**Notes by SM5BSZ**
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The information on this page is based on my own very limited experience and on information from a few other sources. This page was initiated by SM6EHY, who kindly pointed out to me that this highly relevant information to the experimenting amateur was missing.

As amateurs, we often use old tubes. They may be unused, but may have spent a very long time stored away. A high power tube should work at very high voltages without arcing so it has to have a very good vacuum. When the tube is stored, vacuum gradually deteriorates over time and the procedures below will help to restore a good vacuum.

Part of the procedures may be unnecessary, or misinterpreted by me. I have tried to explain what I believe the different procedures are intended to do and why, but if you have better information please send an E-mail so I can make corrections.

### The cathode

The cathode is the "heart" of the tube. There are several types of cathodes, and they have different properties. Read in the manufacturers data book how to treat the cathode of the tube you are going to use.

A pure tungsten cathode will give maximum tube life if the heater voltage is made as low as possible for the desired output power, while a thoriated tungsten cathode may be damaged if it is underheated.

For QBL5/3500, the PHILIPS handbook (1968) says: Maximum life is obtained when the heater voltage is held within 1% of the nominal 6.3 volts (measure directly on the tube pins). Temporary deviations from the nominal value must not exceed 5%.

When the heater is switched on for the first time, it may be important to allow it to reach its final temperature slowly. I have been told that a slow heating, raising the voltage from zero to nominal gradually, over a time of several hours, will increase tube life considerably in normal professional operation. I guess this has something to do with a rechrystalisation that takes place when the heater wire is heated for the first time, but I do not really know.

### The vacuum pump

Maintaining a good vacuum is a fundamental problem in vacuum tube technology. Some atoms of various kinds, such as nitrogen, carbon, oxygen and hydrogen may be dissolved in the metals or other materials from which the tube is built. These atoms gradually leak out and form molecules that make a very thin gas inside the tube. When the pressure of this gas becomes high enough, the gas may become ionised and form a short circuit from the anode to the nearest electrode that will be the outermost grid. If the power supply contains a big capacitor, and there is no current limiting resistor, the tube may become destroyed by a single discharge. Even with reasonable protection, a discharge is likely to release more gasses and make further arcing more likely.

In order to remove the gas from inside the tube, the tube is equipped with a vacuum pump. A getter is a surface made from some particularly reactive metal like barium. In a small glass tube, the getter is the shiny surface on the inside of the glass wall. It is very reactive, and will react with more or less any molecule that hits the surface, and form a non-volatile reaction product. If there is a leak in the tube, this surface becomes white.

In a big power tube the pumping may be arranged differently. I do not know how, but as I understand it, the pumping does not work unless the tube is heated. Maybe the gas is bound by chemical reactions that occur at high temperatures only, or the pumping is obtained by acceleration into the metal of ions produced by ionisation of the gas molecules.

In any case, the tube should be brought into operation slowly, and the bigger the tube is, the more important it is.

### Reconditioning of a tube, SM6EYH style

1. Apply the heater voltage, but no other voltages. You will probably have to start the fan to avoid overheating. Leave the tube with heater only for 1 hour.

2. Connect the anode through a 50 to 100 kiloohm resistor. Leave the tube with the plate voltage through this resistor for 2 hours. If the tube has been unused several years, leave it for 24 hours.

3. Now the vacuum is improved, and you can replace the 50 to 100 k ohm resistor by 1 k ohm and apply the screen grid voltage. Start with a reduced screen grid voltage for half an hour and then apply full voltage and wait for half an hour again. In both cases, the control grid voltage should be adjusted for negligible plate current.

4. Now it is time to remove the plate resistor and start to use the tube with some RF.

### Reconditioning of a tube, ON4ADN style

1. Apply full heater voltage for 24 hours with no other voltages applied.

2. Apply 33% of the normal plate voltage and adjust the control grid and/or screen grid voltages for the plate current to become about 5% of the nominal current at full power output. Run the tube like this for at least one hour. Be careful to place a fuse rated no higher than twice this current in the anode supply line. Make sure you use a fuse capable of breaking the current at the high voltage. It may be a good idea to use a fuse on the primary side of the mains transformer instead. During this step it is a good idea to disconnect large filtering capacitors from the high voltage supply since arcing will discharge capacitors and dispose all their energy into the tube. If you leave capacitors in the power supply, add a safety resistor for the anode current. This resistor should be in the range 10 to 100 ohms and it should be capable of withstanding a short pulse of 66% of the full plate voltage. Find a big wire-wound resistor with a reasonable separation between the turns.

3. Increase the plate voltage to 66% of the full voltage and adjust grid voltage(s). for the same current as in step 2 while protecting for arcing as in step2. Run for at least one hour.

4. Increase the plate voltage to the full value and set the current as in step 2 with the same protection.

5. remove the small fuse and run the amplifier with 50% of full output power for several hours.

**Other alternatives**

If you have a variable mains transformer, or other means to run the tube at reduced voltages, you may simply start to use the tube at drastically reduced voltages. Reduce both anode and screen voltages in proportion and start very low, something like 25% of full voltages (and 0.25 squared = 6% power output.

