

# 13 & 23 cm Power Amplifiers Using the GS9b and GI7b Tubes

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## INTRODUCTION

Most high powered 13 & 23 cm band amateur equipment transmitters rely on the 7289 triode tube and are capable of significant output power when using water cooling. If more transmitter power is desired beyond the output of a single tube, then the options available are very limited, typically combining the output of multiple amplifier cavities, or using a very high power UHF Television Tube amplifier devices. This paper describes amplifiers which make use of a family of larger triode tubes from Russia, and fill the void between the 7289's and the larger vacuum tube devices.

These amplifiers will provide significantly more power than a single 7289, however at lower gain and with a "significant but tolerable" tuning drift. This can be managed if operated carefully, and adequate cooling is provided to the tube and cavity resonators. The tubes will not deliver 13 & 23 cm power to their full electrical potential without significant tuning drift. This has been evidenced by a number of EME operators who have tried the GI7b at 23 cm with mixed results (See reference 1). With reduced output power to limit tuning drift, these amplifiers will produce 300 W on 23 cm and 75 W on 13 cm. At "full" power these tubes will produce over 400 W on 23 cm and 100 W on 13 cm, however the tuning drift is likely to be excessive.

## THE GS9B AND GI7B TRIODE TUBES

The amplifier designs are based on the GS9b and GI7b triodes. Physically the tubes are similar in size, shape and ratings to a 4CX250K (coaxial version of a 4CX250B). They are triodes however and are rated for operation at 18 cm (1.7 GHz). The tubes have a 300/350 Watt air cooled dissipation rating, but the air cooler can be easily removed to utilize water cooling. The maximum electrical ratings are 2.5 KV on the plate and 330 mA of cathode current for the GS9b and 660 mA for the GI7b. Notably the grid current rating is 5 Watts or approximately 5 times the rating of a 7289 for the GS9b and 7 Watts for the GI7b.

The cathode/grid area of the GI7b is approximately double that of the GS9b. This increased grid size is responsible for the higher tube capacitances and higher tuning drift with the GI7b at 23 cm. The GI7b is only suitable for use at 23 cm due to its lower gain, but the GS9b will work well at both frequencies. Although the internal tube capacitances are different for the GS9b and the GI7b, with the tuning range available in the 23 cm cavity design, operation should be possible with either tube.

These tubes are of Russian origin and are currently available new/used on the European surplus market as low as \$20 US or new directly from UR4LL or DF6NA<sup>2</sup>. The tube data sheets are included for reference in Appendix A.

## CAVITY AMPLIFIER DESIGN

The 13 & 23 cm coaxial amplifier design use a  $3/4$  wavelength anode cavity and for 13 cm a  $5/4$  wavelength input cavity tuned by a tunable short. For 23 cm a 1 wavelength coaxial cavity is tuned by a variable piston capacitor. The input and output cavities are coupled to with capacitive probes. The output cavities are tuned with a large diameter capacitive probe. The design is similar to previous efforts <sup>3,4,5,6</sup> only with larger diameter coaxial lines. Thus only the unique features of these designs will be discussed in detail. Please see the amplifier drawings contained in the Appendices.

## TUBE COOLING

As with other tubes like the 7289, the GS9b & GI7b output power capability is constrained by the 300/350 Watt limit of the air cooler. This design makes use of a water cooling jacket to replace the air cooler. The use of water cooling also serves to reduce tuning drift.

The water cooling jacket slips right over and is fastened to the approximate  $1/4$  inch diameter stud in the centre of the 1 inch diameter plate contact surface. Since this is an RF contact surface no thermal grease is used between the plate connection and the plate bypass capacitor. The water cooler is attached on the "RF cool" side of the bypass using thermal compound. The water jacket is made from thick copper and by using a fairly thick brass stock for the bypass capacitor plate, the thermal resistance is kept low.

The water connections are made through two  $5/16$  inch diameter soft copper tubes. The water jacket assembly is soldered together, but is clamped to the tube using a  $1/2$  inch diameter nut provided with the tube.

In addition air cooling is required to reduce the operating temperatures of the tube seals and to further reduce the tuning drift problem. For the tests performed on the GS9b there has been no direct internal air cooling of the tubes seals, however the cathode section of the cavity gets quite warm with the 12 Watts of heater power. A muffin fan blowing across the lower portion of the cavity and the cathode line extension has proven effective.

For the higher powered GI7b the addition of direct air cooling inside the cavity is required. Two (2) screened windows have been introduced into the anode cavity, which allows the forced of air to flow directly against and over the grid area. A plastic manifold was introduced into the cavity to optimize the air flow at the surface of the tube. A small squirrel cage blower with a 1 inch square opening provides ample air flow. In Europe CT1DMK and others have avoided doing this by not using finger stock and using a thick, tight fitting copper grid line with thermal compound. All of this is good practice however it makes tube insertion more difficult and risky from a mechanical stress point of view. Further it will not eliminate the tuning drift problem.

One possible method to reduce it's effect would be to convert to a radial type cavity (like N6CA  $\tau$ ), however with the higher plate to grid capacity (approximately 2 x 7289) there may be enough

cavity left to work with. The GI7b should be interesting if used in place of 2 x 7289s in a square cavity such as described by W2CQH et al.

Further in the GI7b amplifier (24 Watts of heater power), a series of holes have been introduced in the cathode & grid coaxial lines to permit air flow around the tube seals. These holes should be made as large as possible and the drawings reflect my recommendations. A small muffin fan approximately 1.5 in diameter was used to draw air out of the bottom of the cathode line. With larger holes perhaps the airflow into the anode cavity will be sufficient to ensure adequate flow through the cathode line.

## CATHODE BIAS SUPPLIES

I have used the bias supply described by N6CA<sub>7</sub> for the 7289 and this has performed well for test purposes on both the GS9b and GI7b amplifiers. The GI7b however requires significantly higher operating and cutoff bias voltages than the 7289 as the plate voltages increase to 2500 V. The output voltage from the 3 lead LM317 regulator will have to be operated near the 37 Volt output limit so that the highest possible output voltage will be available for cutoff purposes. The resistor values around the LM317 do not have to change as adequate adjustment is available.

Typical bias values for a 2.5 KV anode supply are 22-27 Volts depending if a 50 mA or 100 mA bias point is chosen. I prefer at 50 mA bias point for the GS9b and GI7b but have used 100 mA for the GS9b as it raises the gain slightly, which is significant for the 13 cm amplifier.

Consideration should be given to the use of a current limiting bias supply on the GS9b or GI7b amplifiers. These tubes as well as 7289s tend to drift towards higher plate current if the "key" is held down. Current limiting will hold the plate current to a maximum value no matter what is going on, with the exception of an internal arc. With the tendency for these tubes to drift in tuning it is also important for the driver power to be "limited". For my 9 cm 7289 amplifiers I use current limiting on both the driver and the power amplifier cavities. The current limiting on the driver can be set to reduce the plate current to a value that just produces enough drive for normal operation. In this way if anything drifts in the tuning between stages or in the exciter, the driver will never output more power.

