PC BOARDS FOR DYNACO Mark 4 Amplifiers

USE AND INSTALLATION INSTRUCTIONS INFORMATION INDEX

READ ME FIRST!

This is a modified version of the usual disclaimer/warning that comes with most transmitting equipment and parts.

Since similar conditions exist in all tube audio amplifiers we believe it be appropriate here. Please note prior to beginning construction that there are high(over 400 volts) DC and AC voltages present in the equipment you are about to work on, and in the right situation these voltages could injure or kill you if you contact them. Normally the worst you can encounter is a nasty shock, however you must remember at all times this possibility of a injurious situation. Follow the same precautions you would with any electrical appliance,including not working with plugged in equipment (including soldering irons) with bare feet on a wet floor, use only insulated probes & tools when working on live high voltage, andif you are working with one hand taking measurements or working in live equipment, keep the other hand off the chassis or other grounded conductive item. Always use the proper size fuse or circuit breaker in the equipment installed when operating amplifiers or any other electronic gear.

In a work situation you would be required to use eye protection when working with tools, soldering, or testing equipment and we strongly recommend you do so also, and remind you that when you fail to use safety glasses or follow recommendations regarding safety or simply do not practice common sense about safe procedures, you do so completely at your own risk.

Failing or defective components in high voltage tube equipment, particularly elderly equipment, when failing may arc, spark,smoke, spit, sputter, get hot enough to burn flesh, catch on fire, rupture or shatter sending shards of possibly hot glass, metal, or plastic at your face or body and may spew possibly hot and injurious goo or fluid, or cause normally harmless pieces of metal to become electrically charged at dangerous voltages.

If you have no previous experience repairing high voltage equipment, we suggest you have a professional repairperson to install this modification for you , or at the least obtain competent third party help and a basic knowledge of electronic components, soldering, and construction techniques prior to proceeding.

IMPORTANT: Go through the manual and read all warnings in bold face type prior to proceeding.

Mark 2 owners should read all notes specifically for Mark 2's, and appendix "Special Notes About Mark 2"

Parts List for Mk4 Conversion Boards

Number (Note 5)	Value (ohms)	Tolerance*	Watts**	Notes
R1,R11,R14	470K	See note 2	1/8	Note 2
R2	10K	10%	1/8	Note 1
R3,R13	10K	10%	2	Note 7
R9	47	10%	1/4	Note 1
R8,R10	619 (620)	10%	1/2	Note 1
R4,R15	22K	10%	2	Note 6
R12	100K	10%	1/2	
R5,R6	100K	10%	1/4	Notes 1,4,6
R7	1.5K	10%	1/2	Notes 1,3
RX1	10K	20%	1/2	

Number	Value	Voltage***	Tolerance*	Material (Note 7)
C6,C3	1.0 uF	200V	10%	
C1,C2	.22 uF	600V	10%	
C5	750 pF	100V	5%	
C7	10 pF	200V	5%	
C4	390 pF	600V	5%	

*Maximum tolerance. Smaller tolerance is preferable.
**Minimum wattage rating. Increased ratings are allowed provided they fit within size limits of board space.
***Minimum required voltage rating. Higher ratings ok provided they fit within size limits of board.
Note 1-These should be matched between the two amplifiers. Anything within tolerance is OK so long as the values remain matched within 2% between the two amplifiers.
Note 2-R1 should be matched between the two amplifiers.This value may be modified as apropo for the preamp used, up to 1 meg, so long as values remain matched to 2% between the two amplifiers. R11,R14 must be 470K or less (see instructions for details)
Note 3-Feedback resistor. Value may be modified.
Note 4-May be changed within limits of output tube DC grid circuit resistance ratings provided the pairs remain matched. (Limit for 6550, KT88 and KT90 is 100K ohms)
Note 5-No provision for PAM-1/WA-P2 preamp power-takeoff is made on the board. This may if desired be done by adding a terminal strip and a 22K, 2W resistor elsehere in the amp.
Note 6-May be varied in some cases.
Note 7- Suggested material. Any material preferred by the user (other than electrolytic) may be used, provided minimum ratings are met.

Technical Support

Tech support is only available for those purchasing completed (stuffed) UNMODIFIED board assemblies. If you buy a blank or unassembled board or install parts provided by other purveyors we *must* assume that you know what you're doing,although we encourage experimentation, unfortunately we can't offer a complete education in tube electronics or provide hundreds of $$ of OEM tech services for less than $100...if you want to install your own parts you may, if you follow the manual and use some common sense it'll probably work, but it's up to you to either know what'll work and what won't..or find out on your own, which after all is what experimentation is about! Note we have no opinions, suggestions, or comments of any kind to make regarding parts provided by other vendors, and direct all questions regarding the use of those parts to the third party parts vendors themselves.

1. Introduction-Circuit Description

The TRIODE ST-PC 1 and MK-PC 1 are intended to be drop in replacements for boards in Dynaco ST-70 and Mark III amplifiers with no modifications necessary (just bolt in and solder in wires to the PC board)- but may also to be used as a platform for numerous easily installed modifications and experimentation. Unlike other so-called "hi-end" modifications, you are not totally locked in to only certain components, nor are you stuck with unchangeable circuit values which limit the versatility of your amplifier and further modifications. You do not have to be picky about parts if you don't want to be-fine sounding amplifiers can be built using flea market parts-or you can modify many component values and try different or exotic parts and tweak to your heart's content if you like. The boards will adapt to output tubes which need very low drive circuit impedance/ DC grid resistance like 8417's- or may be modified to whip out enough voltage to drive 2A3's! Yet the board sounds fine even with the cheapest bargain-bin tubes, and special grading and matching is not absolutely necessary.

Although the board was not originally intended to be an "audiophile" modification, third-party subjective testing has shown that it performs quite well in that regard. It is a good example of what can be done with the original type of circuit with improved components, and makes a good case for the virtues of simplicity and short signal path in audio design.

PC1 boards emulate the simple but highly effective (due to the short signal path and single gain stage) original Dynaco circuit, but with lower hum, noise, distortion and a wider voltage swing across heavier loads than a 7199,6GH8,6BL8/ECF80, 6U8/ECF82 or 6AN8 are capable of.

Installation requires the following tools-soldering iron, screwdriver, needle nose pliers, and a fairly accurate DC voltmeter capable of registering up to 500 volts DC and low as 1 volt DC. An audio oscillator, oscilloscope, dummy load, and AC-VTVM may be useful as well.

The board is constructed of .093 inch epoxy-fiberglass, with 2 ounce copper plating -single sided, tin plated, with connector holes plated-through. For convenience,component locations are silk-screened on the top of the board. Standard PC mount ceramic & plastic sockets may be used. Stuffed version includes 1% metal film resistors, polypropylene coupling capacitors, and ceramic tube sockets with gold plated contacts.

Warranty: Completed ("stuffed") versions of the PC board are supplied warranted against defects of parts and materials. Warranty remedies are limited replacing or repairing non-operative boards, or at customer's request repair parts will be supplied at no charge. Choice of warranty remedies is solely our option.

Please note warranty (except as noted below) applies to UNMODIFIED stuffed boards only. While these boards give you considerable leeway for experimentation, after all it is experimentation, and we can't be responsible for the results. Return shipping on defective boards is at purchaser's expense. Since this item is intended for installation by qualified personnel only, and will be installed only in equipment that old enough to require repair, or has been repaired or modified, or in new custom installations of specifications unknown to us, we specifically disclaim any warranty express or implied as to use with, or suitability of purpose for use with, any hardware supplied by third parties, and disclaim responsibility for any secondary damage to any items apart from the board itself.

Blank PC boards will be replaced if found to be defective BEFORE you begin installing parts. Please double check for board cracks and broken traces, bridged traces PRIOR to soldering on it. Note we must assume that if you buy a blank or unassembled board that you know what your'e doing, therefore, assemblies supplied incomplete at your request, and blank boards without parts installed, are supplied "as-is", without warranty express or implied, once you begin installation.

