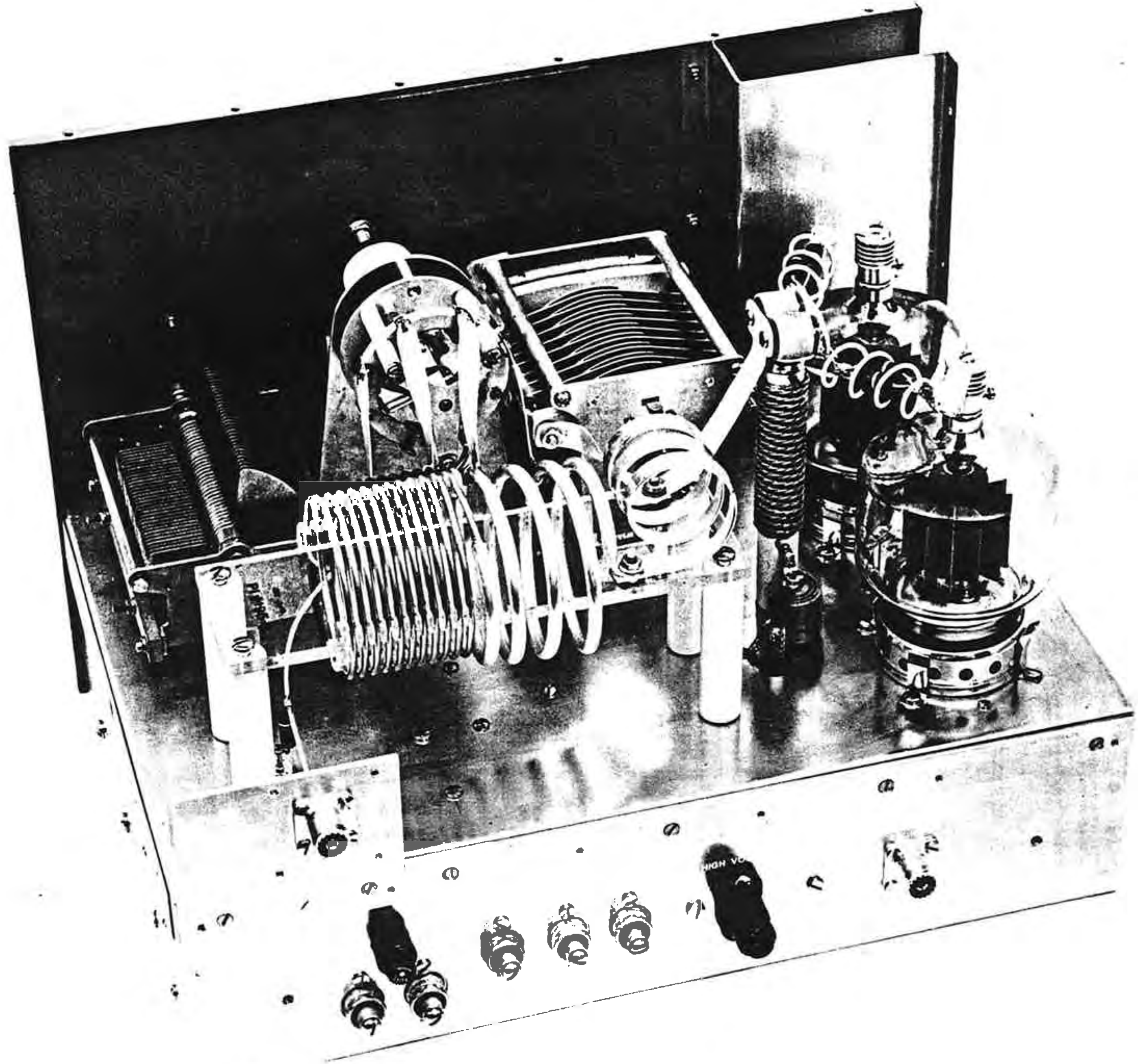


Fig. 8

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

