Operating manual for the

144 MHz High Power Amplifier using 2 x 4CX250B valves

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General description

The amplifier was designed for high power operation in CW or SSB mode and employs a pair of ceramic tetrodes type 4CX250B in push-pull configuration. The original construction was developed and published by KY4Z, but later improved by LA1BEA, DF8LC and LAØBY.

This manual provides all information necessary to operate and maintain the amplifier. Schematic diagrams are included in the Appendix. The basic data are as follows:

Essential operating parameters		
RF output power:	1000	W
RF drive power:	8	W
Gain at 1 dB compression:	21	dB
Mains voltage:	230	V AC
Power consumption:	1,8	kVA

The power supply is housed in a separate cabinet and provides the different voltages for the amplifier cabinet. It also includes a T/R sequencer, design N6CA, that helps to avoid damage to the preamplifier and high power coaxial relays. The sequencer ensures that all switching is done at zero power output.

Warning 1: *This amplifier operates with lethal voltages. Any measurement or tuning on the open RF or power supply compartment has to be done with extreme care. Wait a reasonable time (10 min) after having switched off before touching any parts normally carrying high voltage. Short-circuit these parts to ground as an additional protective measure.*

Warning 2: *One should normally allow for at least 2 minutes filament preheating before the anode voltage is applied. The amplifier should never be operated without forced air cooling. Even the filament heating power may lead to overheating of the cathode section of the valves.*

Warning 3: *The amplifier should never be operated in FM or any other continuous duty mode at RF output power levels exceeding 500 W. Overload and valve damage may occur.*

Initial measurements and adjustments

First check the filament: The filament voltage at the transformer inside the power supply was measured to 6,28 V AC when loaded with both valves, dropping to 5,85 V at the valve terminals (nominal value 6,0 V ± 10 %).

Prior to any operation, neutralisation tuning has to be done. Neutralisation is necessary to avoid self-oscillation. The principle is to feed a small amount of power from the output circuit back to the input circuit, equal in level but in opposite phase to the forward coupling through the valves themselves. The coupling capacitors are made from silver plated wire (Ø 1 mm), stretched from the grid circuit of V1 close to the anode of V2, and vice versa. Their length inside the anode compartment is about 1,5 cm.

Neutralization tuning should be performed for the resonant position of the input circuit. This position can be found by feeding 2-3 W to the input circuit from 50 Ω transceiver. The cover of the input compartment should be in place. Only the filament and grid voltages are to be applied. Now adjust the input tuning for minimum reflected power (VSWR < 1,1).

After having removed the grid and filament voltages the neutralisation tuning can be performed. A small amount of power (< 1 W) is fed into the input through double-shielded cable. Then connect a spectrum analyzer or receiver to the output. Now adjust the position and perhaps length of the coupling capacitor wires such that the signal at the output is minimised. The final attenuation through the inactive amplifier was measured to 68 dB.

The amplifier is now ready for the smoke test. Both input and output circuit cover should be in place, before all operating voltages are applied. Tune up is straightforward, starting with low levels (< 1 W) of drive power, and stepwise tuning of all controls. Always tune output circuit first. Stop when grid current exceeds 10 mA per valve. It appeared to be quite easy to put the amplifier into operation. Even with unpaired valves a maximum power of 1,1 kW has been achieved. After the initial tuning with surplus valves a matched pair of new Eimac valves was installed in 1991.

Meter readings

All important voltages and currents are displayed on panel meters in the power supply. The meters can be switched by push-button switches to read either voltage or current. Additionally one may select between either valve 1 and valve 2 for screen and grid parameters. The meters were calibrated to give full scale deflection according to the following table:

Push button	Power	Anode	Screen	Grid
high	~1200 W FWD	3000 V	500 V	- 200 V

low	~100 W REV	1 A	50 mA	20 mA

The power meter reading is not calibrated. Note that the directivity of the directional coupler is only about 15 dB. That means that only mismatch worse than about 15 dB return loss will show on the meter. The leakage of forward power into the reverse path will cause a fake meter reading even for ideal matching.