Credits...
Thanks to:
Ken Schurak for original prototype (1991)
Al Hart for designing the Grommes model 260 amp (1959) that this design is adapted from
J. Gordon Rankin of Wavelength Audio for original PC board artwork

2. Installation of completed PC Board assembly (prestuffed, or after stuffing)

IMPORTANT NOTE:

A. These instructions assume you are replacing the ORIGINAL (Dynaco supplied or copy) board. If you are replacing a NON-original board, refer to diagram and connection chart to verify connections, as some numbers or connections MAY be different.

B. Use of high input impedance digital voltmeter or vacuum-tube voltmeter is assumed. Low impedance meters (5,000 to 20,000 ohms per volt VOM's) will measure lower than normal voltages at certain circuit points.

1. Remove bottom cover of amplifier and all tubes.

2. Turn Amplifier upside down

Also at this time, check any of the original wiring that is going to be used - over the years, the wiring may have become brittle and movement now could fray some wires. As most modifications involve new wiring, we found it best to replace the original wiring with Teflon or other new insulated 20 gauge stranded wire.

3.Unsolder all wires from board, also resistor(s) connecting ground side of input jack(s) to board.

4.Unscrew bolts (or drill out rivets in factory-wired unit), remove old PC board.

5.Bolt in the new board (use short 6-32 or 4-40 screws and nuts if old ones not available)

6.Note that all eyelet/pad numbers on the conversion board **DO NOT** correspond to the original Dyna eyelet numbers.

Old Pad Number	New Pad Number
1	11
2	10
3	7
4	6
5	8
6	6
7	4
8	5
9	3
10	1
11	2A and 2B

Two eyelets were changed on the conversion board, 2A and 2B, to facilitate the addition of a separate bias control for each tube. If you do not wish to do this, jump pins 2A and 2B together, using the jumper pads provided. Connect wire that originally went to eyelet #2 to either 2A or 2B.

7. Reconnect and solder all other wires (not resistors) to pads as numbered.

1 - To pin 6 of one 6CA7/EL34 (see note above)

2A **or** 2B (with jumper installed, as noted above) Center terminal of 10K bias control.

3 - To pin 6 of other KT88/6550 (see note above)

4 - To Pin 4 on one of the KT88/6550 sockets.

5 - To third lug of 525V can capacitor (after the 6800 ohm resistor, with the original setup, after the 4700 ohm resistor, our suggested setup)...see note at bottom of page if your amp does not have a 525V can capacitor .

6 - To fourth lug 525V can capacitor or with our suggested setup using a 3 section cap, to the separate 47 uF 500V cap. See note at bottom of page if your amp does not have a 525V can capacitor .

7 - To the 16 ohm tap on the output transformer secondary (usually, yellow wire)

8 - To the filament supply (either one of the green wires on the power transformer)

9 - To the filament supply (either one of the green wires on the power transformer)

10 - To the center lug of the input jack

11 - To the ground lug (outer shell) of input jack, **and** one of the outer shell lugs of the aluminum 525V can capacitor or directly to the center tap (usually red/yellow wire) of the power transformer high voltage secondary. You may need to use an additional length of wire for the second connection. If your amp still has the aluminum 525V can capacitor, the red-yellow wire from the transformer should be connected to one of the outer shell lugs of that capacitor.

8.We suggest using new UNSHIELDED wire to connect the center post of the input jack to the board.
Using shielded wire in this location merely adds another HF rolloff and shield may short out against PC board traces. If you attempt relocating the input jack to the back of the amp, you may have to use shielded wire to avoid hum pickup. Make sure the shield does not contact anything except grounding points. Use an insulated jack, avoid connecting the jack outer case directly to the case.
If the original 13.5 ohm 1% bias-measuring resistors (usually present between pin 8 of one of the EL34 tubes on each side) are burnt out or missing, they may be replaced with 10 ohm 1% resistors. This will change the "Biaset" voltage to 1.2 (instead of 1.56) volts for 60 ma per EL34 zero-signal bias current. If this is done we suggest erasing the "Biaset 1.56V" from the front panel an putting a notation on the amp somewhere that the correct biaset voltage is now 1.2 volts, to prevent accidental overbiasing.
Relocating Bias Control: Adjusting bias on the amps is a bit precarious due to the location of the bias control pot between the output & rectifier tubes.If it is at all feasible to do so, it is possible to drill a hole on the side of the amplifier and relocating the bias control there, so that bias may be set with the cage on. A ground lug could be attached to the chassis as well to make it easy to attach the negative lead of the meter used to set bias.**Alternately,** punch a small hole in the cage directly above the bias control so that bias may be adjusted using a long screwdriver with the cage in place.
9. If the original selenium bias rectifier (small unit with square "fins" connected to bias supply line) is present, replace this unit with a new silicon unit, rating at minimum 1 amp 400 volt (1N4004 or better), this, replacements for the original 50 MFD 70V capacitors, and a terminal strip for mounting the diode is included in the "Bias Repair Kit". Note the banded end of the diode must be the end pointing **TOWARDS** the power transformer, otherwise the wrong polarity of voltage will appear at this point, damaging the bias supply capacitors and possibly the output tubes! Check out the polarity of this voltage during the next step. (**it must be NEGATIVE DC voltage** in relation to the the chassis!) prior to plugging in tubes or hooking up the bias supply filter capacitors to the bias diode. The **NEGATIVE** end of the replacement capacitors (we supply 100 uF 100V or 47 uF) is hooked to the NEGATIVE voltage.
10. Now, inspect your amplifier's filter capacitors. If of sufficient voltage rating(525 volts DC or better rating) and recent vintage (generally not over 10 years old) then you may proceed with next test. If not, or if you are not sure, or if you are not even sure what filter capacitors are, then PROCEED TO STEP 12 and DO NOT EVEN TRY step 11. If you know what your amplifiers' filter capacitors are and are confident of the condition of then and that they meet the conditions stated above, (fairly new and minimum 525 WVDC rating), then proceed to next step.)
11. Read STEP 10 FIRST. Install the 5AR4 rectifier tube ,or substitute with identical or lower voltage output: 5U4-GB, CV378/GZ37, 5V4-G/GA or 5R4-GY/GYA/GYB, and output tubes and board tubes (12AU7's).
WARNING! Do NOT attempt to operate the amplifier with straight diodes or solid-state plugin replacements in place of 5U4 or 5AR4/GZ34 unless a filter capacitor of at least 525V rating has been installed. In many cases the original filter can capacitors are NOT in serviceable condition. If you do not have proper equipment to test the capacitor at close to rated voltage to be positive that it's in good, useable condition, you must change it.Failing capacitors can damage transformers,tubes and spew hot goo and smoke. Do not attempt to operate the amplifier without either a speaker or dummy load resistor (4, 8 or 16 ohms across the correct terminals and zero) connected,and the input connected to a preamp or shorted.The load or speaker rating must be 50W or more as if the amplifier oscillates, which it can if incorrect connections are made, it can put up to 50W or more across the speaker or load, depending on conditions. WARNING: Dummy load resistors can easily get hot enough to burn flesh. Do not touch. Avoid operating the amplifier with the rectifier tube installed AND without the output tubes installed using the original power supply capacitor. Verify that the voltage without output tubes installed **does NOT exceed the rated voltage** of the power supply capacitors. **Switch off the amplifier immediately** if this is the case.
If you are using 5V4, 5AR4/GZ34 or CV378/GZ37 recifiers, the rectifier tubes must be allowed to warm up sufficiently (30-45 seconds) to check this. **Be Careful**, if the capacitors fail, they will spew goo & smoke! **Wear safety glasses** or face shield if you attempt to check this.
Now refer to voltage & pinout chart for location of pins to check voltages, and set the bias control roughly in the middle of its range. Turn the amplifier on (you may wish to change the fuse to 1A fastblow just in case there's a short or wire connected wrong). Observe board and other resistors, if any appear to be overheating or smoking shut amplifier off immediately. If not check voltages against chart, the voltages may appear 10-15% over normal depending on line voltage and rectifier tube used. If you replaced the bias supply diode, check DC voltage at that point at this time also. If your amplifier has had previous modifications to power supply the voltages may appear higher also, so long as the these changes are proportional to the changes in the supply voltages , then this is normal and not cause for concern, the tubes and parts are working well within ratings .Assuming voltages check out correctly and components not stressed (overheating resistors, glowing tubes, etc.) proceed to step 14.