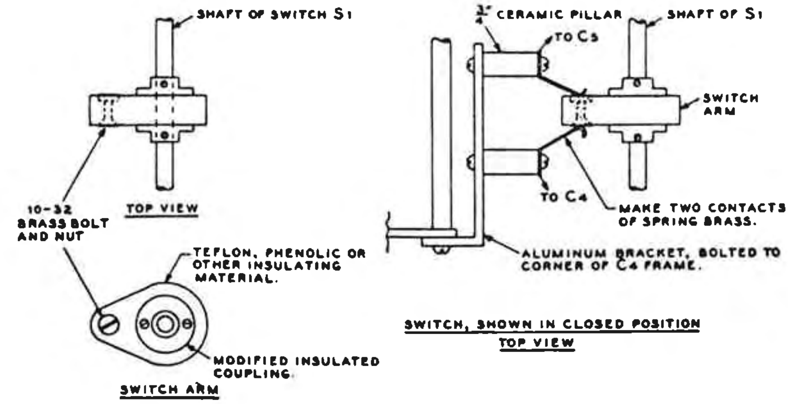


Fig. 4

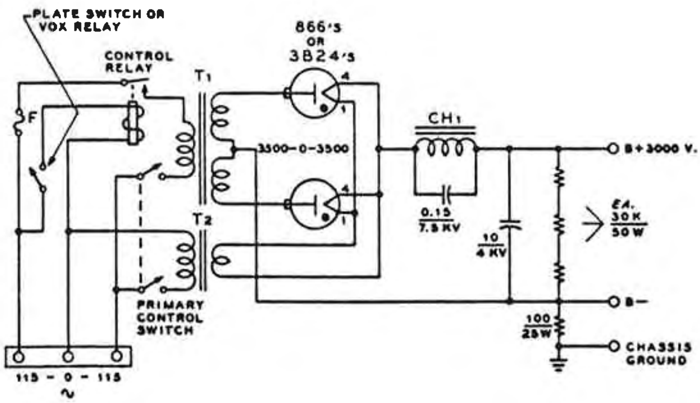


