

What makes a "Good" tube-type HF amplifier?

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This article is written for the ham who is about to purchase their first HF amplifier or wants to buy an elite class of amplifier that could last the rest of their ham career. Reliability being the primary concern, with cost and power output the secondary. A ham could build an HF amp that has all the features needed for this parameter, but this article is directed toward those who don't wish to tackle that large of a project. No one brand or model of amplifier is named, but the most needed features are laid out here, so the buyer can be well informed when inspecting a prospective unit. It is possible that, with the info presented here, a home builder could design and build an amp to these specifications. If that's your aim, go for it. If you would rather buy a ready built amp, we hope this article can help you get the BEST...

Tube type 1 kW + class amps.

Tubes you should stay clear of, any glass envelope tube. This type of tube is near the end of their life-span. Within 5 years, no company will be manufacturing any RF power amp tubes with glass envelopes. Certain ceramic tubes that will also be discontinued soon, are; 8874/3CX400A7, 8873, & 8875(currently discon) 3CX1200A7, D7 & Z7, some of the less popular ceramic tubes made in Russia & China will also become hard to get soon.

The **8877/3CX1500A7** is projected by EIMAC/CPI to be in production for at least the next 10 years, so these would be a safe bet to use, but get a spare anyway. With this info in mind, the only tube type amp I would consider purchasing would have an 8877 in it. An alternative would be an amp that uses (4) 4CX250B, which are a cheap and plentiful tube, but

there are no current amateur amps using them.

There have been some supply and reliability issues with the Russian metal/ceramic tubes, so if you opt for these, you might acquire as many as you can at a low price, as soon as the amp is purchased. There is nothing worse than purchasing an amp, only to find that the tube(s) are no longer made or available. Used tubes "might" be found, but the condition is hard to tell until they are installed, many times the used "rare" tubes are VERY high priced, sometimes higher than their were when new.

Power supply

One of the main items that is needed for a good amp is a good power supply. A legal limit HF amp needs a plate transformer separate from the filament and control PS. The plate supply should be capable of 1500 watts continuous in any mode. For example; a 3kV plate supply should be able to sustain 700mA of current under full key-down CW output. A PS able to do this WILL weigh about 60 lbs. A plate supply capable of legal limit output, would have a filter capacitor bank of from 25-60 μ F, with a surge voltage of at least 1.41 times the plate voltage. A full wave bridge rectifier in the plate supply is a must, NO doublers! The diodes in the rectifier bank should be double or more the full rated plate current. The total diode PIV should be no less than 1.41 times the peak plate voltage. Meaning that the diodes would have a total voltage rating for a 3kV plate PS, of 5kV PIV.

The lower the plate voltage, the higher the filter capacitance that is required. For a plate voltage of 2kV @ 1A. would require about 120 μ F, 3.5kV requires about 60 μ F. The higher the plate voltage, the lower the required capacitance. The required capacitance follows a linear line tied directly to plate impedance. A graph of this can be found in the William Orr, "Radio handbook", 21st edition.

A Peter W. Dahl Co. Hypersil type transformer in a commercially built

amp, is a sure sign of a good unit. Any company that manufactures an amp and goes to the extra expense and trouble to install these high quality transformers, has reliability and power reserve in mind. <As of Dec. 31. 2007, P.W. Dahl Co. is no longer in operation.> A good many Dahl Co. transformers can be found wandering around ham-fests and the Internet

Harbach electronics now owns P.W. Dahl Co. and continues to build these fine transformers.

A couple transformer manufacturers that make good products are;

Universal Transformer in Farmersville, TX. The person to speak with is Chris. Tel. 972-442-2231

Power Magnetics is a large transformer co in Trenton, NJ. 1-800-747-0845, or see: <http://www.powermagneticsinc.com/>

A note about "Hypersil®" transformers. The "Hypersil®" was the trademarked brand name for a high-silicon, grain-orientated steel core transformer, developed and patented by Westinghouse in the 1930's, designed by the legendary inventor Nikola Tesla. The patent expired many years ago so many transformer companies soon began building this design of transformer. Why Hypersil®? Because a Hypersil steel core transformers have a higher magnetic-flux efficiency then a plain iron core, and can be made smaller, but still deliver the same output as the equal iron core transformer.

