Radio FUNdamentals

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THINGS TO LEARN, PROJECTS TO BUILD, AND GEAR TO USE

Loose Filament Pins on the 3-500Z

Quite a discussion has been going on concerning loose 3-500Z filament pins and how to "cure" the problem.[1] Unfortunately, the suggestions given cure the symptoms, but not the problem!

In brief, some amateurs have encountered loose filament pins on their 3-500Z power tubes after many hours of operation—or to put it more accurately, loose pin sleeves on the filament pins (fig. 1). This seems to be a problem common only to the amateur world, as it is virtually unknown in the realm of commercial and broadcast equipment. Why do amateurs have this problem while others do not? A good question.

In order to understand what is happening, it is helpful to look at the construction of the base structure of the 3-500Z envelope.

The 3-500Z Base Structure

The 3-500Z base is made of glass, which has a low but specific coefficient of expansion. When it is heated or cooled, tensile stresses are introduced into the material. The stresses are temporary and disappear on attainment of temperature uniformity. Glass is a good insulator and lends itself readily to forming. These factors make glass an ideal envelope for a power tube.

Connections to the internal tube elements are brought out of the glass envelope by means of glass-to-metal seals. A seal requires that the glass and metal have somewhat similar expansion coefficients and rates of expansion to prevent excessive mechanical stress from being set up in the glass envelope. The filament leads of the 3-500Z are tungsten rods of sufficient diameter to carry the filament current (14.5 amperes) without undue heating of the glass seal. Tungsten is chosen for the leads, as it has approximately the same expansion coefficient as the glass. The "feed-through" seal is made by forming a metal oxide on the tungsten surface at a high temperature. The plastic glass (also at a high temperature) is fused to the rod to form a glass oxide/metal transition area. Once the seal is made, the union is slowly brought down to room temperature.

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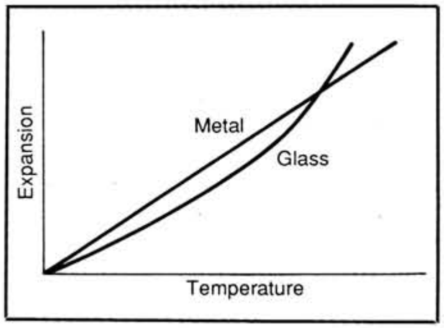


Fig. 1– Typical example of glass and metal expansion. From Roseburg, Handbook of Electron Tube and Vacuum Techniques, *1965, Addison-Wesley Publishing Co., Reading, Massachusetts.*

In making a glass-to-metal seal it is important to remember that a perfect expansion match is not possible, because while the expansion of metal is a linear function of temperature, that of glass is not (fig. 2). The useful life of a seal is greatest when the seal is heated and cooled slowly and when the temperature difference between the hot and cold seal is the least. It is a good idea, therefore, to closely control the operating temperature of the seal.

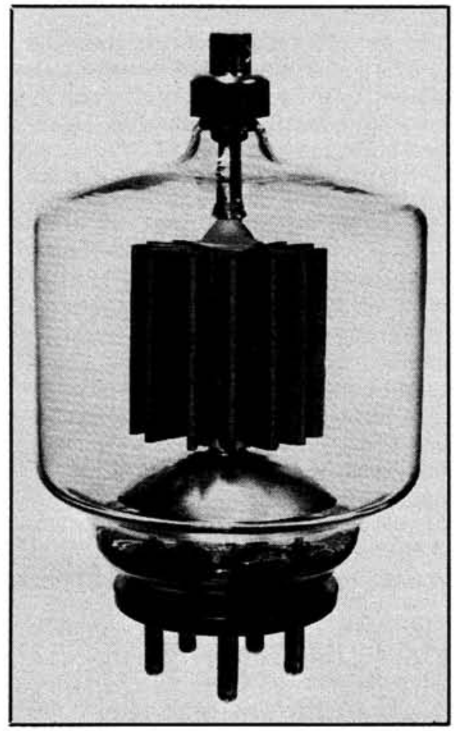
These restrictions are well-known to the tube engineer, and that is why maximum seal temperature is specified in the tube data sheet.

In the case of the 3-500Z, maximum temperature rating of the filament seals is 200 degrees Centigrade. In order to hold this limit, cooling air must be applied to the seals.

Filament Operation

For maximum filament (and seal) life of the 3-500Z, the following rules should be observed.

