

Vacuum Tube Safety Procedures

1. Overview
2. Power Source
3. Personal Safety
4. Specific Procedures

Section 1: Overview

The purpose of this document is to share various safety practices when working on thermionic devices. I would greatly appreciate comments and suggestions. Please do not hesitate to add to this document, especially if I have made any errors.

All vacuum tube amplifiers operate at potentially lethal currents. Even unplugged, some amps can store a DC charge in the power supply capacitors. Although the likelihood of getting killed by your amplifier is quite low, it can and has happened. We often discuss working in dangerous situations not realizing that many whom we converse with may not be aware of proper procedures for working on high voltage circuits.

From Wikipedia:

***Electric shock** occurs upon contact of a human body with any source of voltage high enough to cause sufficient current through the skin, muscles or hair. The minimum current a human can feel is thought to be about 1 milliamper (mA). The current may cause tissue damage or fibrillation if it is sufficiently high. Death caused by an electric shock is referred to as electrocution. Generally, currents approaching 100 mA are lethal if they pass through sensitive portions of the body.^[1]*

Notice they talk about currents and not voltages.

***Electrocution** is the stopping of life (determined by a stopped heart) by any type of electric shock. In the vernacular, the term electrocution is used to mean:*

- *death, murder or suicide by electric shock*
- *deliberate execution by electric shock, usually involving an electric chair; the word "electrocution" is a portmanteau for "electrical execution"*

Electrocution is also frequently used to refer to any electric shock received but is technically incorrect.

A domestic power supply voltage (110 or 230 V), 50 or 60-Hz AC current through the chest for a fraction of a second may induce ventricular fibrillation at currents as low as 60 mA. With DC, 300 to 500 mA is required. If the current has a direct pathway to the heart (e.g., via a cardiac catheter or other kind of electrode), a much lower current of less than 1 mA (AC or DC) can cause fibrillation. If not immediately treated by defibrillation, fibrillations are usually lethal because all the heart muscle cells move independently instead of in the coordinated pulses needed to pump blood to maintain circulation. Above 200 mA, muscle contractions are so strong that the heart muscles cannot move at all.

Ah... now we see that higher voltages require less current to be lethal. Tube amps typically operate in the 250VDC to 500VDC range so not a lot of current is required for things to potentially get ugly. Later on I will discuss ways to avoid getting shocked.

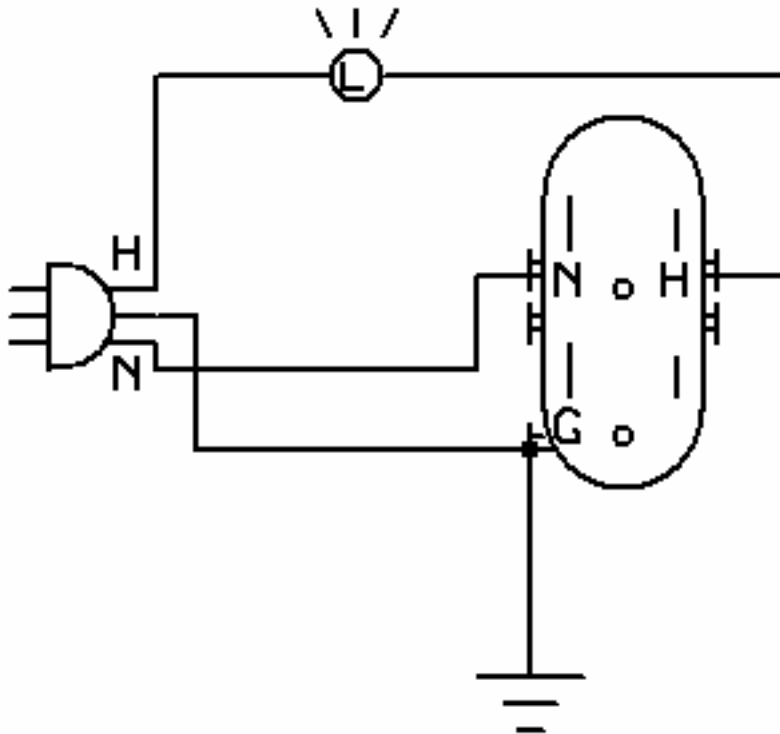
Here's a little more trivia. More electricians are electrocuted by an extension cord than by working on energized circuits. This is because when you're working on energized circuits, you're typically paying close attention. How many times have you plugged into an extension cord w/o thinking twice? My point here is that carelessness leads to accidents. The #1 cause of injury to electricians is falling off a ladder. Fortunately ladders are rarely require to service a tube amp.