12.Do you have a variac? If no or not sure go to step 13. If so, proceed with the following steps..

A. Turn both bias controls to the middle of the range,or leave them where they were before you changed boards, if you have the same tubes and they were biased correctly previously.

B. Install the bottom cover. Install all tubes and the fuse. Turn the power switch off.

C. Install the amplifier cage and screw on.

IMPORTANT Note that when you turn on the amplifier full voltage the first time that defective components or improper wiring may cause certain parts to smoke, sizzle, bubble, stink, get hot, or in the worst case, rupture, shatter, or spew nasty stinky (and possibly hot) goo. This is why you are being instructed to install all covers before proceeding.

D. Turn the variac all the way down (counterclockwise as above). Plug the amplifier into the variac.

E. Plug the variac into the wall socket. Turn on the amplifier, if the variac has a switch turn it on too.

F. Over the next 30 minutes, turn the variac knob bit by bit SLOWLY up until you reach 100% or line marking 100% of line voltage. **As soon as the 100% voltage is reached, shut the amplifier off.**

If any components show undue stress (smoke, bubbling, red glowing tubes or resistors) at any time, shut amplifier off immediately then allow to cool sufficient time too cool off then disconnect everything and remove covers. Do not proceed past this point, go to Troubleshooting Procedures.

G. This next step is a bit tricky if you haven't relocated the bias control pot or poked a hole in the cage for adjusting bias with the cage on. If you just absolutely have to do it the old-fashioned way,**wear a long sleeve shirt and a face shield**, and use a screwdriver long enough that you do not have to stick your hand between the hot tubes. Next, adjust your voltmeter so it reads a least two digits (or low enough range to read 1.00 to 1.56V with an analog meter). Attach the negative lead to any point on the chassis, alternately, pin 3 on the back panel chassis socket. Put positive meter probe in the hole in the back panel chassis marked "BIASET 1.56V". If the markings have been rubbed off, take off bottom cover, follow the wire from the 11.2 ohm, 12 ohm, or 10 ohm resistor hooked to the output sockets to the the back panel chassis socket. That's the biaset pin, you shouldf mark this as such on chassis.

Now, turn on amp and adjust bias control until the BIASET voltage is at the appropriate level (usually 1.56V, see step 8 above for exceptions).

H. Shut amp off, take off bottom cover. Keep the negative lead of your meter attached to any point on the chassis. Adjust the meter range to read at least to 600V. Attach the postive probe of the meter to pin 8 of the rectifier tube (5AR4/GZ34 or 5U4). Keeping the bottom of the amp pointed away from your face, turn on the amp on and observe the voltage after the amp is completely warmed up (about 1 minute).

NOTE: It's normal for the voltage to go quite high (as much as 525 volts) before the output tubes warm up. When the output tubes warm up sufficiently**, the voltage will drop to its normal operating value.** Observe this voltage after it has settled..if you are using a 525V rated can capacitor and the voltage is under 510 volts, OR if the voltage is at least 15V lower than the ratings of the capacitors you are using, everything's OK, and we can go to the next step.

I.Turn on the amplifier and allow to "burn-in" for about 1/2 hour.

Assuming nothing alarming has developed after the 1/2 hour, turn off the amplifier and unplug both the amplifier and variac. Remove the covers and inspect all parts for overheating.

In particular, put your hand on the large can filter capacitor sticking up from the top of the chassis, if it feels abnormally warm or hot it must be replaced. Repeat same procedure with small electrolytic capacitors in bias supply. Note that a slight temperature due to AC dissipation will occur but these units should not feel obviously warm to the touch.

Assuming components appear OK,proceed forthwith to step 14.

13. Assuming you do not have a variac and do not know exact condition of all components....

IMPORTANT NOTE: In most cases the original, 525V filter can capacitors are NOT in serviceable condition. If you do not have proper equipment to test the capacitor at close to rated voltage to be positive that it's in good, useable condition, you must change it.

A. Install all tubes.Turn both bias controls to the middle of the range, or leave them where they were before you changed boards, if you have the same tubes and they were biased correctly previously.

B. Install the amplifier cage and screw on. Terminate the speaker 8 ohm terminals with a dummy load resistor or expendable speaker (read:one you can afford to blow up) of at least 50 watts rating.**Do not attempt to operate the amplifier without either a speaker or dummy load (4, 8 or 16 ohms across the correct terminals and zero) connected, and the input connected to a preamp or shorted out.The load or speaker rating must be 50W or more, preferably 100 watts, as if the amplifier oscillates, it can put 50W or more across the speaker or load, depending on conditions.**

C. IMPORTANT Note that when you turn on the amplifier full voltage the first time that defective components or improper wiring may cause certain parts to smoke, sizzle, bubble, stink, get hot, or in the worst cases, rupture, shatter, or spew nasty stinky (and possibly hot) goo.

Next, adjust your voltmeter so it reads a least two digits (or low enough range to read 1.00 to 1.56V with an analog meter). Attach the negative lead to any point on the chassis, alternately, pin 3 on the back panel chassis socket. Put positive meter probe in the hole in the back panel chassis marked "BIASET 1.56V". If the markings have been rubbed off, take off bottom cover, follow the wire from the 11.2 ohm, 12 ohm, or 10 ohm resistor hooked to the output sockets to the the back panel chassis socket. That's the biaset pin, mark as such on chassis.

Now that you are prepared for such an unlikely occurrence, stand to the side of the amplifier-so there's a solid piece of metal between you and the components (The superstitious may wish to cross fingers or perform incantations at this point) plug in the amplifier and flip the power switch.

After about 1 minute adjust bias control until the BIASET voltage is at the appropriate level (usually 1.56V, see step 8 above for exceptions).

D.Shut amp off. Keep the negative lead of your meter attached to any point on the chassis. Adjust the meter range to read at least to 600V. Attach the postive probe of the meter to pin 8 of the rectifier tube (5AR4/GZ34 or 5U4). Keeping the bottom of the amp pointed away from your face, turn on the amp on and observe the voltage after the amp is completely warmed up (about 1 minute).

NOTE: It's normal for the voltage to go quite high (as much as 525 volts) before the output tubes warm up. When the output tubes warm up sufficiently**, the voltage will drop to its normal operating value.** Observe this voltage after it has settled..if you are using a 525V rated can capacitor and the voltage is under 510 volts, OR if the voltage is at least 15V lower than the ratings of the capacitors you are using, everything's OK, and we can go to the next step.

E. Assuming nothing alarming has developed, allow the amplifier to "burn-in" (operate with no input and no load) for about 1/2 hour. If any components show undue stress (smoke, bubbling, abnormally hot, buzzing or humming transformers red glowing tubes or resistors) shut amplifier off immediately.

Allow to cool sufficient time too cool off then disconnect everything and remove covers. Do not proceed past this point, go to Troubleshooting Procedures.

F. Assuming nothing alarming has developed after the 1/2 hour, turn off the amplifier and unplug it.Remove the cage and inspect all parts for overheating. In particular, put your hand on the large can filter capacitor sticking up from the top of the chassis, if it feels abnormally warm or hot it must be replaced. Repeat same procedure with small electrolytic capacitors in bias supply. Note that a slight temperature due to AC dissipation will occur but these units should not feel obviously warm to the touch. Assuming components appear OK,proceed forthwith to step 14.

14.With the amplifier off, and turned upside down with bottom cover off, plug in a preamp to the inputs and turn the volume down(or you may just short the inputs with a jumper temporarily if you like). Leave the resistor or speaker connected to the speaker terminals.

Now turn on the preamp then the amplifier. Get out your DC voltmeter and set scale to at least 600 volts. Connect the ground (black) lead to the chassis.Now check the voltages with the red (positive) lead to check voltages at points noted on the PC board diagram.