1. Filament voltage should be held within specified limits. A thoriated-tungsten filament operates at a temperature in the range of 1800 to 2200 degrees Kelvin (1527 to 1927 degrees Centigrade—very, very hot!). For typical amateur linear service I suggest the filament be operated near the lower limit of this range. In practical terms this means running the nominal 5 volt filament of the 3-500Z at



The 3-500Z power triode. Tungsten leads pass through glass-to-metal seals in bottom of envelope. Base consists of nickel-plated pins swagged into a phenolic ring. Leads are dip-soldered to pins.

about 4.9 volts. This enhances filament life and also permits the filament seals to run cooler than if the filament is run at or above the nominal voltage.

2. Electrical connection to the filament pins must be accomplished with minimum contact resistance. Any voltage drop across the contacts represents an "I-squared R" loss, which shows up as additional heating at the filament pins.

3. Sufficient cooling air must be passed across the filament pins and seals to hold pin and seal temperature below 200 degrees Centigrade. The temperature can be checked by means of temperature-sensitive paint or decals applied to the base of the tube directly at the filament seals.[2]

All of these requirements can be met by carefully measuring the filament voltage, using the proper tube socket, and applying an adequate amount of cooling air.

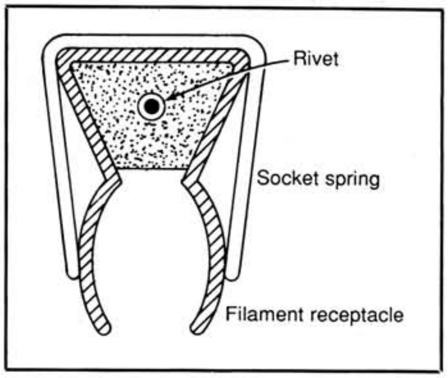


Fig. 2– Example of filament receptacles and tension spring in ceramic socket.

The EIMAC Air-System Socket

The nickel-plated brass filament sleeve is soldered to the tungsten filament rod using 60–40 solder (60 percent tin, 40 percent lead). The melting temperature of the solder is about 268 degrees Centigrade. This allows only a 68 degree margin of safety between maximum rated pin/seal temperature and the solder melting point. It is a good idea, therefore, to hold base temperature below 200 degrees, if possible. Lower seal temperatures will prolong tube life. Too much air cannot be applied; the maximum limit is reached when the tube is blown out of the socket!

A special EIMAC SK-410 Air System socket is available and recommended for the 3-500Z tube. This socket is constructed so that cooling air can be passed easily up around the tube pins, making temperature control a relatively simple matter. Unfortunately, the socket is expensive, and many home builders prefer to use a cheaper ceramic socket which inhibits air flow to the tube base. Even so, the ceramic socket can be used successfully, holding the filament seals below maximum allowable temperature, provided extra cooling air is passed through the socket holes.

Temperature Runaway

If filament pin temperature climbs much above 260 degrees, the pin solder starts to melt, first turning to a sludge and finally to a liquid. The tube can continue to operate when the solder has turned to sludge, but the resistance of the solder rises rapidly under these conditions and the "I-squared R" heating loss increases accordingly. If the solder has not turned to liquid and dropped out of the pin, it will crystallize when the tube is turned off. Only close examination of the filament pin will disclose that the solder is now "grainy" in appearance and there is a small but measurable voltage drop between the pin sleeve and the pin.

A runaway condition now exists. Because of the change in the solder, the pin now runs hotter than normal. This means that melt-down will happen sooner rather than later. The filament pin temperature rises quickly and reaches a level that can take the temper out of the tension spring on the socket receptacle. In addition to tube damage, the socket is now slowly being destroyed. This causes additional voltage drop across the socket/tube interface. Soon the sleeve will drop off the pin and the solder will disappear into the innards of the amplifier!

Proper Cooling for the 3-500Z

The Rotary Blower. The solution is to cure the problem, not relieve the symptoms. It is possible to resolder a loose filament sleeve (exerting due caution), but the problem remains unless the base of the tube is cooled properly. It may also be necessary to replace the socket filament receptacles if they have been discolored by the excessive heat, and the socket spring, if it has lost its tension (fig. 3). But this is only a temporary fix, as filament pin temperature is not under control.

It has been my personal observation that a lot of blowers and cooling fans in ham amplifiers are marginal at best. That is, they do not supply sufficient cooling air to the tube. Operators don't like blower noise, and the temptation is to use a low-noise blower. Since moving air creates noise, the only way to reduce the noise is to use a blower which moves less air! Right? Wrong!