Fig. 5

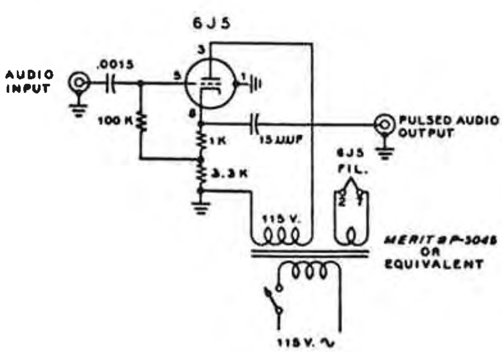
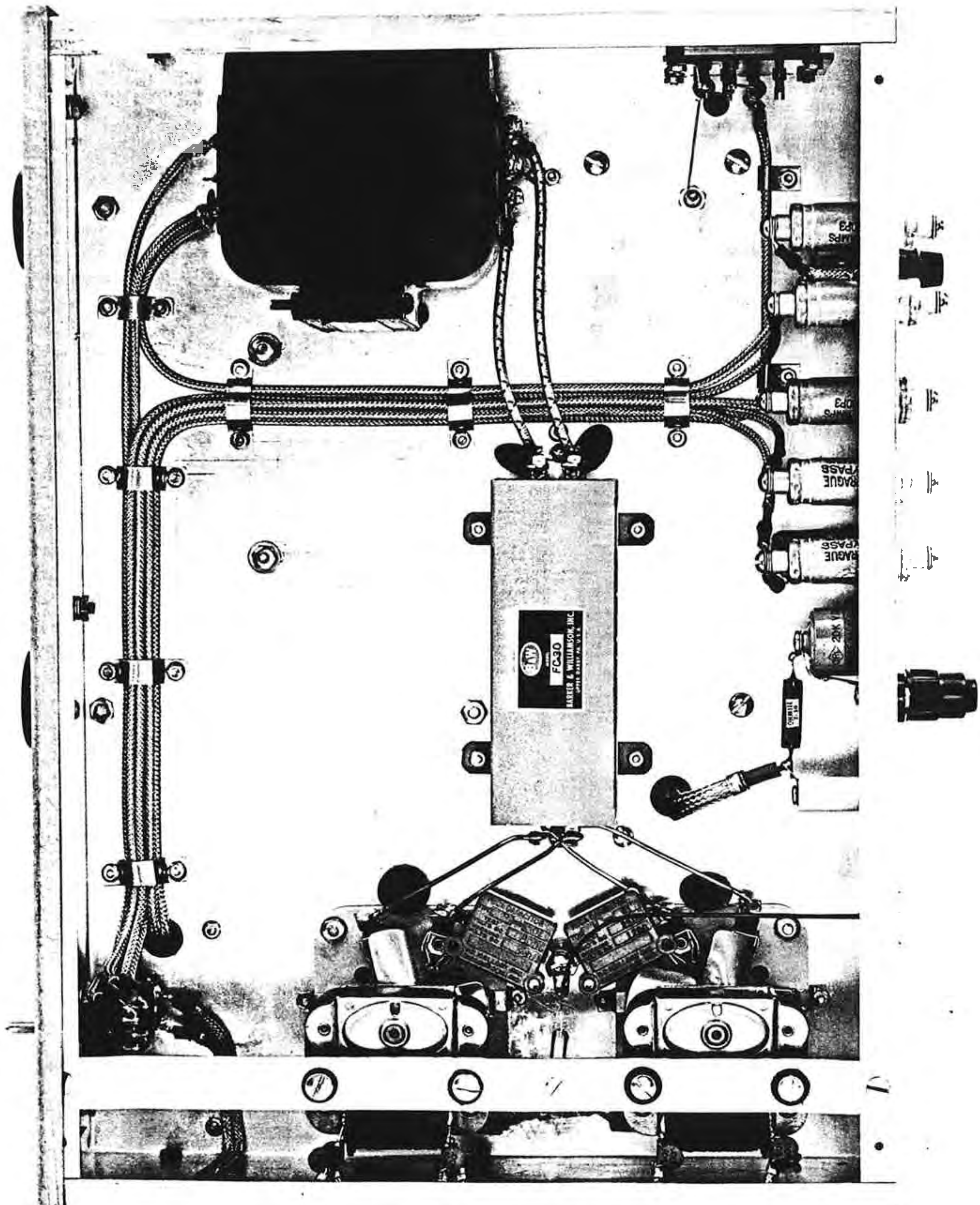