Note that normal line voltage, output tube biasing and component variations may cause differences beyond the above figures.Use of non-standard rectifier tubes (5U4,5R4,CV378,etc.) in place of the 5AR4 will cause voltages to appear up to 20% lower than normal.

This will cause somewhat reduced maximum output power but is not of much concern provided these voltages remain roughly proportional to each other and amplifier operates properly.In fact in some systems the higher voltage drop substitute rectifier tubes may sound better,provided the amplifier is not required to be driven into clipping to provide adequate power.(This is mostly a function of the type of speaker load and its efficiency).

15. If you do not have any of the following test equipment go to step 16. .
If you have a dummy load (4, 8 or 16 ohms, should be 50 watts or more,although smaller resistors may be used provided you do not exceed wattage rating for more than a brief period of time.Resistors slightly off standard 5 ohms instead of 4 ohms, 10 instead of 8, 15 instead of 16-may be used, as these variations do not exceed what will usually be encountered on actual loudspeakers. Doing so will alter readings slightly but nowhere near enough to prevent you from determining whether the amplifier is operating properly.), an oscilloscope and/or distortion analyzer and an audio oscillator,now is the time to drag them out and hook them up to your amplifier and run the usual tests (unfortunately we don't have the space to instruct you how to use all this test equipment here,and must assume you know how if you have this type of equipment for testing amplifiers).An analog (a la HP 400 or similar) vacuum tube or FET input AC voltmeter will be very useful,although a standard VOM such as Simpson model 260 may be used for output voltage (across speaker terminals) checks, and a digital voltmeter will provide sufficient information provided you are reading a clean, consistent sine wave with it.Standard 20,000 ohm-per-volt meters will give inaccurately low AC and DC voltage readings in high impedance portions of the circuit, and may load it enough to induce distortion. Depending on the rectifier and output tubes chosen and the AC power line voltage, the amplifier will produce between 30 to 50 watts per channel clean sine wave output power prior to onset of clipping.
NOTE please that dummy load resistors can get hot enough to cause nasty burns, melt plastic, etc.!!
Provided the amplifier passes all usual tests and displays no signs of instability or oscillation, the amplifier may now be placed into service, after rechecking the biaset voltage.
16.Assuming that you have do not have any other test equipment, get a pair of cheap speakers (meaning ones that you won't miss if they are damaged) and hook them up to the proper impedance outputs.Note that even if all the voltages check out properly, oscillation (audible, subsonic or ultrasonic) and or intermittent connections can damage speakers. Always check out repaired amplifiers on dummy loads or expendable speakers first.
Provided that the amplifier operates to your satisfaction under those conditions, recheck the biaset voltage and then you may place the amplifier into service.

3. Installing Blank (unstuffed) PC Boards

The same procedures as explained above for installing prestuffed boards should be followed after first soldering in all parts except the tubes on the top side (side with parts numbers silkscreened on it) per the parts list prior to installing the board in the amplifier. Although the parts installation is fairly straightforward and self-explanatory, these items should be noted:
1. Always use eye protection when soldering. Use a small (around 25 watts) soldering iron or a temperature controlled iron for printed circuit board soldering. Excessive heat will make solder flow difficult to control, and in worst case may cause traces to lift.
2. A short jumper must be installed between pins 2A and 2B, unless you wish to install separate bias controls for each output tube.See top side of PC Board for exact location.
3. The circuit traces should appear on the bottom of the board when you are finished.
4. Most commonly available 9-pin minature (called B9A in Britain) PC mount tube sockets may be installed on the board, including our ceramic & plastic sockets or plastic Cinch 9PC or equivalent.

4. Changing Output Tube Configuration

1.Bias control modifications- Many tubes which may be installed in the Mark 4 after completion of the conversion board installation will require negative bias voltages outside the normal range of the bias voltage controls of the original arrangement. The following arrangement will allow more bias control range and accommodate most tubes.
A. Locate the original 10K ohm bias control potentiometer. Remove and replace with linear control of 25K to 30K. Use of a 1 or 2 watt control is recommended, however a 1/2 watt unit will work.
C. Turn the controls 3/4 way counterclockwise (left), turn on the amplifier, and re-bias the output tubes per the instructions under Step 14 under "Installing Stuffed PC Boards".
2. "Fat Bulb" 6CA7-EL34 (Philips ECG, Sylvania, or General Electric US manufacture, or Sovtek Russian or Ei-Yugo). These tubes should install and operate properly in the finished amplifier with no further modifications.

3.KT90,KT88,6550,6L6-GC, 7581, 5881 EL37, EL38(6CN6), KT66, 350B, 350A, 807, 6BG6, 7027A tubes.
These tubes should operate properly in the finished amplifier with the above bias control modification installed, except that the Biaset voltage for 5881 should be set to 50 ma per tube max, ie: approximately 1.35 volts. If the tubes will not set bias properly the above modification to the bias controls will resolve the problem. Note that EL38 and 6BG6 tubes require both relocation of some of the socket connections and installation of appropriate size anode (plate) caps. Refer to base diagrams for these in your tube manual. 7027A operates the same (and newer ones look virtually identical to)as 6L6-GC, except for additional pin connections, refer to tube manual. **IMPORTANT: 7027 has additional screen connection at pin 1, the usual pin 1 to pin 8 jumper must be removed. 7027 has an additional grid connection at pin 6, also.** 350A and 807 have identical pinouts, require installation of different (5-pin) sockets, and installation of plate (anode) caps. See tube manual diagram for 807 for additional info.
NOTE after resetting the bias to accomodate these tubes, recheck the voltage coming from pin 8 of the rectifier tube to assure that this voltage is not over the voltage rating of the filter capacitor.
4.8417 Tubes. These tubes should operate properly by installing the bias control modification described in section 1 and making the resistor and tube changes described in section 3 above. However if the following problems are noted these steps should be taken:
A.Bias voltage required out of range of controls. (biaset voltage too low,insufficient current) Locate the resistor between the bias controls and ground (chassis).Reduce the size of that resistor (try 5K for starters) until the range of the bias control allows the biaset voltage to reach the correct level.
B.Motorboating (low frequency oscillation), tube runaway (plates turn red or orange on one or more tubes), or unstable biaset voltage (biaset voltage drifts up and down).
First, try reducing the the size of R5 and R6 to 47K ohms.
(pairs on each side of the amplifier should be matched to within 2%, preferably 1%) Attempt to operate amplifier, if motorboating or biaset instability continues, first increase the size of R7 to between 2200 and 3000 ohms,if no success, reduce R5 and R6 to approximately 33K ohms. If problem continues,try testing amplifier with input shorted- if problem disappears, this indicates an acoustic feedback problem (see Troubleshooting Procedures). Note that intermittent tube sockets, intermittent or high- resistance internal tube shorts, cracked resistors or resistor leads, or microphonic tubes can induce motorboating or low frequency instability. If tube runaway (glowing plates) continues after modifications, try switching tubes between sockets, if problem follows the tube, this indicates a probable defective tube, if problem recurs in same socket,this indicates a possible defective socket or other intermittent in components attached to that socket.
5.Triode operation of 6CA7, 6550, KT88, 6L6-GC, and tubes with similar pinouts-
Find the green (not green/white) wire (from the output transformer) hooked to pin 4 on one of the EL34 sockets on the amplifier, there is also a wire leading from that pin to pad 4 on the PC board. Disconnect the green wire from its socket and run directly to pad 4. Disconnect the green/white screen tap lead from pin 4 of the other EL34 output tube, then insulate the end of the wire so that the bare lead is not exposed. Remove the wire that previously ran from pad 4 to the EL34 socket.
Install a 100 ohm (1/2 watt minimum) resistor between pin 3 and pin 4 of each of the other 6550/KT88/EL34 tube sockets. Turn the bias controls full left, reinstall the output tubes, and rebias as noted on notes for these various tubes above. This will result in a 15 to 20 watt triode connected amplifier, power varying with output and rectifier tubes chosen, and AC line voltage input.
Triode connection may be utilized with tubes with a different pinout, simply disconnect the screen leads as noted above and insulate the loose screen leads, then connect a 100 ohm resistor (usually at least 1/2 watt) between the plate and screen.