The current limited bias supply I use for 7289s and which should be usable for the GS9b is an adaptation of K4QIF's design (now K4QI) and is shown in Appendix B. This supply may not be appropriate for the higher plate currents 660 mA experienced with the GI7b.

## FILAMENT VOLTAGE

Both tubes are rated for a nominal filament voltage of 12.6 Volts and the current requirements are approximately 2A for the GI7b and 1.1 A for the GS9b. In the process of trying to reduce the tuning drift the voltage was varied up and down between the limits of 12 to 13 Volts. I could not

find a voltage that offered any advantage for intermittent operation cycles and so all the tests were performed at 12.6 Vac.

## TEST RESULTS

### GS9b

The 13 cm amplifier using the GS9b has produced 85 Watts output with 1300 Volts on the plate and approximately 300 mA. The grid current was about 20 mA with 12 Watts of drive and the bias setting was 17V. The gain was thus about 8.5 dB. When the voltage was raised to 2400 V the power output did not increase dramatically, although with adjustment of the loading the grid current dropped to 12 mA and the gain increased to about 10 dB. I did not concentrate on getting maximum output power.

I found that you could tune for more power but it was not stable with the warmup tuning drift problem, so I was loading the amplifier as heavily as possible to minimize drift. The amplifier is begging for more drive as the output power continues to climb smartly with increasing drive. Ed K9EK<sub>9</sub> has seen 100W output. Perhaps Ed's use of link output coupling gives him better loading control. Previous work conducted at 1600 Volt showed that above approximately 400 mA the tube's grid current became unstable resulted in a tube arc. With the lower grid current at 2400 V perhaps 400 mA of plate current is still a reasonable limit and certainly more than 100 W output should be possible.

### GI7b

There have been a lot of tests done on the GI7b at 23 cm over the past 2 years. My conclusion is that at 250 W output this amplifier will provide good & "stable" service with approximately 13 dB gain. As the power is increased to 300 W the tuning drift starts to become evident, but is reasonable for general use. The GI7b has produced 400W output for me at 1900 V with 500 mA and 50 mA of grid current. (My swinging choke power supply is not rated for 500 mA and the voltage sags dramatically above 350 mA). The tuning drift however was unacceptable. Similar results have been reported by CT1DMK<sub>1</sub> and others.

The only result I experienced that has not been reported by others is the need to neutralize the amplifier! This may be due to my use of fingerstock rather than tight fitting slotted copper tube for the grid line. My initial tests with filaments on and the amplifier tuned showed only 10 dB through loss (Output to Input with no HV). This is a power oscillator waiting to happen! I neutralized the amplifier by inserting a 3/4 in wide strip of mylar (thin teflon OK) between the tube and the grid fingers. I had the advantage of a cavity side access panel, but without it you should be able to put mylar tape onto the tube in a strip 3/4 in wide and achieve similar results. The final through loss was 16 dB, not much but acceptable as long as the amplifier is being operated in a large signal mode (power output) and not tuned for maximum gain (not enough drive).

## COMMENTS ON THE GS9B 13 CM CAVITY CONSTRUCTION

Please refer to the drawings in Appendix C. The parts identified by number in the overall drawing of the cavity and warranting further explanation will be discussed briefly as follows:

1. Part #1 is a teflon insulator intended to support the filament connection pin (Part #15). It is drilled and tapped to accept a #4-40 screw that holds Part #2 the Cathode contact and outer sleeve of the cathode bypass capacitor. A 1/8" hole has been drilled to allow a wire to pass from Part #2 out to the bottom of the cavity and to the cathode bias and filament supply. A second wire might be required depending on how the filament connection is made to Part #15. Please note that both wires are coiled over a small drill bit to form an RF choke and then terminated on 1000 pF RF feedthru capacitors which are mounted to the end of Part #3 which has been allowed to extend beyond Part #4 by approximately 1.25 in ( 4 cm). This is not shown in the overall drawing!
2. Part #2 is a standard 3/4 in copper water pipe coupling. You should try to choose the style with the "dimple" rather than the indentation all the way around the circumference. The fingerstock I used is Instrument Specialties 97-360, and it is soldered inside the coupling with the help of a hot plate so as not to lose the temper on the fingers.
3. Part #5 are Type N female connectors. Standard UG-58 units are shown in the drawing but in order to achieve better mechanical strength and a greater range of adjustment, some connectors with longer body length should be used if available. The body on the units I have used are 4 cm long.
4. Part #8 & 9 are brass or copper plate approximately 1/16 to 3/32 in ( 2-3 mm) thick This is not critical as long as major changes are not made. The thicker material will be better strength wise and offer slightly better thermal conductivity. These plates are soldered to Part # 7 using 4% silver solder.
5. Part #10 is brass or copper plate approximately 1/16 in thick.
6. Part #12 is the anode cavity main tuning adjustment. For convenience this is shown as a threaded screw assembly. I actually used a very good surplus tuning screw assembly, however even silvered screw assemblies tend to become noisy and erratic if the plating wears off. I strongly recommend that you use a movable plunger type system as described by Ed Krome K9EK <sup>10</sup>.
7. Part #13 are Teflon shoulder washers used to hold down the plate bypass (Part # 10) to the anode cavity top plate (Part #8). The dimensions will of course depend on the thickness of Part #10. My washers were turned on a lathe from a piece of 5/8 in Teflon and are drilled to clear a #6-32 screw.
8. Part #14 is the tunable short on the cathode (input) line. I used a metal ring with fingerstock soldered in. I used the same Instrument Specialties fingerstock 97-360 used

for the grid connection. You are free to substitute different types and sizes of finger stock as long as there is a good fit. It would be better to have a double set of fingerstock on the inner and outer connections, so as to ensure a reliable connection. These connections will be subjected to filament powered heating that will propagate down the cathode line, thus tarnishing of bare copper may result. As explained earlier the area will be kept cool by blowing a small amount of air at the open end of the cathode line and Part #3 which extends outside.

For adjustment purposes 2 dielectric tuning rods (teflon, epoxy, bakelite, etc) are fastened to the tuning ring (not shown in the drawings). These are extended outside the cavity and joined together with a joining bar. The shorting plunger is then positioned by pushing/pulling on the joining bar.

9. Part #15 is the filament connector. I was fortunate to find that a modified Japanese 75 ohm low frequency coax connector (type SP) that fits perfectly after the centre connector is removed.