Fig. 9



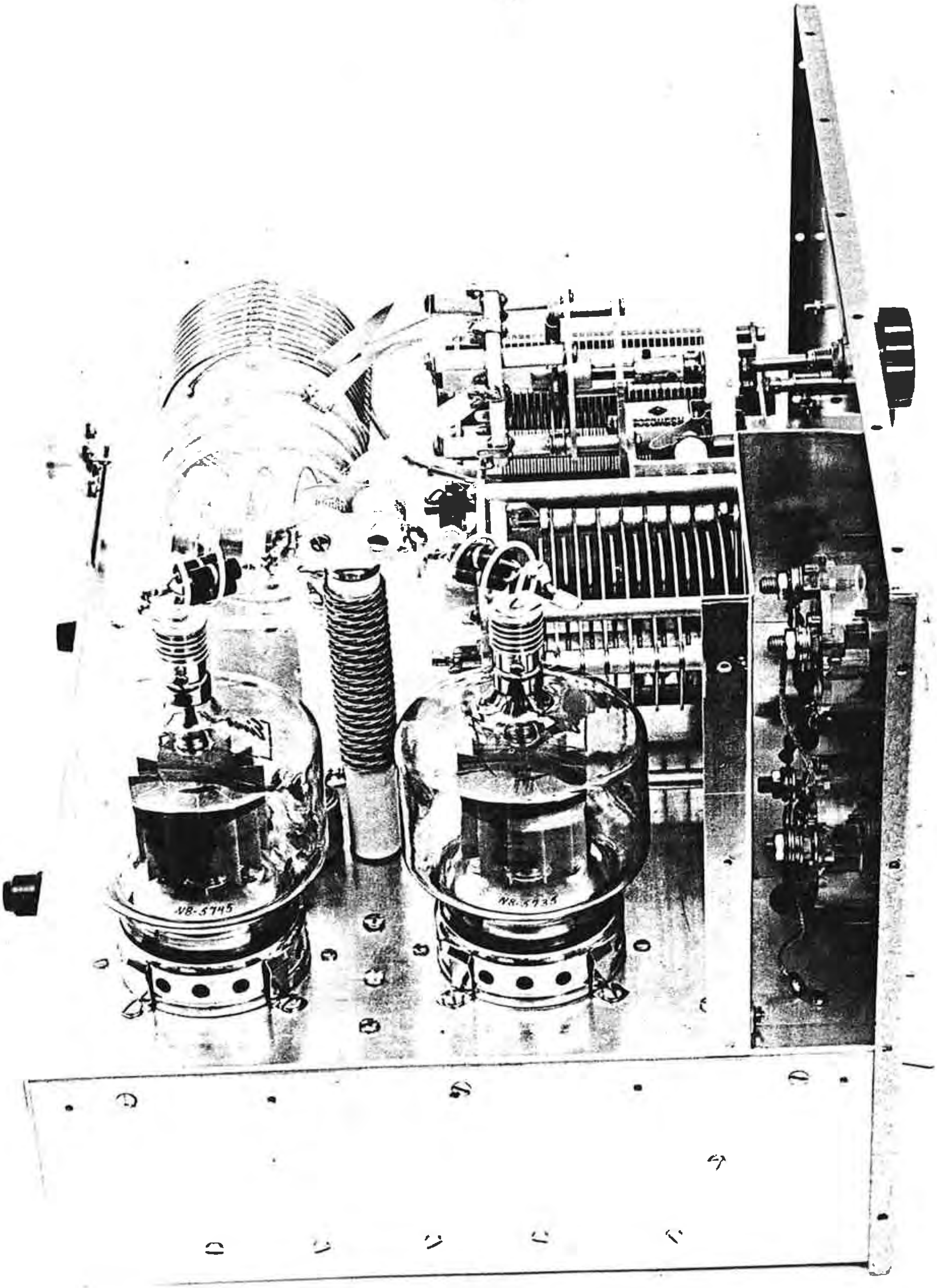
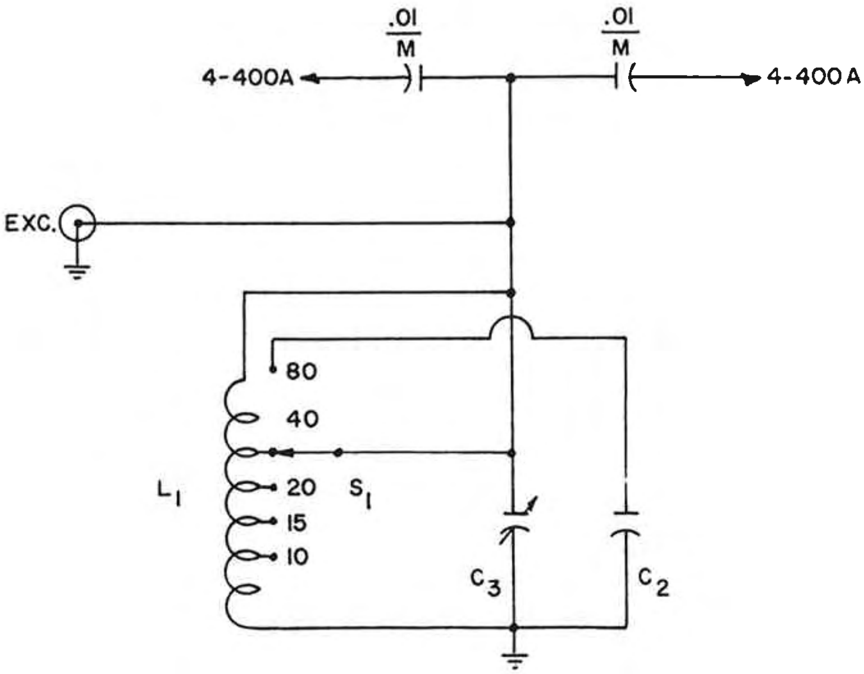

NB-5745
NB-5735

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