Section 2: Power

If I had to choose any 1 thing for electrical safety, it would be the Ground Fault Circuit interrupter. These things are the bee's knees. A regular circuit breaker trips by sensing a current overload. A GFCI trips by sensing an imbalance of current between the hot and neutral conductor. If there is an imbalance, there current must be finding another return path to ground other than the neutral. It could be through the chassis or a person. The GFCI trips at 5mA of current imbalance, a far cry from 20A of overload current.

Your work bench should have GFCI protection on all receptacles. You should also ensure that your polarity and grounding are correct. There's no point in even attempting to trouble-shoot a circuit if the supplying circuit needs troubleshooting itself. A GFCI will not save you if you (meaning your person) gets tangled up between secondary voltages, but it will save your ass if you have a primary short or live voltage on the chassis.

Now that you have proper premises wiring, YOU ABSOLUTELY HAVE TO HAVE A LAMP LIMITER. Whenever you have an amp that's blowing fuses, is old and unknown, or has just undergone surgery, you want to fire it up using a lamp limiter. If an amp is blowing fuses, putting in a new fuse and plugging it in is just gonna blow another fuse + stress the circuitry. If you don't know anything about the amp, it's fool hardy to just plug-n-pray. Do you ever make mistakes when making repairs? I do. A lamp limiter is so simple to build, there's no reason not to have one. All it is, is a lamp in series with the wall power. If your amp is dead shorted, the bulb will glow brightly, no fuses blow, & nothing smokes. You power down, divide and conquer until you find the problem. A happy will cause the lamp to lightly flash when first energized. This is the filaments in cold state. As they warm up, the lamp will glow dimly. Coming off standby, the lamp should get slightly brighter but still be very dim. A bright lamp means there's a problem. A 100W lamp is typically large enough. If you're messing with a big ol 100 watter, you may wanna grab a 175W flood lamp. You can check voltages when using a lamp limiter, but they will be quite low. You should be able to hear the amp, but don't expect it to play well. You also shouldn't stay plugged into the limiter any longer than necessary. Since voltages are lower, currents may rise and some things may heat up pretty quickly. It's just a safety step. Once you're sure the amp isn't shorted, bring it up under normal power.



Section 3: Personal Safety

Back at the beginning, “Electric Shock” was defined in terms of current. The greater the voltage, the potentially more harmful the shock can be. Every wonder how a bird can sit on a HT wire and not get electrocuted? The average transmission line is sitting at 345kV. It’s because the bird is not completing a path to ground. They hang these steel cables on 5 ft insulators to ensure nothing can make a path to ground. The same holds true for working on amps. If your body is completely insulated, you can touch energized parts. As soon as you touch something of a different potential, you are now a current carrier, you’re part of the circuit, you are getting shocked. If enough current crosses your heart, you may get electrocuted. The key is to minimize this possibility. Most of this is common sense but: Always wear rubber sole shoes when working on an amp. A rubber mat is a wise thing to have in front of your bench. Do not hang onto the chassis with 1 hand and probe with the other. Do not put both hands inside the amp at the same time. Watches, necklaces, and metallic jewelry are verboten. Use a wooden chopstick for poking and prodding, not a screwdriver. Please wear eye protection.

Unfortunately many amps are constructed so that it is difficult probe some areas safely. A cramped and crowded bench only compounds this. Often times it is helpful, if not completely necessary to build a jig to hold the chassis. Precariously balancing an amp while working on it, is begging for trouble.

Section 4: Specific Procedures

Up until now, I have focused on ways to avoid getting shocked while working on amps. Now let's talk about making the amp itself safe.

Right from the get go proper grounding is a must. Grounding should be the 1st priority when servicing an amp. Not only is it a big safety system, but better grounding = quieter amplifier. Back in the old days, it was common for amps to have ungrounded cords and have their chassis isolated from line power using capacitors. These have been nick named "Death Caps". I don't like this name because they were intended to be "Life Caps". If an amp has an ungrounded cord and the isolation cap on the hot side fails short, then your chassis will become 120VAC hot. If it fails open, then your chassis could be floating anywhere between 0 & 120VAC. Caps do fail, and usually they fail short. Relying solely on a pair of capacitors is an antiquated idea. Anything in a metal chassis is supposed to be grounded. Nothing leaves my bench w/o a grounded power cord. I also believe you should leave the isolation caps in place. If the hot side cap fails short but the chassis is grounded, then the caps simply pops, or the fuse may blow. Having caps across the AC helps filter out RF and other trash you may find on the line. In the event you plug into an ungrounded or reversed polarity receptacle, you now have life caps keeping you safe from shocks. A lot of people will argue, "Death Cap Death Cap" but if the chassis is properly grounded, then it's more of a belt and suspenders situation.

Proper fusing is another big safety feature that is often overlooked, or blatantly disregarded. I don't know how many times I've found a 20A SLO BLO fuse where a 2A should be. My old Hammond organ didn't even have fuses. By definition, a fuse is an over current protection device. Putting in the wrong size fuse completely defeats the purpose.