6. 300B and Sovtek 6B4-G Tubes. Using these tubes requires more extensive modifications than the others listed above. The board will work, unlikely to drive the tubes to clipping, but useful output (up to 15 watts) may be obtained. The high voltages prohibit use of US made & Chinese made 6B4-G,6A5 and 6A3.
Follow these general procedures.
A.For 300B,disconnect the screen tap leads from the output tubes (usually pin 4) insulate ends, and wrap up. These will not be used.
B.Disconnect the biaset resistor from power tube sockets.
For 300B tubes, install new 4-pin sockets and attach the plate (anode) and grid leads.
Install a .25 ohm (.22 is close enough), 2 watt resistor in each filament lead between the green wires and the two big pins (filament leads) of the 300B sockets.
For 6B4-G, no socket changes are necessary as the additional pins (4,1 & 8) are not used on 6B4-G
C. Change R5 & R6 to 270K ohms (or similar, match to 2% or better)
E. Change 12AU7 phase splitter tube (V2, closest to output tube sockets) to 12BH7, ECC99 or 6CG7/6FQ7
F. Find the wires running from eyelets 2A and 2B to the bias control. Disconnect the end of each of those connected to the bias control. Reconnect these wires to the power transformer negative return lead, or any convenient ground (chassis) connection near the power transformer. Do not reconnect to the bias controls, the bias controls are not used in this installation, and may be removed or disconnected.
G. Disconnect the .02 capacitor between the center tap (green/white lead) of the filament and ground. Replace with a 750-800 ohm 20 watt resistor bypassed by a 47 uF(or higher) , 100V capacitor.
Alternately, attach a 100 ohm (2 watt minimum) control across the filament winding (green wires) then, attaching the 750 ohm resistor between the wiper (center terminal) and ground.
Then, parallel the 750 ohm resistor with a 47 uF (or higher), 100V capacitor
The capacitor in both cases must have the the positive end attached to the tube end and the negative end attached to the ground end of the resistor.
Note that the filaments are run in parallel, and that the filaments also function as the cathode, therefore there is no separate cathode connection.
Note that the cathode resistor does dissipate some 10 watts or so, and it must be mounted in such a way as to allow that heat to ventilate properly. Do not mount next to meltable or flammable items.
K.Test the amplifier per instructions 10 through 15 of Section 3, "Installing Stuffed PC Boards",ignoring references to tube biasing. Since this modification requires change to automatic ("Self-bias" or "cathode-bias") bias of output tubes, no bias setting per se is necessary.However, it may be necessary to increase the value of the 800 ohm resistor, depending on the actual power supply voltages encountered in the amplifier, and the output tube characteristics. In particular, if tube overheating (often red or orange color to plates) occurs, the size of the cathode-bias resistor will need to be increased. The total current draw for a pair of tubes across this resistor should be no more than 140 ma (.14 amps), which is equivalent to approx 96 volts across 800 ohms.
L. If you installed a 100 ohm control as takeoffs for the cathode-bias resistor, hum may be minimized by adjusting those controls, assuming that the output tubes are the source of the hum.

5.Changing Certain Resistor/Capacitor Values In Circuit.

Note that use of a high impedance input AC voltmeter and an oscilloscope is invaluable in assessing the effects of changes to circuit resistance values. Analog meters (HP 400 or equivalent) usually are easiest to use.

1.Testing Driver Circuit Gain and Output Voltage. The driver board must supply undistorted AC signal voltage to each output tube equal or greater than the bias voltage in order for the amplifier to produce its maximum output. Since the output tube grids will begin to draw current when the signal drives the grid to zero volts, thus clipping the signal, it is necessary to remove the output tubes prior to measuring the AC grid drive voltage or checking distortion, this presents a problem as voltages in the amplifier usually will exceed the filter capacitor ratings with the output tubes removed. However, we can at least check that the driver board is supplying sufficient voltage to drive the clip the output tubes.

To do this, a dummy load (as noted previously) is required, and the feedback resistor R7 must be disconnected. The voltage generated is measured by attaching oscilloscope probes (and an AC voltmeter if available) across one of the output tube grid resistors (R5,R6) or or between eyelets 1 and 3- the second method will give readings double that of the first, tests both sides of the phase splitter (12AU7 or substitute) at once, and gives a peak grid-to-grid AC voltage swing (which is a parameter referred to in some tube spec sheets)- then attaching an audio generator that will make clean sine waves to the input of the half of the amplifier being tested. Note that accurate AC voltages cannot be measured on a square wave! Square waves should only be used to compare the deformation of the square wave between the input and output of the amplifier or section being tested. At any rate when a sine wave of sufficient voltage is input to the driver board, the oscilloscope hooked up the the board in the manner described above should measure an peak to peak AC voltage either equivalent to the negative bias voltage (or double the bias voltage, depending on how you have it hooked up) prior to visible waveform distortion. Preferably the driver stage should generate considerably more voltage than the bias voltage, in order to guarantee a minimum contribution of distortion from the driver stage when the amplifier begins to reach maximum output. Note, not all AC meters measure peak-to-peak voltage.

2. Adjusting the size of the feedback resistor (R11). Changes in output or driver circuits will change the actual open-loop (no feedback) voltage-to-output power gain of the amplifier. This will also change the net amount of feedback in dB assuming the feedback resistors remain the same. Our suggestion is to replace the resistors with a control of perhaps 2.5K to 5K ohms audio taper, then adjusting the feedback level to individual taste. Some may prefer no feedback at all, in which case R11 may be removed.

Note that reducing feedback (increasing the size or omitting the feedback resistors altogether), will also reduce the signal to noise/distortion level (ergo, more noise and distortion) and increase the sensitivity of the amplifier. Since the overall system "noise floor" is normally set by the preamp, the signal to noise ratio is often not significant. There is generally little correlation between measured small distortion levels and the sound quality perceived, you may find sound quality better or worse (but rarely the same) without feedback.

The increase in sensitivity when the feedback is reduced may result in acoustic (mechanical) feedback if the amplifier/preamp is not sufficiently physically isolated from the speakers. Microphony may become excessive as well. One method to alleviate these problems is to install volume control (s) at the input of the power amplifier. The best method is to use separate controls for each channel, as these controls are usually set once and then left alone for extended periods, then volume controlled from the preamp. For tube preamps with output taken off the plate (anode) of the last tube (a la Dyna PAS-3 and PAS-2), controls of at least 250 K ohms should be used although preamps with final tubes with low plate resistance (6CG7, 6SN7, etc) may function fine with lower values. Transistor preamps and tube preamps with cathode-follower output (output from cathode,rather than plate of last tube) can use a value of from 25K to 100K ohms. Excessive distortion or too low output indicates you are using to low a value of control. After drilling a hole and installing the control, looking at the control from the back with terminals on the bottom, solder the left terminal to a wire going to the center of the input jack, solder the middle terminal to the input of the PC board, (eyelet/pad 10), and the right terminal to the ground (case) of the input jack.

Rotate the controls full counter-clockwise, turn on the system, then adjust the controls to where maximum output is obtained without significant preamp distortion (usually so the preamp control is set about 70-85% of rotation at maximum power amplifier output). The net effect of this exercise is to reduce the noise, hum, and microphony voltages seen at the input of the driver board, since these are reduced by the level control. Since the preamp volume control, usually directly ahead of the last gain stage or at the input of the preamp, is also higher, the ratio of signal to noise, hum, and microphony voltages in the preamp itself is much improved as well. Note that preamp input that is taken from a fixed high-gain tube amplifier section (usually moving-coil preamp) may not be affected too much by this if it had microphony problems previously.