Run the tube like this for several hours (local FM QSO's) and then increase the voltage in steps of 5% of nominal voltage, each time allowing the tube to run with full RF output for several hours at each new voltage level.

When you have reached 80% of nominal voltage it may be wise to allow even more operation time between each voltage step.

The maximum plate voltage for a tube in amateur service is well above the maximum voltage stated for professional use in class AB(SSB) or class C(FM/CW). Look for the maximum plate voltage in class C, anode and screen grid modulation. The plate voltage at the modulation peaks in this mode of operation is twice the given values. Not even an amateur should apply quite that much voltage, but somewhere 50 to 75% of the extra voltage can be used.

As an example, 4CX250B is rated 2000 volts, but with anode and screen modulation it is rated 1500 volts (allowing peaks up to 3000 volts) In amateur service this tube works fine at 2500 volts, but going much above that level may easily cause arcing and destroy the tube.

**Notes by ND2X**
*Contact nd2x via arrl.net*

### THE PROBLEM:

After I had obtained a few surplus Russian tubes from Dr Alex, UR4LL he sent me an e-mail entitled "Starting Procedure". The subject of this message certainly piqued my curiosity! As I read it, I realized I had forgotten a very important aspect of using tubes which have spent a significant amount of time, often years, "on the shelf" awaiting use! Due to the nature of physical materials, a certain amount of gases are always trapped inside the metals and ceramics, etc., used to construct each tube. A vacuum tube depends on a relatively hard vacuum to function without arcs and other undesired, often disasterously destructive, internal current flow. While in storage, a certain amount of the gases trapped in its materials is "leached" out into the vacuum of the tube. If one were to plug such a tube into an amplifier and apply all voltages and drive, the small amount of gas within the tube would ionize and provide said undesired internal conductive paths; such conduction often reduces an otherwise useful tube to trash. It is, however, possible to prevent these events from occurring by taking some rather simple measures to prepare such tubes for use!

### THE SOLUTION:

Fortunately, tube manufacturers considered this situation, and inside each vacuum tube is a metal surface called a "getter" - a surface made from some particularly reactive metal like barium. Being very reactive, it will react with more or less any molecule that hits its surface, and form a non-volatile reaction product. In a small glass tube, the getter is the shiny surface on the inside of the glass wall. The trick is to get the atoms of gas to move around enough to strike the getter and become absorbed. This is what UR4LL's e-mail addressed. I also did some reading on the internet and found an applicable Technical Bulletin from Svetlana and a very nice treatise by ,SM5BSZ including input from SM6EHY, which put it all in perspective. I include three excerpts from SM5BSZ:

> "As amateurs, we often use old tubes. They may be unused, but may have spent a very long time stored away. A high power tube should work at very high voltages without arcing so it has to have a very good vacuum. When the tube is stored, vacuum gradually deteriorates over time and the procedures below will help to restore a good vacuum.
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> The cathode is the "heart" of the tube. There are several types of cathodes, and they have different properties. Read in the manufacturers data book how to treat the cathode of the tube you are going to use. A pure tungsten cathode will give maximum tube life if the heater voltage is made as low as possible for the desired output power, while a thoriated tungsten cathode may be damaged if it is underheated.
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> When the heater is switched on for the first time, it may be important to allow it to reach its final temperature slowly. I have been told that a slow heating, raising the voltage from zero to nominal gradually, over a time of several hours, will increase tube life considerably in normal professional operation. I guess this has something to do with a rechrystalisation that takes place when the heater wire is heated for the first time, but I do not really know."

**PREPARING SURPLUS TUBES FOR USE**

From UR4LL:

1. Only Ufil during 12 hours min.
2. To ground all grids.
3. 25% of Ua during 4 hours.
4. 50% of Ua during 4 hours.
5. 100% of Ua during 4 hours.

COMMENTS: We have found that some of the larger tubes do a lot better if we bring filament voltage up, either over a period of a minute or so using a variac, or using the procedure in "Step 1", below, and leave the power on in this manner (with cooling fan on or liquid coolant flowing) for three to five days. We have found, for example, that GS-23B operation can be SIGNIFICANTLY enhanced, especially for those which work at 23cm, by a minimum of five (5) days with the filament on as described!

Subject to adjustments as outlined above, the steps shown below (prepared 16 June 2000) will change as further experience dictates:

Step 1: Per SM5BSZ, I'm going to bring the filament voltage (Ufil) up slowly; probably 20% Ufil for the 1st hour, 40% during the 2nd hour, 60% in the 3rd hour, 80% for the 4th hour and, finally, apply 100% Ufil after four hours, leaving it applied until 12 hours has elapsed. I will turn the forced air cooling on at the start of the second hour.