## COMMENTS ON THE GH17B 23 CM CAVITY CONSTRUCTION

My construction of the 23 cm differs slightly from the 13 cm cavity in that I used a square output cavity. I did this because I had a square silver plated cavity of the right size and with a large tuning screw in the right position. It further had a side cover that could be removed for inspection, adjustments, etc. The result is very similar to CT1DMK's cavity with minor variations due to my construction preferences and material availability. If a 6 cm round outer cavity as was used for 13 cm is desired, the length of the cavity should be the same as for the square one described here, as any minor differences in impedance will be compensated for by the tuning screw.

Please refer to the drawings in Appendix D. Most of the parts identified by number in the overall drawing of the cavity have been described in the 13 cm amplifier design and only the unique aspects will be discussed here as follows:

1. Part # 1 has a large number of holes drilled through it to support the passage of air around the base of the tube. The source of the air is from the anode cavity and through Part # 2. The air may also be drawn out from the bottom with a small fan as discussed in the text.
2. Parts # 2, 4 & 14 have also had a large number of holes drilled to facilitate air flow.
3. Parts # 2 & 3 are coupled together and soldered. The screw in the side of Part # 2 is only there to hold Part # 1 in place.
4. Part # 7 may be a 7.25 cm square cross section or a round 8.1 cm cross section without difficulty. The air holes in the side of the anode cavity must be shielded to prevent RF leakage! I used copper screen and soldered it to the side of the cavity. The exhaust port is

smaller than the input in order to generate some back pressure and thus encourage air flow into the cathode line.

5. Part # 14 is a ½ in (1.25 cm) thick piece of 1.5 in (3.75 cm) teflon rod. This will not fit tightly within the 1.5 in copper Part # 4 and thus the circumference should be wrapped with mylar tape (not cellulose) until a tight fit is obtained. As this is required to hold the cathode line assembly in place, if a stable fit cannot be obtained I suggest using a 1 in (2.54 cm) piece. Part # 14 should be held with 2 to 4 short (1/4 in) #4-40 screws through the side wall of Part # 4.
6. Part # 15 is as discussed previously a surplus coaxial connector that is modified slightly. Obviously without this Part # 15 will change dramatically, as will Part # 1 that supports it in the cathode line assembly.
7. Part # 16 is a Johanson piston trimmer about 10 pF, however it was tuning very near minimum capacitance. I have shortened the cathode line (Part 3 3 to compensate), but some experimentation may be required.
8. The RF chokes on the filament and cathode leads are formed by coiling about 5 turns on a 3/16 in (4.5 mm) form.

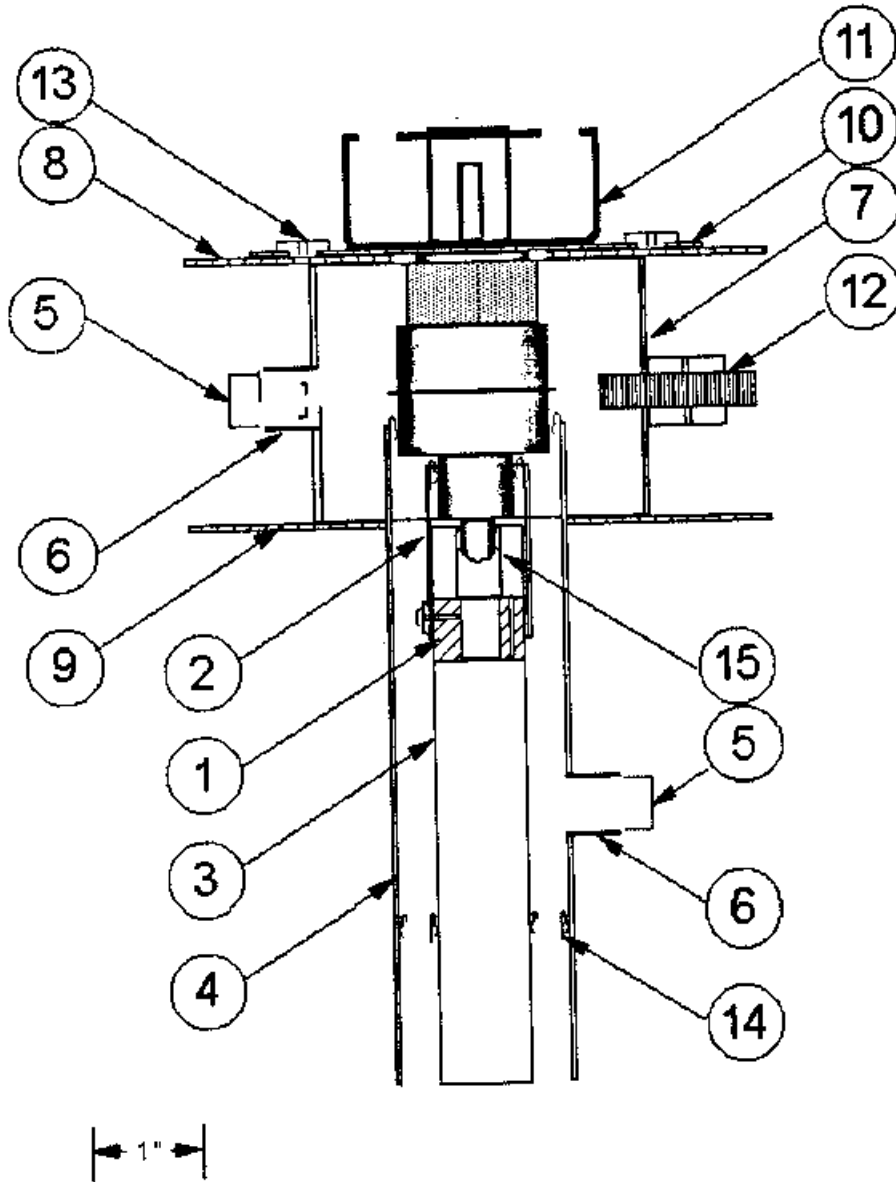
## REFERENCES

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2. Alex UR4LL "alex@zcrb.kharkov.ua" & Rainer Allrun DF6NA "df6na@df6na.mayn.de"
3. Barry Malowanchuk VE4MA, "2304 MHz Power Amplifier Using 7289 or Similiar Tube" Proceedings of the 1994 Microwave Update, Pages 140-144.
4. Barry Malowanchuk VE4MA, "A 7289 Amplifier for 3456 MHz", ARRL UHF/Microwave Projects Manual , Pages 8-89 to 8-92..
5. Barry Malowanchuk VE4MA, "Update on a 7289 Amplifier for 3456 MHz", Proceedings of the 1994 Microwave Update, Pages 182-183.
6. Barry Malowanchuk VE4MA, "High Power Tube Amplifiers For 2304 MHz", Proceedings of the 1989 Microwave Update, Pages 88-108, ARRL.
7. Chip Angle N6CA, "A Quarter Kilowatt 23 cm Amplifier", QST March 1985, Pages 14-20, ARRL