Decreasing the size of R11 will increase the amount of feedback. This has the effect of increasing damping factor, making the amplifier less sensitive,and reducing measurable distortion. If negative feedback is excessive, low frequency phase shift in the output transformer will cause an subsonic oscillation called "motorboating", which may be alarming and could damage speakers. Since the amplifier as designed has a safety margin of probably 12 to 15 dB,feedback *usually* can be increased somewhat before encountering the oscillation.
By reducing the size of the capacitors C2 & C3, to induce a low frequency rolloff similar to that of the output transformer, it is possible to extend the safety margin to allow more feedback. As with reducing feedback, increasing it may have either a good or bad effect on perceived sound quality. Unfortunately experimentation is the only way to determine what produces superior perceived sound quality (as opposed to measured sound quality) on any individual system.

3. Changing Input Impedance. With some cables, particularly long ones with high capacitance, the high value of the input resistor (470K across the input jack) may produce an undesirable high frequency rolloff.
The value of these resistors may be reduced as low as 25K ohms if the change does not produce excessive distortion by overloading the preamp. Some preamps (usually ones using 12AX7 as output tubes) require a fairly high value of load resistor to maintain distortion at acceptable levels. However we do not normally recommend increasing the value of the input resistors over 500K ohms, as excessive hum pickup, grid leak biasing and/or HF rolloff may result.

4. Output Tube DC Grid Circuit Resistance (R5, R6). The value of these resistors may be varied within the maximum DC grid circuit resistance limitation for the output tubes chosen, so long as excessive distortion does not result from overloading of the 12AU7/12BH7. The values of the coupling capacitors (C1, C2) should be changed in inverse proportion to changes made in the value of these resistors if the value is reduced,otherwise low frequency rolloff will result.For example if a value of 47K ohms is chosen for these resistors, the value of the coupling capacitors should be increased to .47 uF. In all cases each pair of resistors used with each pair of output tubes should be fairly closely matched.
Low values for these resistors (in some cases you may wish to make as low as 22K ohms) will require that the phase splitter resistors (R7,R8) be made a lower value as well, generally speaking the phase splitter resistors should be half the value or less than the grid circuit resistors to keep distortion levels acceptable.
The previous chapter ("Changing Output Tube Configuration") gives general guidelines for the value of these resistors with different output tubes.

5. Phase Splitter Resistors (R3 & R4). The value of these resistors may be varied from 10K to 47K ohms, provided that the output tube grid circuit resistors (R9 and R10) are at least are at least twice the value of the phase splitter resistors chosen. The output tubes chosen will limit how high a value you may use, as noted in section 4 above and under "Changing Output Tube Configuration". Using values less than 15K will require changing RV1 to 5K ohms.
If phase splitter resistors with a value of 15K ohms or less are chosen, use of 12BH7 tube in lieu of the usual 12AU7 is suggested for best voltage swing and lowest distortion. Note also that these resistors must be of sufficient wattage, resistors of 33K or lower will need to be at least 1 watt rating, those of 18K or lower at least 2 watts.

6.12AU7 Cascode Plate load, Cathode and Grid-Decoupling Resistors (R12,R11,R10,R8).
The load resistor (R12) sets the gain for the driver board and limits the amount of current drawn by this tube.
Considerable variation may be made in the value of these resistors (values between 100K and 330K are normally used) provided the following is observed:
A. Changes to R10 and R8 (cathode resistors) generally should be relative to changes in the plate load resistor R12.
B.After making any changes to R12, the bias of the 12AU7 must be adjusted manually by changing the cathode resistors R8 and R10 to produce a plate (anode) voltage of between 60 and 115 volts.
If the plate voltage is too far out of this general range the tubes will not be able to swing sufficient voltage to drive the output tubes.
Decreasing the value of R3/R4 will reduce the plate voltage of the 12AU7,conversely, increasing the value of R3/R4 will increase the plate voltage.
A potentiometer or resistance decade box is useful for experimentation with these values, however we caution you to use a dummy load resistor instead of connecting speakers to the amplifier while making changes with live voltage present as noises in the cathode circuit will be amplified to the output.
C. Plate load resistors of excessively low or high value will not allow the 12AU7 to swing sufficient voltage to drive the amplifier to full output. Very high values will limit open-loop circuit bandwidth as well.

D. The R X C constant of the combination of R11 and C6 must remain as high or higher than as designed. In other words, if R11 is decreased to 250K, for example, C6 must be increased to 2.0 uF. R5 should not be made more than 470K, otherwise signal grid current on the upper half of the cascode can adversely affect the current (thus the plate voltage) of the upper half. This limits the minimum value of C6, for practical purposes, to 1.0 uF. Higher values of C6 may be used. Electrolytics may be used for C6, but due to the naturally higher leakage of electrolytics, we do not suggest using a R11 value of over 100K with this type of capacitor. This means any electrolytic used as C6 would have to be 4.7 uF or higher. We would suggest paralleling electrolytics used for C6 with a film capacitor of .047 or larger at 200V or higher rating.

7. Other resistors on the board. The other resistors generally speaking should not or need not be changed.

8.Coupling capacitors (C2,C1) The values of these capacitors may be varied considerably, taking into account that too small a value will cause a low frequency rolloff, and too large a value, particularly in conjunction with high values of negative feedback,may induce low frequency oscillation ("motorboating").or pass subsonic signals and cause acoustic feedback from the speakers.
Electrolytic capacitors should not be used for C2 or C1, otherwise about any material is acceptable.

9.Other Capacitors on the board (C7, C4, C5). These are intended for high frequency phase-compensation and prevention of ultrasonic oscillation, the basic values are set by the output transformer characteristics. These can be tweaked *if* you have the proper equipment (basically, a dummy load, square wave generator and an oscilloscope).Trying to tweak by ear alone is not a good idea as if the amplifier oscillates at ultrasonic frequencies, or if there's transformer ringing , this can often only be seen on a scope.

10. Changing other tubes (12AU7). Generally different brands of 12AU7 tubes may be interchanged at will, and also interchanged with other tubes of identical pinout,identical filament voltage and similar voltage gain - usually 12BH7 (rarely, E80CC).

11.Swapping cascode voltage gain tube (V1). As noted above, generally 12BH7 and 6085/E80CC will drop in and work with no further change. Generally you will get better results with 12AU7 than 12BH7 or E80CC. Using tubes with higher mu & Gm, such as 12AT7, 12AX7 and 12AV7/5965 and others with 9A pinout will require will generally require reducing the values of R4 and R3 to get the plate voltage of the upper half of the cascode within limits as noted above. Value of R4 & R3 may have to be increased to accomodate very "hot" 12BH7's, if the plate voltage is too low.

12. Phase splitter tube (V2) Tubes with higher voltage gain (12AT7, etc.) will generally not split phase as evenly as the lower gain ones. The current draw required and the excessive output impedance of the 12AX7, 12AY7/6072 and 5751 tubes prohibits their use in this application. 12AU7, 12BH7, 6085/E80CC,6FQ7, 6N1-P and ECC99 are best.
Use of 6CG7/6FQ7 or 6N1-P requires changing filament voltage jumper on the board to 6V.

6.General Troubleshooting Procedures.

1.Low B+ (HT) voltage from rectifier diodes or tube cathode. (Turn amplifier off before performing tests.)
This indicates either a restriction in the power supply (open or high resistance windings in transformer or choke, bad rectifier tube, low capacity of power supply capacitors) or excessive current draw (caused by leaky filter capacitors, or shorts in tubes or output transformers) pulling down the voltage.

A. Test or substitute rectifier tube or check continuity of diodes. Replace if necessary.

B. Check continuity between the rectifier plate leads (pins 4 and 6) and between these leads and ground. If open at any point, check for broken connections in the leads. If high resistance found on one side of the winding, check for cold solder joints, inside the transformer as well if necessary. If high resistance condition exists after repairs, probable defective power transformer.

C. Discharge all filter capacitors, by shorting terminals to ground, then test with ohmmeter, observing polarity. Meter should first indicate close to dead short then rise slowly to a high value. If one or more sections will not rise or is much lower than the others indicates defective capacitor. Unfortunately some capacitors will pass a low voltage ohmmeter test but leak enough to cause trouble at high voltages. Use of a high voltage capacitor tester would be preferable, or a milliammeter in series with a high voltage power supply. Any current over a few ma after charging up would be suspect.Filter capacitors becoming excessively warm or hot during operation indicates a leaky condition also.