In a home-built two-tube amplifier with a pressurized chassis and a "squirrel cage" rotary blower, at least 26 cubic feet-per-minute (CFM) air flow at a back (static) pressure of about 0.1 inch of water is required.[3] This can be accomplished by a 3 inch diameter rotary blower having a speed of 1600 RPM if EIMAC Air System sockets are used and the air path is unimpeded. A smaller diameter blower won't do the job, even at a rotational speed of 2800 RPM.

If, however, ceramic sockets are used, the air path is impeded by the socket and more blower power is required. In this case, a 3 inch diameter blower with a speed of 3100 RPM is suggested. About 11 percent more blower speed is required to do the job when the ceramic sockets are used!

In either case, the determining factor is seal temperature. Basing temperature on blower speed is tricky, as the force of the air flow may be impeded by air turbulence or restrictions in the air passage. It is a difficult task, too, to make the chassis air-tight so that the air flow passes only through the sockets and does not escape via other miscellaneous chassis holes.

The Rotary Fan. Some amplifier builders use a rotary fan instead of a blower (fig. 4). This is satisfactory, provided the air actually reaches the filament seals. The air is blown across the socket pins and conducted up around the tube base. Small ducting plates may be placed under the amplifier to direct the air in the right direction. If the fan is big enough and properly placed, it may not be necessary to pressurize the entire chassis. A cleverly placed fan can cool both the filament and plate seals of a pair of tubes.

Under-chassis obstacles can impede an otherwise direct air-flow. The old Heath SB-220 amplifier, for example, uses a rotary fan which is big enough to do the job, except a chassis flange creates turbulence in the under-chassis air flow, thus preventing the cooling air from doing an efficient job. It is possible, therefore, to overheat the filament pins in this amplifier under severe operating conditions, high filament voltage, or high outside air temperature, with resultant pin problems. When properly mounted so that air reaches the filament pins, a fan such as the "Rotron Sentinel" or "Ripley 425" is suggested for your home-built amplifier.

The operator usually finds that filament pin problems occur with only one of a pair of tubes. This indicates the tube socket is not receiving sufficient cooling air, while the other tube socket is doing okay. It may be necessary to replace the socket, or at least the socket pins, when a good 3-500Z is placed in the amplifier, or the problem will start up over again when filament seal temperature is excessive.

Extended operation in a DX contest with plenty of speech processing can make an otherwise adequate air flow suddenly become insufficient. Style of operation has a lot to do with filament pin problems.

Resolder Your Base Pins?

Some fellows have done it (see the *QST* references). If you want to try it, make sure the tube and base seal are heat-sunk from the soldering area to avoid overheating the tube seal. A non-caustic soldering paste (Kester) can be used. Rosin-core solder is effective (60-40 alloy). The trick is to do the job without overheating the tube seal!

The tungsten filament rod is carefully cleaned with emery cloth and the inside of the sleeve is cleaned by running a close-fit drill through it. Using a high-wattage soldering iron, gun, or jeweller's torch (so as to get the job done quickly), the rod is tinned. The sleeve is then slipped over the rod and quickly soldered in place. While it is still warm, the sleeve is wiped clean with a rag moistened with solvent. I have not tried this process my-

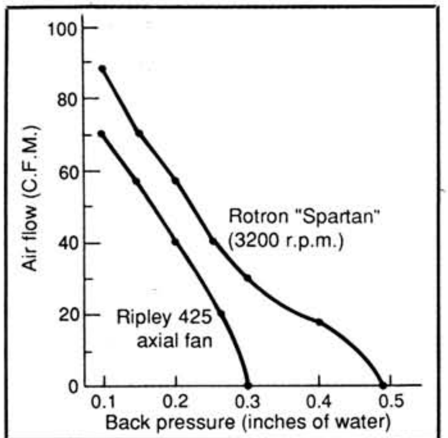


Fig. 3– Plot of small rotary (axial) fan as a function of back pressure and air flow. Rotary fan is satisfactory if air actually reaches filament pins.

self, so what I recount to you is heresay and not guaranteed in any way!

As for me, I prefer to send the tube back to the manufacturer and let him do the job under the right conditions, using the proper tools and techniques. To do this, write to Customer Service Department, Varian-EIMAC, 1678 South Pioneer Road, Salt Lake City, UT 84104 and ask for permission to return the tube for resoldering. When last I checked, this was done at no cost for licensed radio amateurs (be sure to include your callsign in your letter).