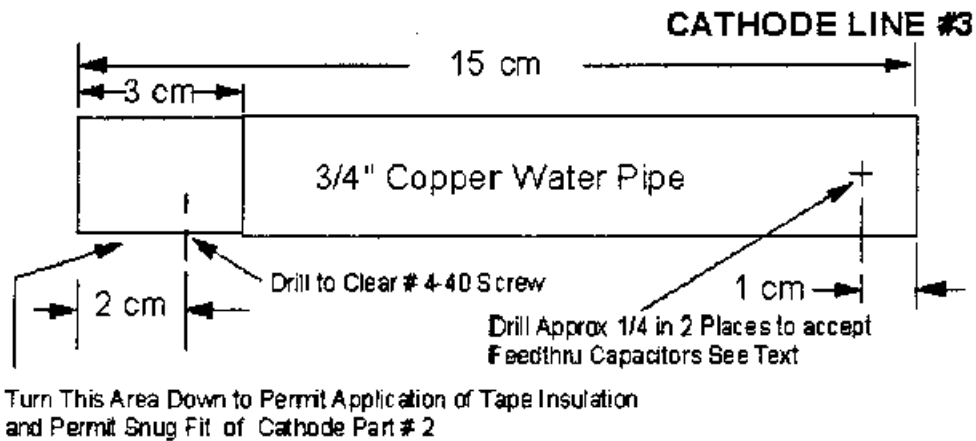
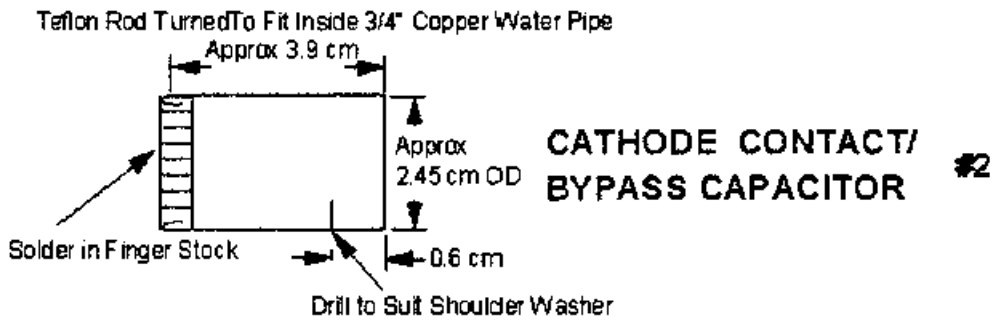
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- 9 Ed Krome K9EK, "Experiments With Gi7b and Gs9b triodes on 13 cm", Proceedings of the 1999 Microwave Update, ARRL
10. Ed Krome K9EK, "Construction Techniques For 13 cm Coaxial Cavity Amplifiers", Proceedings of the 1997 Microwave Update, Pages 184-189, ARRL



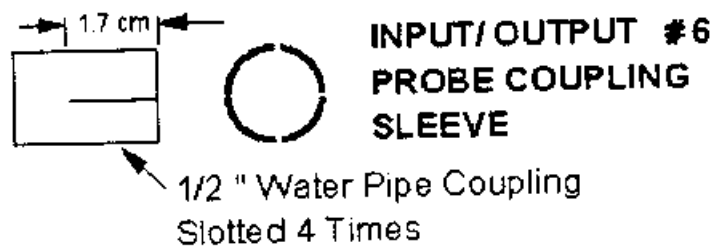
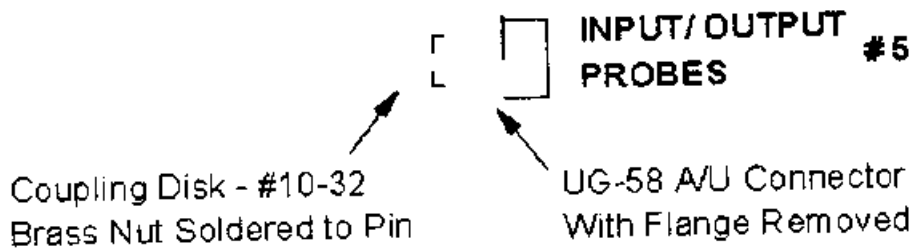
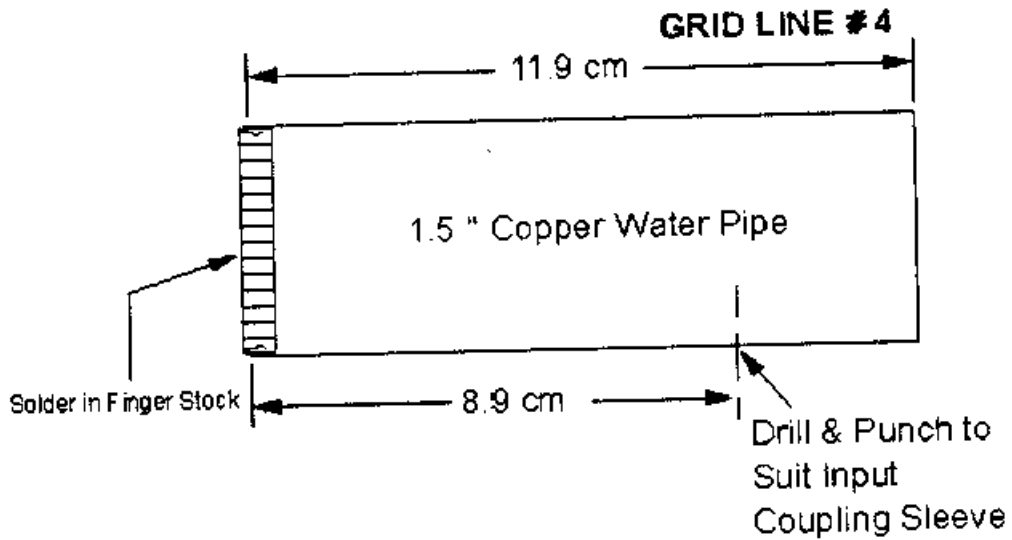
### GS-9b Power Amplifier for 13 cm