D. Pull output tubes, and disconnect the leads running from the filter capacitors to the output transformers. Check with ohmmeter resistance between transformer leads and ground (chassis). Resistance should be very high. If not indicates possible defective transformer. If suspected, try reconnecting the good transformer, installing the output tubes on that side, then operating the amplifier. If condition does not recur, but recurs when other transformer is hooked up (try without output tubes, so a short tube will not give you a false indication), then that transformer is the culprit.

2.Output tubes draw excessive current (biaset too high).
Swap the offending pair of tubes with the tubes from the other amp.
If the problem follows the tubes to the other side indicates probable bad tube.
If the problem remains on the side where it was originally, possible bad tube socket or bad connection in grid bias circuit (often open bias control) on that side.
Check voltages in bias circuit. If they appear normal (usually will create negative voltage of 30-40 volts at eyelets #2A and 2B), then check for excessive voltage drop (use a high impedance voltmeter to check this such as a VTVM) across R9 and R10.
If a drop of more than a few volts is found on only one,indicates severe tube unbalance or possible defective tubes.
If found on all tubes indicatesthat amplifier must be modified for lower DC grid circuit resistance (see chapter 4, "Changing Output Tube Configuration") to accommodate the tubes you have chosen. If no excessive voltage drops found across these resistors, and other bias circuit voltages appear normal, indicates type or brand of tube used requires modification to bias circuit to be used in this amplifier. See Chapter 4, "Changing Output Tube Configuration" for details.

4.One tube glows red or orange. Swap the offender with another tube (keep track of which one you swapped!) If condition follows tube, this indicates a probable defective tube or possibly bad solder joint inside the tube pins (which may be fixed by heating the pins with soldering iron). If condition appears in the same socket with a different tube indicates either a bad or wrong connection to that socket or a bad socket.

5.Biaset won't go high enough. Generally either means output tubes are worn out, or the 10K resistor from the bias controls to ground is either defective, not connected or out of tolerance (value too high). This could be caused by a bad or internally cracked/damaged bias control.
Occasionally even new tubes do not draw sufficient current, in this case, either replace the 10K bias controls with a higher value, or reduce the value of the 10K resistor going to ground from the bias controls (try a 5K or similar).

6.Transformer hot or vibrating excessively. Indicates either a component in the amplifier is drawing excessive current due to leakage (see section 1 above for how to track that type of problem down), tube are biased to draw an excessive amount of current, or transformer has internal short. Note that some Dynaco transformers as shipped from the factory vibrated excessively and physically isolating the transformer with rubber grommets or other methods may be necessary to solve the problem. All power transformers will dissipate some heat during operation, even with no load, however getting too hot to touch without burning skin indicates a problem.
If the first two possibilities are ruled out then turn the amplifier off and unplug, disconnect the ground (chassis) lead, remove the rectifier tube (5AR4) or disconnect from rectifier diodes, and pull all other tubes.
Check the resistance between the ground lead of the transformer and each of the leads going to the 5AR4 socket. The resistance on each side of the ground wire will not exactly the same but similar (say within 30%).
Check the resistance between the yellow wires connected to the 5AR4 and chassis or transformer case. The resistance should be very high (usually 1 meg or more). Check between the leads going to the 5AR4 and the different filament wires (pins 2 and 8 of the 5AR4 itself, also pins 2 or 7 of the 6CA7/ EL34's). Again the resistance should be very high. If any of these do not check out, a defective transformer is indicated, however other possible leakage paths should be checked, including where insulation where wires run close to the chassis, where wires enter the transformer, and under transformer bottom cover.
7.Capacitors bubbling, crackling, venting or smoking. Indicates that the capacitor was exposed to an overvoltage (or in the case of an electrolytic capacitor, reverse voltage), or is simply defective. Replace the capacitor, however before doing so, check to make sure the capacitor is of sufficient voltage rating, that the cause of any possible overvoltage condition (wrong size of voltage dropping resistor installed, etc.) is corrected, that the voltages in the circuit where the capacitor is installed are correct, and make sure the capacitor, if it is an electrolytic, is installed with the proper polarity- note that in the bias circuit where there are negative voltages present the capacitors are connected with the positive side to ground (chassis), for example.
8. Resistors overheating or smoking. Indicates either a resistor of the wrong wattage rating was chosen or that some element in the circuit (usually a defective tube or capacitor) is short and drawing a high amount of current through the resistor.
To determine resistor wattage rating, use Ohm's Law thusly:
Divide the voltage drop across the resistor by the resistance. This will give you the current in amperes drawn through the resistor. Then multiply the current in amperes by the voltage drop to get the wattage dissipation. Then double the wattage to find the minimum necessary rating. For example if voltage drop is 200 volts, size of resistor is 330,000, current is .0006 amps. Take .0006 times 200 equals .12 watts dissipation. The minimum rating for the resistor would be .24 watt, ergo a quarter-watt (1/4 watt) resistor would do.
Note that for resistors that effectively do not have a DC current drawn across them, principally grid resistors and phase or frequency compensation networks, the wattage rating can effectively be ignored, and the smallest convenient rating used. While AC currents exist in this amplifier, except for the resistors included in the feedback loop (R11 and the 680 ohm resistor across the output), these currents are negligible and may be safely ignored for wattage dissipation calculations. If the resistor is indeed of the proper wattage, then the other defective elements that are making the resistor overheat must be located and replaced prior to reinstalling a new resistor. In the case of a plate or screen resistor, test the tube for shorts or substitute with a known good tube and see if the problem recurs. In the case of possible defective capacitors, follow the procedures in the previous section for testing them.
9. Crackling, hissing, or noises through one or both amplifiers. First eliminate tubes as the source of the problem by substituting tubes one by one, and turning on the amplifier to see if the problem recurs.
If, after substituting all tubes the problem continues, a little detective work will be necessary. First, pull the tubes from the PC board, then turn on the amplifier again. If the sound disappears, then the problem is probably on the board or power supplied to the board. If not, and the sound appears in both channels, the problem is probably in the power supply (power transformer, choke, filter capacitor (s), or resistors attached to the filter capacitor (s). If not and the noise only appears in one channel, the source is most likely in the output stage, often the tube sockets, occasionally the biaset resistor or negative bias supply circuit, more rarely the output transformer. Bad bias control pots are often the source of output stage noise, try moving the controls slightly back and forth to see if the noise changes or goes away. Try wiggling carefully (without burning yourself or breaking the tube!) the output tubes on the affected channel, this will often indicate tube socket that are dirty, corroded, or have lost contact tension and must be replaced.