There is one other type of transformer that is even more efficient than a "Hypersil®", it is known as an "amphorus" steel core. These cores are so efficient, that an extra winding must be made to cancel out the massive "back-pulse" of the collapsing magnetic field when input power is cut to the transformer using this core. Typically, this type core is used in the transformers used in power distribution systems by large electric power

companies. Don't look to install one in your home-brew amp, most all of this type units are very large, weighing several tons each, and operating at extremely high voltages used in long distance electrical transmission lines.

K2AW "silicon-alley" type block HV rectifiers, are high quality units, but must be mounted on a heat-sink to stay cool. An over-heated HV diode will effect the voltage regulation.

Step-starting is a must, At least for the plate supply. If a voltage adjustment resistor is not used in the filament transformer primary, the filament supply should also be step-started.

"Glitch resistor" two ways this can be done, (1) With a 0.68 ohm 1-2 watt resistor in the B+ line, which acts as a "fuse" should a internal tube "flashover" or a parasitic happen, the resistor will explode opening the circuit and protect the PS. (2) A 50 watt, 50 ohm power resistor is used, to limit the B+ current by brute force and is designed not to "fuse". Some amps have an electronic plate over-current circuit, which is a good thing, but a "glitch" resistor is still needed. AC line fuses should NOT be the only current limits in the unit.

Oil filled caps are very good but not really the end-all, or be-all of caps. A good set of electrolytics in a well ventilated cabinet, on an insulated bracket will serve you well for at least 20 years. A matched set of "computer-grade" caps can last 20 years or more dependent on the amount of heat they must endure, which brings us to the area of bleeder resistors.

Bleeder resistors were at one time needed most to prevent "soaring" voltage in supplies that used filter chokes (*see note*). Since most amps built in the last 30 years do not use filter chokes anymore, the bleeder resistors need not be as large or dissipate as much heat. The "old" practice of using bleeders that draw 10% of full load current on the PS,

are not needed anymore. The only purpose that bleeder resistors serve now, is to draw down the HV after amp shut down, and equalize the DC voltage division across each cap in the string . A bleeder load of as little as 1% with work.

(Note; Filter chokes are no longer used for the simple fact that they are not needed now. The old reason was that plate transformers years ago had a rather high secondary impedance, which caused drastic voltage drops under a load, currently plate transformers are much better and have very low secondary impedances and therefore little voltage drop. Also, SSB and CW operations have a lower current load requirement on the plate supply. The old days of AM being the primary operating mode are long past, so the HV supply need not be as stiff as they had to be for clean undistorted AM. A filter-input HV supply, provided that has enough capacitance, will work very nicely for all modes in currently designed amplifier power supplies.)

I have found that a resistance of 100-500K ohms across the entire filter bank works very well for bleed-down.

Individual resistors can range from 68-75K ohm each at 3-5 watts each. If a single power resistor is used across the entire bank, the wattage rating should be 100-200 watts dependent on the resistance.

It is best if the bleeder resistors are mounted away from the cap bank, to keep the heat they produce from shortening the capacitors life span.

Wiring... The best possible wiring is Teflon® insulated wire, but Neoprene® is OK. The wiring harness should be well laid out, tie-wrapped and anchored to the chassis. Wire size matters. The primary AC wires should be no less than 12ga. size, any thing less will cause excessive voltage drop.

The HV wire should be heavy Teflon® or silicone rubber insulated, of no

less than 18ga. size.

If all wire connectors are soldered, it's a sure sign of a quality amp manufacturer. Shrink-wrap connections are one more sign of a truly well made amp.

Where the wires are routed makes a difference too. A bare minimum of "non-RF" wires should be found in the RF "hot" areas of the unit. Full Pi-section RF by-passing of all wiring are a must, but are getting very hard to find in "some" commercially built units.