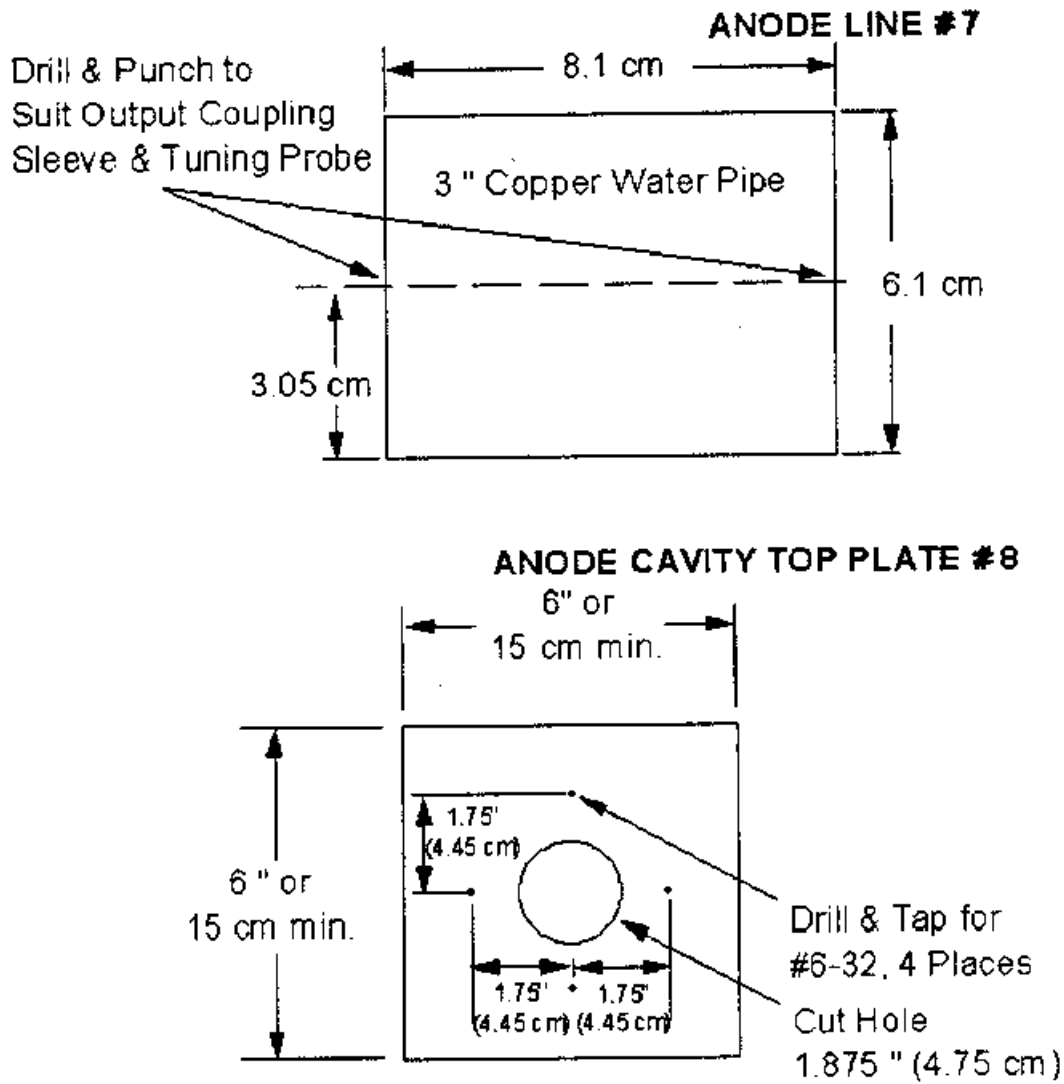
## GS9b 13 cm Power Amplifier Parts Cathode



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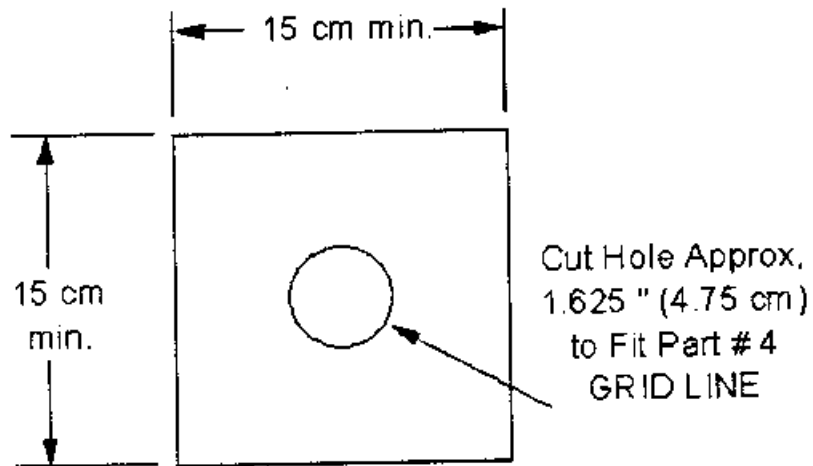
## GS9b 13 cm Power Amplifier Parts Anode