Operational adjustments

Once properly tuned for maximum output power, the amplifier does normally not need any retuning, neither after long continuous operation, nor after periods of inoperation. However, as a measure of caution, the symmetry and correct tuning should be verified from time to time.

If the tuning status is unknown, or the amplifier detuned for som reason, only low drive power (< 1 W) should be applied. First the anode plate and load capacitors, then the grid and drive capacitors should be adjusted for maximum output power. Equal grid current (symmetry) is achieved by tuning the dual differential capacitor of the input circuit. In 2-3 steps the input power may be increased then to the maximum permitted value (about 8 W). For each steps the above described tuning process should be repeated. The limiting parameter for the drive power is the maximum value of the grid current (20 mA). For linear operation one should in SSB not exceed 10 mA.

Please note that the maximum values for anode voltage and current as specified by the manufacturer are exceeded considerably in this amplifier. Good Eimac valves will tolerate this, and wear out of valves has not been observed yet. However, all high power tuning must never be performed in continuous duty mode, but always in high speed CW keying.

Cooling

The amplifier is cooled by forced air. A blower, Papst type RV133/42-200, injects the air into the anode compartment. While the major flow leaves through the anode radiator a very small portion goes through the socket into the grid compartment.

The backpressure generated by one valve (and the socket) was measured by blocking the air exhaust of the other valve for a short moment by a manometer made from a water filled U-shaped hose. The water level difference to the unpressured level is a measure for the backpressure, and was measured to 14 mm (corresponding to 137 Pa). Without blocking the backpressure from two valves should be about half the measured value, perhaps 8 mm.

In the literature the cooling requirements for a single 4CX250B were specified to 0,6 m^3/min at 16 mm backpressure. The Papst blower is rated to provide 235 m^3/h (= 138 CFM) airflow at 320 Pa backpressure. It is quite oversized, which is confirmed by the low exhaust air temperature at maximum power dissipation (perhaps 50 °C). A compatible blower is the Ebm type G2E 120-AR77-90.

The power supply was initially cooled only by natural convection through the perforated cover. Later a small low pressure fan was mounted above the stabilisation circuit, in order to remove heat from HV transformer and the stabilisation transistor heatsink. The chassis temperature does now not increase beyond about 30 °C.

Typical operating parameters

The following table shows typical operating parameters for different levels of output power, measured during the initial tests with two unpaired surplus 4CX250B valves from different manufacturers. The amplifier was keyed in high speed CW mode, transmitting dashes at 1000 lpm. It is assumed that the tables lists real values. The power was determined by an analog Bird power meter and spectrum analyser.

RF power	anode voltage	anode current	screen voltage	screen current	grid voltage	grid current
W	V	mA	V	mA	V	mA
0 (0)	2250 (75)	200 (20)	325 (65)	8 (16)	-55 (28)	0 (0)
250 (40)	2190 (73)	440 (44)	325 (65)	8 (16)	-55 (28)	0 (0)
500 (60)	2130 (71)	690 (69)	325 (65)	8 (16)	-55 (28)	4 (20)
800 (80)	2040 (68)	900 (90)	325 (65)	6 (12)	-55 (28)	20 (100)

The figures in brackets indicate the relative meter readings. The real values are computed from the meter calibration. Both screen and grid voltages are very stable. The screen current showed a minor decrease (due to negative screen current) for very high levels of output power, but the main contribution comes from the current through the bleeder resistor.

Another set of readings was obtained in January 1999 with a matched pair of new Eimac 4CX250B valves:

RF pwr	bolo-meter	power meter	mode	anode voltage	anode current	anode eff.	grid current	AC voltage	AC curr.	AC pwr
W	mW	rel.		V	mA	%	mA	V	A	W
0	0	0	std by	2160 (72)	0 (0)	0	0	220	1,75	390
0	0	0	PTT on	2100 (70)	80 (8)	0	0	220		
293	73,6	49	FM	1920 (64)	530 (53)	28,7	0	220	6,0	1320
553	139	68	FM	1890 (63)	690 (69)	42,4	8 (40)	216	7,6	1670
870	190	74	CW ---	1860 (62)	760 (76)	53,4	20 (100)	216	8,1	1750
890	161	63	CW ...	1890 (63)	640 (64)	52,9	17 (84)	217	7,25	1575

The CW keying was with high speed, transmitting dashes (---) or dots (...) at 1000 lpm. The power was measured by a calibrated bolometer sampling the power through a directional coupler (35,5 dB + 0,5 dB cable loss). The bolometer always reads average power, and its calibration was verified on DC before the tests. The meter readings are in brackets (not for power meter).