RF circuit

The RF section or "Tank circuit" is likely the most important and visible part of the interior of an amp. A well designed RF tank, will determine the overall performance/efficiency of the amp. DC blocking caps or "RF coupling" caps. NO disk caps! Door-knob caps rated for high RF current service are the rule here. A voltage rating of (2) times the DC plate voltage is the bare minimum. If two or more caps are used in parallel, the current handling is better. I have found that (4) caps in parallel work great, but (2) will do the job just fine. Lower capacitance values can carry higher RF currents, so (4) caps can carry more than 4 times the current of a single high value cap.

A **Pi-L** output network is the only way to go, it has far less harmonic distortion than an old Pi network.

The tank coil should be made of copper tubing, no less than 1/8th inch dia. If wire is used, the size should be no less than 12 ga. size. If the amp covers 160 meters, many builders use toroid cores to reduce the size of the 160 meter coil, which is OK, but it must be done right to prevent future problems. A toroid core size of 3 x T-200-2 cores, red mix type are the minimum. Wrapped in glass tape, stacked 3 deep, with a inside minimum diameter of 2". The wire used on the core should be no less than 12 ga.

Teflon® insulated wire. The core should be stood-off, well away from any metal surface to prevent arcing.

Band-switch! The heart of any multi-band HF amp. Ceramic ONLY! No phenolic switches allowed here!

In a KW+ class HF amp, the band-switch should be able to carry no less than 20 amps DC current, with a peak voltage level of 10kV DC. For RF service, the DC rating is "de-rated" to 60% of the DC level. This is one area where BIGGER is better. A failed band-switch will take your amp off-line instantly, and are very hard to replace. A high quality band-switch is a MUST, "corner-cutting" is NOT allowed here.

Plate choke. No less than 200 μ H and 1" dia. Wire size of 26-18ga. Formvar insulated. If the unit operates on the WARC bands, it may be necessary to switch in a cap to ground in the plate choke to prevent unwanted resonances.

Many amps can not operate on 12 meters, if the manual specifically states not to use the unit on 12 meters, don't even try it there, it could be the last time the amp operates before the plate choke blows up! However, most of these amps can be modified to work on 12 meters with a change in plate choke.

To read more detail on plate chokes, click [here](#).

T/R change-over relays. A well made amp will use vacuum relays or high power PIN diodes for T/R switching, Dow-key/KiloVac coaxial RF transfer relays are acceptable as well. Open-frame relays work Ok, but are loud, slow, and prone to failure when used in a high RF applications. Jennings or KiloVac relays are the best for this purpose. PIN diodes have been used in a few designs, but don't have a great reliability record, specifically when a high SWR is present, they tend to fail when presented with high RF voltages and currents found in these high SWR conditions.

Tuned input network or not? Most modern amps have tuned input networks, to suppress harmonic distortions and present a nice steady 50 ohm load to the exciter. If the amp works the WARC bands, it would be best if the amp had individual tuned input networks for each band. Some amp builders try to "stretch" a single tuned network to operated on more than one band, but this is not a good engineering practice, the "Q" would be far to low in the network to be of any use.

If the amp does not use a tuned input network, then a "passive resistive" input network must be used. These resistive networks can be found in many high gain triodes, and many tetrodes & pentodes.

Some form of input network must be used to suppress the level of harmonic distortions and present a constant 50 ohm load to the exciter. Direct feed of the tube is NOT acceptable! This might confuse a few users, since the tube manufactures have posted the input impedances for the tube. A user might think that if the tube has a 50 ohm input impedance, it can be directly fed by the exciter. This is NOT true! The 50 ohm load is present only during half of the sine-wave input cycle, during the other half of the cycle, the impedance load can swing anywhere from a few ohms to several kilohms, which will distort the input wave-form, not to mention the exciter will "look" into a poor SWR for that portion of the input cycle.

Protection

Grid trip A must in any amp that uses high gain metal/ceramic tubes. Should over-drive, high SWR or mis-tune happen (and it WILL), this protection circuit will disable the amp until it is reset and the conditions is corrected. Any amp of good quality and design will have this circuit in it.

ALC An ALC circuit with an adjustable threshold control is a must. Use the ALC despite what others tell you, and your own assurances that, "I

won't over-drive this amp." You WILL. So, as a "fail-safe" use the ALC as it was designed, to prevent over-drive, by feeding a DC negative voltage back to the exciter, which reduces the output level from the exciter.