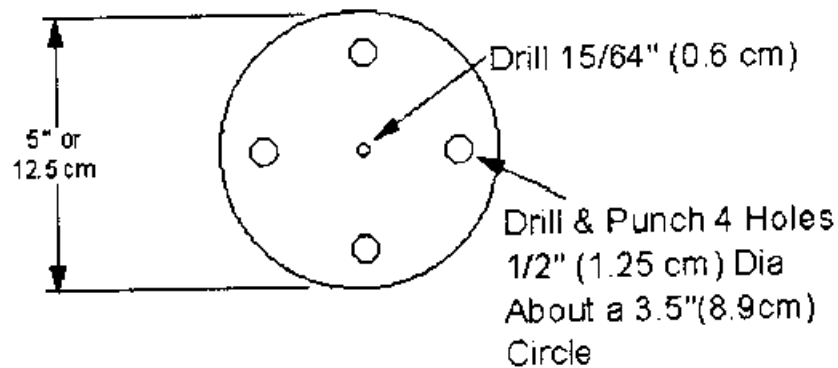
# GS9b 13 cm Power Amplifier Parts

## Anode

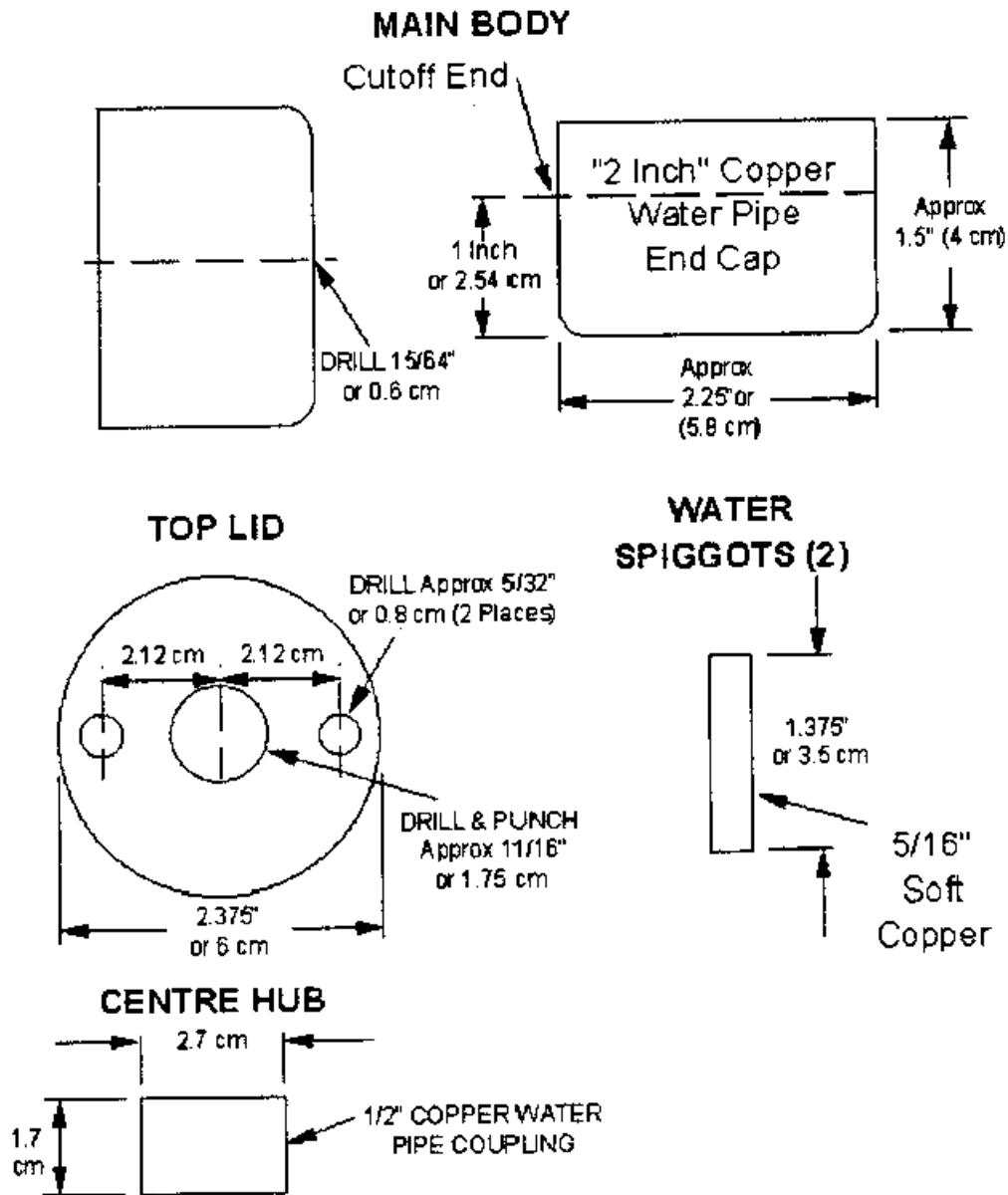
### ANODE CAVITY BOTTOM PLATE # 9



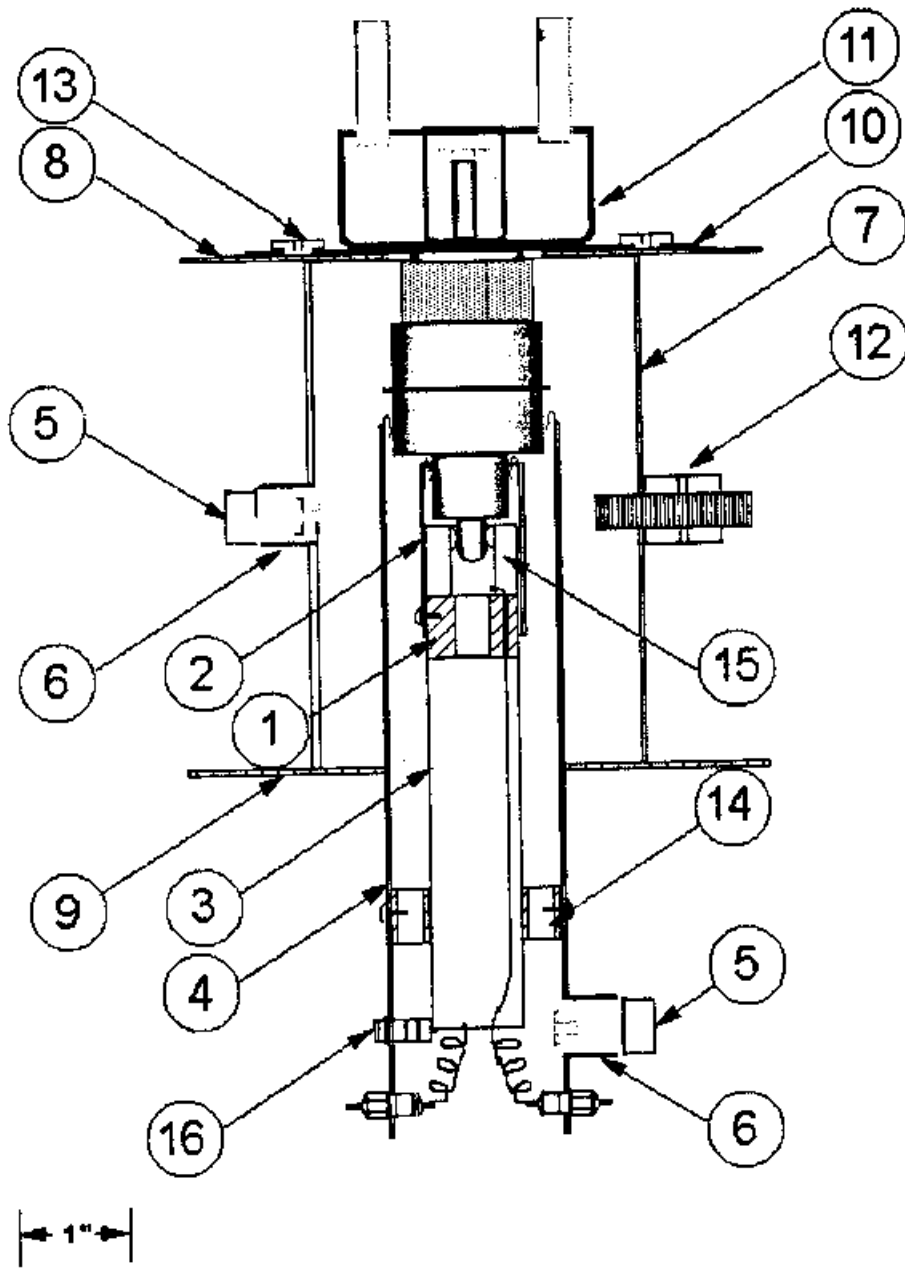
### PLATE BYPASS CAPACITOR # 10



# GS9b 13 cm Power Amplifier Parts