Most of the noise problems you may encounter derive from the following sources (from most to least common)
1.Loose, dirty, or corroded sockets, pins or connectors, in this case specifically tube sockets or input jacks or plugs. Tighten and clean or replace to correct.
2.Outside electromagnetic interference. Too much can be said about possible sources and solutions to go into heavy detail here (fortunately much has been written elsewhere on the subject), however the general idea is to either shield the signal from picking up the interference, eliminate the source of the noise, or shield the source to prevent it from emanating the offending interference.
3.Tubes. Substitute possible suspect tubes starting from the input. Replace defective tubes.
4.Bad solder joints. Reheat suspect connections to reflow solder. If solder does not seem to stick to a wire, connector, or lead, desolder the suspect unit, clean thoroughly, and resolder.
5.Broken or loose wires or leads. Inspect wires carefully and reconnect any potential offenders.
6.Capacitors (particularly electrolytic ones) with intermittent shorts or leaks. This is common if some of the old original capacitors are still present and not replaced. Also often caused by installing the bias supply electrolytic capacitors backwards. Note in the bias supply (where negative voltage is present) capacitors are installed with positive end at ground (chassis) potential.
7.Cracked or overheated resistors. Often found in power supply (by the main filter capacitor(s). More common if the original carbon resistors are still installed.
8.Intermittent arcing inside power or output transformer. Best indication of this is that other possible causes have been eliminated, and the noise eminates from speakers even though all tubes have been removed. Note that in the case of internal arcing noises will often be heard from the transformer itself.
10.Excessive audio hum. This is usually caused by one of the following:
1.Negative feedback wire from the 16 ohm output to pad 7 is not hooked up.
2. Ground loops, multiple ground paths, and bad ground connections. The audio system should be connected to earth ground only at one point (normally the preamp) and ground connection must be good. Having a component installed with poor transformer isolation (leaky insulation) will induce hum as well as having components with unpolarized (one prong is slightly wider than the other) line plugs.Try turning over unpolarized plugs first.
3.Tubes with cathode-heater shorts or leakage. Hum is bleeding from the AC filament to the cathode. Test or substitute possible offending tube (s) and replace if necessary.
4.Any audio connections (RCA plugs, tube grid pins, etc.) open or not making good contact.
5.Transformer vibration (thus inducing grid vibration in the tubes). This can be considerably exaggerated by tube microphony. If substituting tubes is to no avail, see section 5 above for more details.
11. Voltages on board are way off or amplifier distorts excessively. Check all of following:
A.The tubes you installed are are 12AU7 or 12BH7 tubes, or equivalents (ECC82, 6189, 5814, 5963, ECC99), and are in good condition. Weak tubes will cause the board voltages to be high.
B. If voltages are only off on one amp of a pair, swap the 12AU7 on that side with the one on the other side. If the wrong voltages follow to the other side, that 12AU7 is bad. Replace it.
C.If voltages are off on both amps of a pair, check resistor values. If the PC board tube plate voltages are too high, then this can be either R8, R9, R11 or R10 being too high of a value, or R12 being too low of a value. Also check R15 and the resistor connected to the can capacitor. If the PC board tube plate voltages are too low, then this can be either R8,R9 or R10 being too low of a value,or R12 being too high of a value.
D.Check output transformer and EL34 tube socket connections. Having any of the output transformer primary (connected to the output tubes) wires connected wrong (occasionally, these mistakes were made when the amplifier was built, so should *not* assume that they're connected correctly), or secondary wires either attached wrong, shorted to the chassis (except for the black wires), or shorted speaker wires/voice coil (don't assume a speaker is good until you've checked it on another amplifier), can do this.

12.Amplifier oscillates (tone comes from speakers with no input). Check wiring from PC board pads 1 and 3 to their respective EL34 sockets.
Pad 1 should be connected to EL34 sockets that have striped (green/white & blue/white) wires connected to them (from the output transformer)
Pad 2 should be connected to EL34 sockets that have solid (blue & green) wires connected to them (from the output transformer) See schematic for details.
Make sure only the GREEN wire from the output transformer is connected (via a wire from the EL34 socket) to pad 4.
If the amplifier is wired triode connected, make sure you do NOT connect pin 3 of either of the EL34's, or the green/white screen wire to pad 4 on the PC board, only the GREEN wire from the output transformer should be connected to pad 4.
Make sure the common/ 0 ohm lead on the output transfotrmer is connected to chassis/ground, and the board ground connection (pad 11) is hooked to ground, check this with an ohmmeter.
13.No sound in one amplifier: If you have two amplifiers, first eliminate tubes as the source of the problem by swapping tubes between the sides (EL34's in pairs), and turning on the amplifier to see if the problem follows the tube (s) between the channels.
Next, check all connections: swap speaker & input connectors (avoid doing this while amplifier is powered up), between the two sides, see if the problem changes to opposite side (in which case you've got a problem with a cable, speaker or preamp).
Look at wires connecting between the board & tubes, make sure no leads going to the output terminals are disconnected or touching the chassis (except the 0/common lead on each side).
Check all voltages on the board where the diagram indicates, voltages way off indicate a resistor is open/wrong value.
Check voltages on pins 3 & 4 of all EL34 sockets (where leads from output transformers connect). They should have between 410 to 470 volts depending on recitifier tubes used, biaset being set correctly, and your line voltage, and power transformer tolerances, but ALL of those pins should have similar voltages. Missing voltage on one indicates an broken wire or open in transformer.

Adjusting AC Balance (RX1 on PC board)

The control on the PC board has been preset to work properly with tubes that measure within standard production tolerances. It is not necessary to adjust this to make the amplifier work correctly.If you don't have the required equipment to adjust this, or don't understand the instructions, leave it alone.

If desired, with the proper equipment it is possible to adjust this to get an exact balance in the drive voltage between the two output tubes.

This can be done via a number of methods, to wit:

1. Using an audio oscillator or function generator (set to sine waves),a dummy load resistor and a high impedance AC voltmeter. Note that a standard VOM like a Simpson 260 or Avometer will not work, and input impedances vary between meters. Read the manufacturer's documentation, the AC impedance must be 1 megohm or more. Hook the dummy load to the output connectors on the proper load impedance, hook up the oscillator or function generator to the input (one lead goes to the chassis, other goes to the chassis ground). Turn on the amplifier, make sure the bias is set correctly. Run a small voltage (say 100 mv, exact voltage isn't important but you have to check both sides with exactly the same voltage, so don't change it once you have it set) from the oscillator or function generator (you can check this voltage with your AC voltmeter)into the amp.. Use the AC voltmeter to check the AC signal voltage between pad 1 and pad 2B on the PC board. Note this voltage. Now, check the AC signal voltage between pad 2A and pad 3. Adjust RV1 so the AC signal voltage is the same across pad 2A and 3, as it was across pads 2B and 1.

2. Using a distortion analyzer. We're going to assume you know how to use one if you have one. Basically, hook a dummy load resistor to the output, hook the input & output to the DA, run a signal similar to usual input (about 100 mv is fine), adjust RV1 for minimum distortion.

Separate Bias Control Modification.

See diagram under "Alternate Power Supply arrangements".

To do this:

1. Remove 2A to 2B jumper on PC board if installed.
2. Install 2 25K linear controls. This requires drilling two holes in top or back of chassis.
3. Run wires from the 10K resistor after the bias diode to the right terminal (looking at the installed controls from the bottom) of each 25K control.
4. Run wires from the center terminal of one control to pad 2A; from the center terminal of the other to pad 2B.
5. Connect a wire between the left terminals (looking at the installed controls from the bottom) of the controls,then connect an 10K 2 watt resistor between one of the lugs and the nearest convienient chassis ground location.
6. Disconnect the wire between pins 8 of the output tubes.
7. Remove the 13.5 ohm Biaset resistor between pin 8 of one ot the tubes and ground.
8. On each of the output tubes, connect a 10 ohm, 1% resistor between pin 8 and one of the ground lugs on the tube socket bracket.
9. Now, only one of the tubes will have a wire between pin 8 and the Biaset terminal on the back chassis panel socket. Run a wire from pin 8 of the **other** tube to an unused terminal on the back chassis panel socket. On the outside of the chassis, using a Sharpie, Magic Marker or any other convienient method, mark this terminal as "Biaset #2, .50 volts", and the original Biaset terminal as "Biaset #1, .50 volts"
10. Follow the wire from the PC trace connected to the tube you just connected the wire to, back to the bias control it's connected to. On the outside of the chassis, mark this control as "Biaset Control #2". Mark the other as "Biaset Control #1"
11. Turn both controls approximately 3/4 of the way to the left (counterclockwise).
12. Hook your negative meter probe to any convienient chassis point.
13. Turn the amp on and allow the amp to warm up sufficiently (1-2 minutes).
14. Put your positive meter probe in the "Biaset #1" terminal. Adjust control #1 until reading at that point is .50 volts (500 mv).
15. Put your positive meter probe in the "Biaset #2" terminal. Adjust control #2 until reading at that point is .50 volts (500 mv).
16. Go back and do step 14 again to recheck the Biaset #1 voltage, which will have changed a bit since you've changed the load on the power supply in Step 15, unless you were real lucky and it was dead on without any adjustment.
17. Go back and do step 15 again to recheck the Biaset #2 voltage.
18. Repeat steps 14 & 15 if necessary until both Biaset voltages are .50 volts (1/2 volt or 500 mv)