Will It Happen Again?

You bet! If a filament pin becomes unsoldered, it is a sure sign tha the tube base is running hot. Contest operation or extended QSOs will build up heat in the tube base that must be removed. Resoldering the pin doesn't cure the basic problem, which is too little cooling air.

Proper base cooling is a complex problem. One doesn't just mount a surplus fan or blower of unknown characteristics in the vicinity of the tube and hope for the best. The capability of the fan or blower, the air path, and the duty-cycle of tube operation must be taken into account. In addition, if the operator lives above sea level, the air is thinner and more air must be passed over the tube to do the job. The wise amplifier builder imagines he always works in a DX contest, lives in mile-high Denver, Colorado, and builds his air system accordingly!

If you experience base heating, the logical step is to improve the air flow. Make sure that SWR meters, rotor control boxes, books, or other objects placed atop or beside the amplifier don't impede air flow. Check your filament voltage. If you suspect your blower or fan isn't big enough to do the job, install a bigger one. And don't let your buddy down the street talk you into placing a smaller fan or blower on your amplifier in order to reduce blower noise! Buy ear-muffs instead!

What About Commercially-Built Amplifiers?

As far as I know, no equipment reviews check out the amplifier air system, or run the equipment under tough operating conditions to check tube seal heating. The use of temperature-sensitive paint or decals on the tube seals can quickly provide temperature information. I suggest that future equipment reviews cover this important subject.

I know of no particular commercially-built amplifier that has a history of socket/base overheating. The problem seems to occur in isolated cases among many brands. More investigation into this problem is required. I suspect it may not be the fault of amplifier design, although it is logical to suppose that temperature tolerance level varies from design to design, and possibly varies between individual amplifiers of the same design.

As I have said, the mode of operation and operator usage can make tube temperature vary between wide limits. If you have experienced pin problems, ask yourself these questions:

- Do I run my filament voltage at or slightly below the nominal value?
- Do I operate for long periods with a lot of speech compression?
- Do I carefully retune my amplifier for proper loading when I change bands, or frequencies within a band?
- Do I take care not to overdrive my amplifier tubes?
- Do I regularly oil my blower or fan and clean the air passages of the amplifier?
- Do I examine the socket pins at intervals for signs of overheating?
- Finally, do I know the characteristics and air-flow capability of my cooling fan or blower? Is it big enough to do the job?

Good luck and may the (air) force be with you!

The Dead Band Quiz

I'm pleased to see so much interest in these little brain teasers. Thank you for your comments. Now to catch up to date, the January quiz concerned a quote "Love to Ann, mind." This remark was made to George Smiley by Roddy Martindale in the TV-movie *Tinker, Tailor, Soldier, Spy.* Additional readers who wrote to me about it include Nels, WØPEC; Quentin, N5ROE; Ed, WB2EAV; and Alp, VE6ALP. Many thanks for your kind remarks!

The February quiz concerned the remark made by Richard Blaine (Rick) about Ilsa Lund Lazlo. The movie was *Casablanca* starring Humphrey Bogart, Ingrid Bergman, Peter Lorre, and Paul Henried.

Lew, K4VX, wraps it all up: "During a trip to Casablanca during World War II, I was sitting in Rick's Cafe American sipping a champagne cocktail when who should walk in but Victor Lazslo and his wife, Ilsa. Although one's memory fades as time goes by, she was such an astonishing beauty that even in that gin joint I can still recall the electricity she generated walking by my table. Sam, the piano player, even missed a beat as I recall. I had hopes that would be the beginning of a beautiful friendship, but those things never work out, even in the movies!"

Congratulations, Lew!

I have rounded up the usual suspects. They are: Marvin, W2AH; Howard, KA1UOK; Dan, WA4JTI; Agnes, N4VPN; Fred, AA4NG; Arnold, W7ZT; Jim, AA4UA; and Geoff, WB5MTV. Congratulations to all!

Footnotes

1. "Hints and Kinks," *QST*, February 1991, pp. 37–38.
2. Temperature-sensitive paint and decals are made by the Tempil Division, Big Three Industrial Gas and Equipment Co., Hamilton Blvd., So. Plainfield, New Jersey 07080.
3. Ripley Type 3, Model 8453. Ripley Co., Middletown, Connecticut. Use Dayton 4C-012 (3 inch, 3340 RPM) for ceramic sockets.