WATER COOLING JACKET # 11



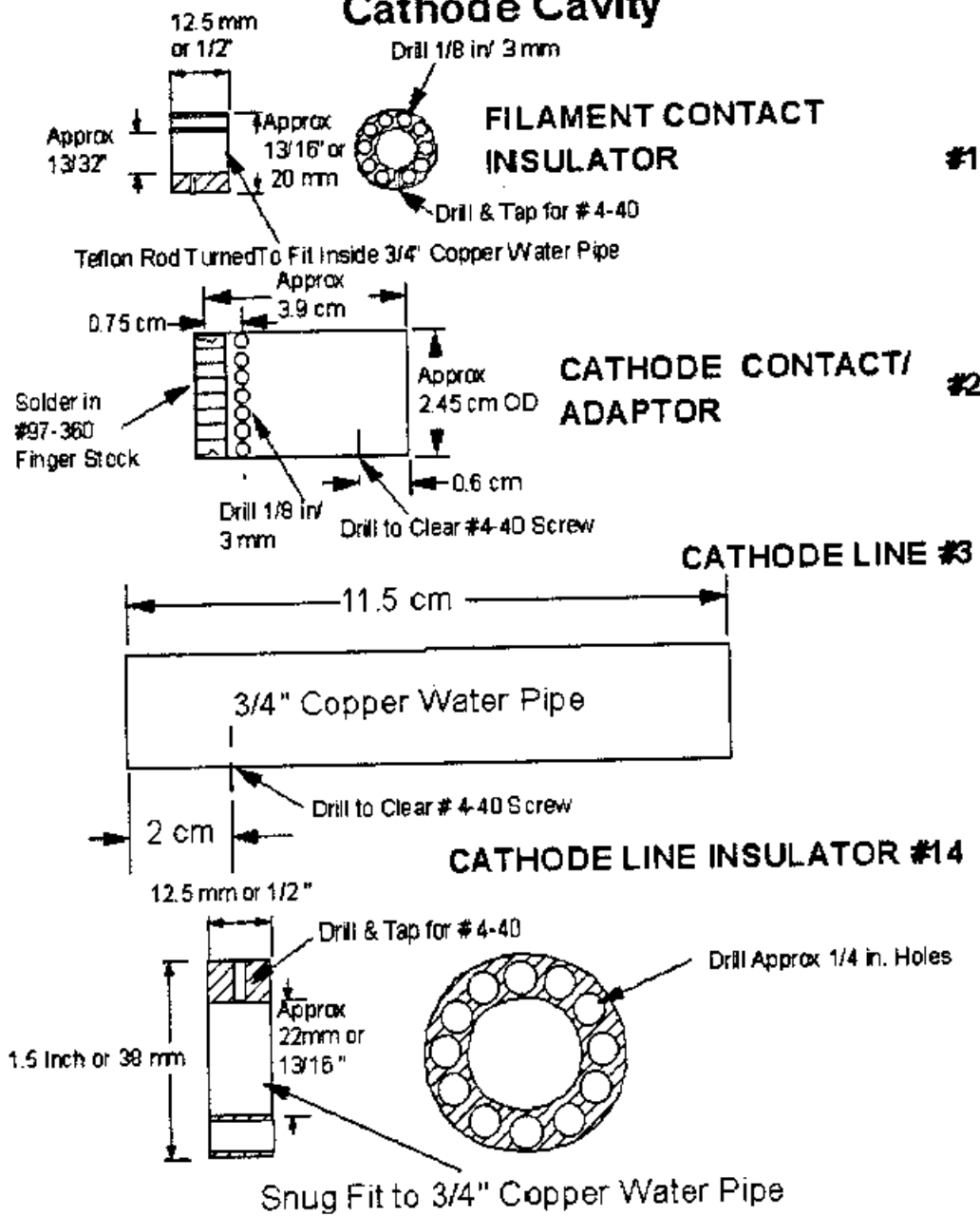
# GI-17b 23 cm Power Amplifier



Appendix D

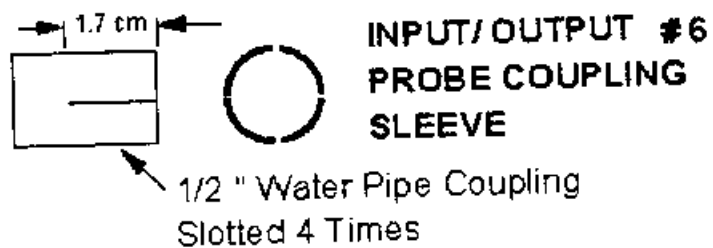
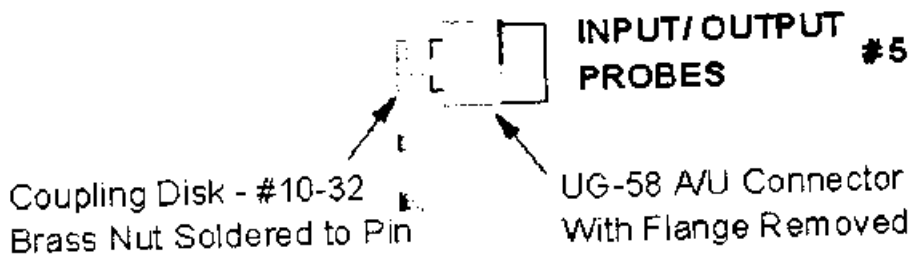
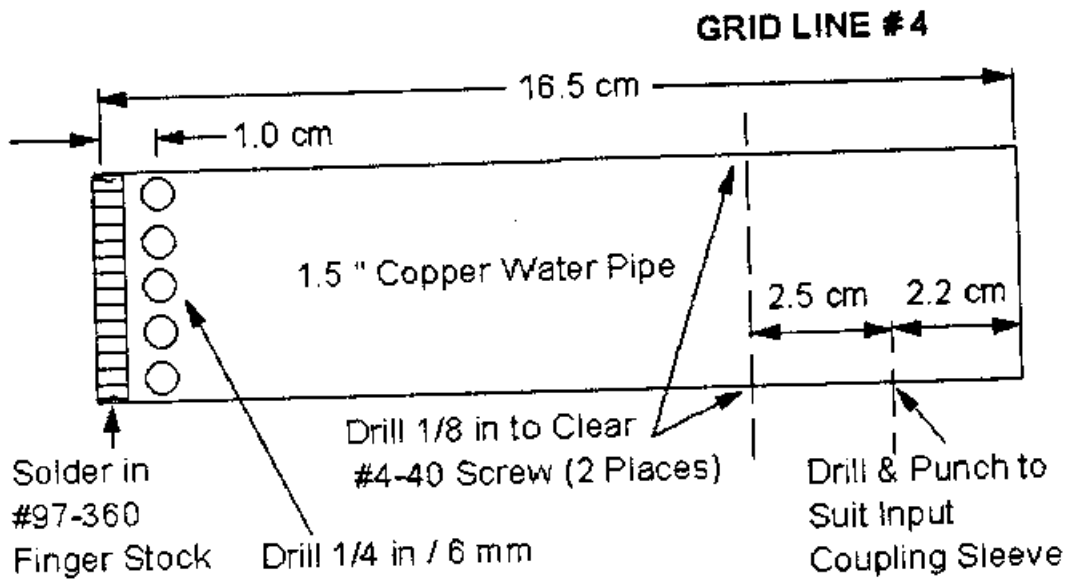
# GI7b 23 cm Power Amplifier Parts