Safety interlocks. Any amp that is worth buying, must have a means of disabling the HV PS should the cabinet be opened while the units is powered up. Far to many hams have died as a result of no interlocks, or interlocks that they disabled. You can never be too careful or safe.

Fuses A single set of fuses are not adequate for protecting the PS from over-loads. A separate fuse for each PS function is best, i.e. A fuse for the plate PS on both AC main lines, circuit breakers are even better, faster too. A fuse for the control PS, and a fuse for the filament PS. This means a minimum of four fuses. This does not count the B+ HV fuse resistor, if one is used.

Meters. You must have a full time dedicated grid current meter, and a plate current meter, any other meters are Ok, but not needed. A high voltage meter is a good item, but need not be full time reading. Meter movements that are lighted are a great feature to have. The new LED bar graph metering are fast, but have generally lower resolution than a good analog meter. For the most part two to three meters will be all you need. A tetrode or pentode amp should have a screen current meter position in addition to the above mentioned.

Full meter protection with back-to-back diodes and RF by-pass caps across the meter. This protects the meter movement should a parasitic or flash-over occur. The by-pass caps prevent random RF from damaging the meter movement.

For newer designs, a fully digital meter is highly accurate. All meters are only useful when the amp is tuned or under a carrier signal operation, during SSB signal operations no meter, weather digital or analog will give accurate readings. An LED or LCD bar-graph readout will give better

indications of peak levels on SSB.

Blowers. A tube able to run legal limit needs lot of air flow, but it is not just air flow through the tube that is needed, but air flow cooling of the PS section too. If the amp uses a separate PS cabinet, it should have it's own fan/blower.

The tube blower should provide no less than the minimum air flow required by the tube manufacturer, but more is better. The problem with lots of air flow, is it usually means much more noise. If a good quality ball-bearing fan is used the noise is likely to be much less, than that of a non ball-bearing fan. If the amp is a single unit, the fan/blower should draw air through the PS section to cool the components that generate heat there. The RF section can use a small amount of air flow to carry away heat that RF generates in the tank. A chimney is a good item, but not really needed if the exhaust is well separated from the air intake area. A means of installing an air filter would be good too. The position of the air exhaust matters also. The hot air should always exit the unit on the top or rear, any other directions will cause you discomfort, or heat up other gear next to the amp.

Cosmetics

An HF amp that you plan to keep for a life time, should have good cosmetic appeal. You will have to look at it for many years, if it is an "ugly" amp, sooner or later you will get tired of looking at it. If the amp is not pleasing to your eye, it might get ugly real fast.

The size of the unit can also be a major concern. If the unit is a desk top amp, the weight on the desk is a real concern, so make sure your desk can handle it before you place the unit there. A "console" amp, must have casters to make moving the unit easy. Measure the area where the prospective unit will go, before getting the unit home.

The front panel should wear a hard coat of paint, preferably an epoxy base or baked on coating. A plastic over-lay is OK to protect panel silk-screen letterings, but will one day become scuffed and yellowed. A thick coating of "clear-coat" will do the same job and last longer, and can be "touched-up" when needed. The color scheme of the exterior of the amp unit can be anything the user likes, but the interior should be light colors so as to make visibility better when servicing. I have found bright silver paint, or white to be the best for the inside.

Final words

A well designed tube-type amp, can easily last an entire on-air career, if the user treats it conservatively. Regular servicing for dust removal, and preventive maintenance will assure a long productive life for the unit.

There is always the chance that a tube can fail, so a second tube/spare would be good insurance. Swapping these "spares" on an annual basis will keep them in top operational condition at all times. Band-switch contact conditioner such as "[PRO-Gold®](#)", will assure that the band-switch will be in top condition also.

"Life is too short for QRP." "Speak softly, and run a BIG amp."

73 de Matt KK5DR

For a more "advanced" in-depth article, read my essay on building your own [tube-type HF amplifier](#).

For the definitive article on "solid-state" HF amplifiers, read [Adam's](#) article.

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