In course of the measurements the duty factors were determined by comparing continuous duty and high speed CW ratings at 250 W and 500 W output power (dashes 87 %, dots 72 %). From those the peak power ratings above 500 W were extrapolated. The maximum power was rather low during the test, probably due to low AC mains voltage.

This last table may serve as a reference for field operation.

Replacement of valves

In case of damaged valves the replacement can be performed rather swiftly. Only the top cover of the amplifier cabinet with the blower has to be removed. No neutralisation tuning is required but the all tuning controls need re-adjustment. It is good practice to leave new valves in the sockets for several hours with only the filament voltage applied before attempting the high power tuning.

Note that valves from certain manufacturers may not tolerate being operated beyond specifications. Besides 4CX250B also 4CX350A, GU-70B and 4X150A can be made fit into the amplifier.

Preamplifier

Primarily for moonbounce (EME) operation, a masthead preamplifier has been constructed that is controlled from the amplifiers power supply. The active device is a MGF 1302 GaAs-FET. In order to operate the preamplifier the power supply must be switched on. The preamplifier is housed in a diecast weatherproof box, together with a coaxial relay, type CX520D, for T/R switching. The table shows the preamplifiers operating parameters when housed in the box, including losses from coaxial relay and internal cables.

Frequency	**Noise figure**	**Gain**
MHz	K	dB
143	73	20,4
144	77	20,0
145	77	19,4
146	75	18,7
147	71	17,9

Note the coaxial relay is operated at its maximum ratings and hot switching must be avoided. The T/R sequencer included in the power supply will take care of this.

The HPA-preamplifier system is designed for separate TX and RX transmission lines. Thereby one reduces the risk of damaging the preamplifier by RF power. One may also use lower quality cable for the RX feeder, because the preamplifier gain will compensate the cable loss.

Experience

Over the years the amplifier has been operated in combination with several transceivers. It has proven very reliable, even in portable operation at unstable mains voltages.

FT225RD: The disadvantage of this transceiver is that the power control is different for SSB and CW mode. One has to be very careful not to overdrive the amplifier. When using the masthead preamplifier the FT225RD has to be equipped with a separate RX input. In order to avoid overloading of the receiver, a total attentuation of 16 dB has to be inserted between preamplifier and receiver.

IC730 (or TS430S) and LT2S: The IF drive power from the transceiver is at about 50 mW, both in SSB and CW mode. The input attenuator of the LT2S is set such that its RF output power is limited to 8 W. The RX gain of the transverter is quite low. The use of the masthead preamplifier is mandatory to achieve maximum sensitivity. If the HF transceiver is equipped with a narrow bandwidth CW filter this is a good combination for EME work.

The only malfunction was caused after 8 years by burned contacts in the HV mains switch. The switch, Arcoelectric type C1353 ATBR3, is rated at 16 A continous and 150 A peak current. The inrush current of the HV transformer perhaps exceeds the peak rating.

The screen fuse has proven very useful and protects the valves in case the anode supply is not present. The anode fuse will protect the power supply in case of a flashover in the high voltage cable.

What can be improved?

Nothing is perfect, and even a good amplifier design isn't. If I should have to construct this power amplifier again I would try the following:

- The highest voltage from the HV transformer should be raised such that the no load anode voltage would reach 2500 V, with taps down to 2000 V in 100 V steps.
- Some screws in the anode compartment are made of steel. Those could be replaced by nickel-plated brass ones.
- The length of the output coupling loop is perhaps on the long side. The load tuning capacitor is very close to it's minimum position.

Perhaps the efficiency could be raised by these measures.