## Cathode Cavity



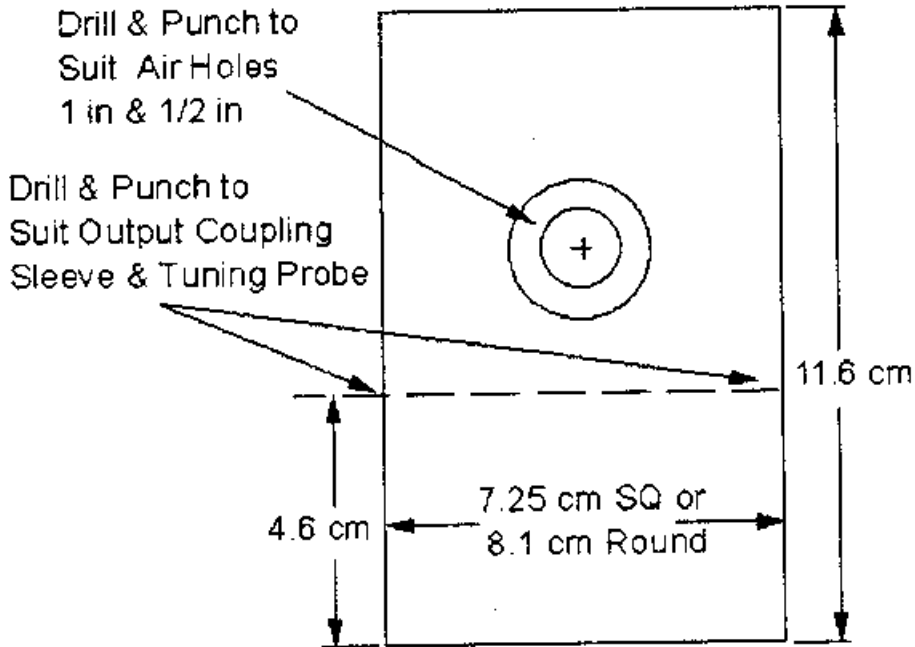


## GI7b 23 cm Power Amplifier Parts

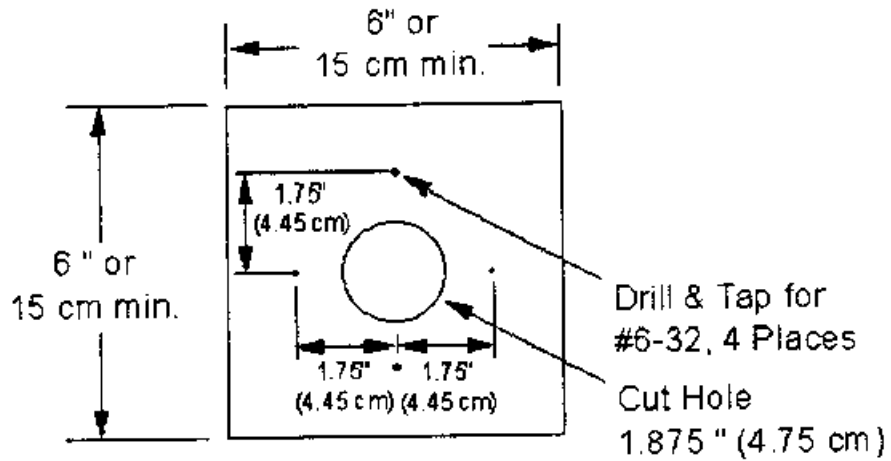


# GI7b 13 cm Power Amplifier Parts

## Anode Cavity ANODE LINE #7

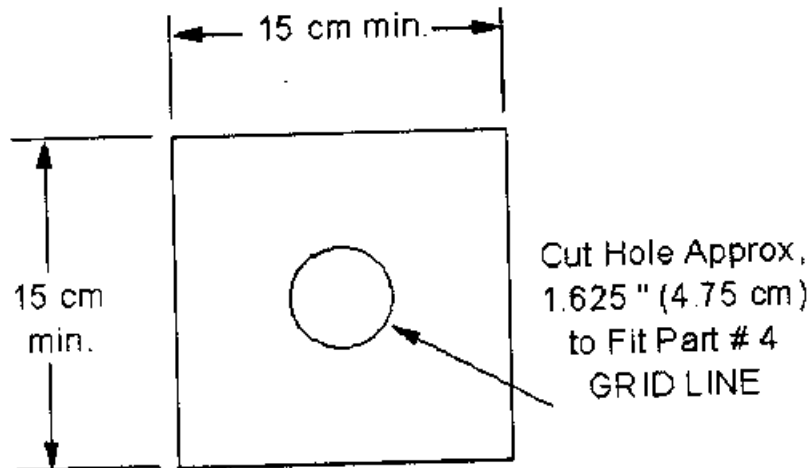


## ANODE CAVITY TOP PLATE #8

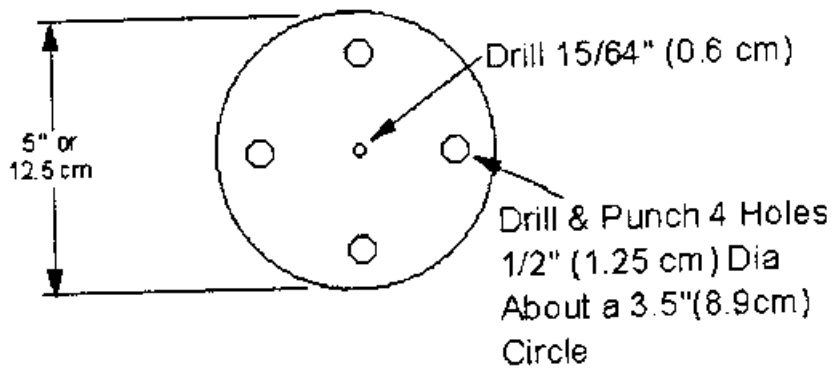


## GI7b 23 cm Power Amplifier Parts Anode Cavity

### ANODE CAVITY BOTTOM PLATE #9



### PLATE BYPASS CAPACITOR #10



# GI7b 23 cm Power Amplifier Parts WATER COOLING JACKET # 11