Steps 2 & 3: I have a variac on the input to my HV supply and will vary the plate voltage (Ua, or anode voltage) as required to obtain the specified percentage for the specified period. If you don't have a means to vary your HV, SM6EHY says, "Connect the anode through a 50 to 100 kiloohm resistor. Leave the tube with the plate voltage through this resistor for 2 hours. If the tube has been unused several years, leave it for 24 hours." Most of my tubes are from surplus "spares stock" and are several years old. Based on this, I will have to err on the side of too much time at each level, rather than trying to shorten the process in any way! UR4LL says to ground all grids before applying Ua; SM6EHY says nothing about the grids until his equivalent of step 4.

Step 4: Again, I will vary my HV using the power supply variac. SM6EHY suggests, "Now the vacuum is improved, and you can replace the 50 to 100 k ohm resistor by 1 k ohm and apply the screen grid voltage. Start with a reduced screen grid voltage for half an hour and then apply full voltage and wait for half an hour again. In both cases, the control grid voltage should be adjusted for negligible plate current." If I see plate current starting to creep up, I will unground the control grid and apply bias per SM6EHY.

Step 5: I will follow UR4LL's procedure. After step five, he says, "Tube is ready for use." Step five per SM5EHY: "Now it is time to remove the plate resistor and start to use the tube with some RF."

**Notes by YO9FZS**

*Contact yo9fzs via office.deck.ro*

This topic was discussed before and at that time I draw attention about, but seems that few observed this.

On the very first page of the Harris RF-110A amplifier manual is stated:

*"INITIAL START-UP NOTICE*
*The tubes used in the final amplifier stage of the RF-110A Power Amplifier may occasionally liberate minute amounts of gas during prolonged storage, according to the manufacturer. To prevent degradation of performance, it is advisable to run the tubes without high voltages applied following storage periods, to remove any gas from the tubes.*
*Therefore, it is strongly recommended that upon installation of this system, or following any period of three or more months duration without operating the system, that the system be run for at least 30 minutes in the STANDBY mode before going to any operate mode"*

Note the "according to the manufacturer" specification.
Note also that, at least for the millitary, storage for long time is not something unusual (see also the date code for some "surplus" western and russian tubes)...
The RF-110 include two 8122 drivers and two 4CX1500B finals, all indirect heated cathode type tubes.

As I know, the getter is intended to remove the very small amount of gas (i.e. molecules of gas) that may be liberated during the time by the tube's internal structure. So, important amount of gas, like in the case of broken seals or important leakage, may not be eliminated by "formating" the tube and these tubes should be considered out of question (i.e. dead).

Some may notice that for the filament cathode (i.e. thoriated tungsten) glass envelope tubes the getter (if any) may be located at the anode, so "formating" the tube with filament voltage only may not help.
For the indirect heated (i.e. oxide) cathodes, the getter is usually located closer to the cathode system so the getter may work with the filament voltage only.

These are confirmed by Joe's experiment.

You may also look to Svetlana Technical Bulletin 54 for some info about.

My conclusion:
I followed the specified procedure (actually let the tubes for few hours with filament on) and did nothing harmfull to the tubes, hi!

Traian

**Notes by G3SEK**

*Contact g3sek via look-in-signature.co.uk*

That all makes very good sense.

I don't believe that these Russian tubes are significantly leaky, in the sense of a faulty seal that lets air in from the outside. More likely they are made from ceramic and metal materials that are less pure than those used in western tubes, and/or they have not been as thoroughly de-gassed during manufacture. Such tubes may pass all the tests at the factory, but over time they very slowly release some of their gas content into the tube envelope.

All "vacuum" tubes actually contain lots of gas molecules. Even a "good" tube contains millions to billions of free gas molecules bouncing around inside the envelope (depending on the size of the tube and the quality of the vacuum). During operation, this gas is continually being removed by the getter, which acts like a 'fly-paper' to which the gas molecules will stick by chemical reaction.

The getter in a receiving tube is the silvery deposit on the glass, and is typically barium metal. It is very chemically reactive and will mop-up gas molecules even at room temperature, but it's too volatile to be usable at the high temperatures of transmitting tubes. Getters for transmitting tubes are made of materials that are less volatile, but also less chemically active, so they need high temperatures to make the 'gettering' reaction go faster. But if the tube just sits in a box and never gets hot, the getter doesn't work at all well.

That is why transmitting tubes can accumulate gas if they are not used, but will often get better again if they are pre-conditioned by a period of pre-heating. (The exception of course is if a seal has actually failed.)

The getter is usually located at the hottest part of the tube. In a ceramic/metal tube, this location is on the cathode, which is why heater-only operation is enough make the getter work - as Joe and many others have found. In a glass transmitting tube, the getter is usually on the anode, so it needs HV and anode current (anode dissipation) to make the getter hot enough to work - but not too much HV, or else the tube may arc.

At extremely high temperatures, higher than the tube will ever reach in service, the chemical reaction will reverse and the getter is forced to release the gas it has trapped. When the tube is being manufactured, it is deliberately heated to such extreme temperatures while the tube is still being externally pumped. Once the tube is sealed, the getter is then responsible for maintaining the quality of the vacuum for the rest of the tube's life.

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73 from Ian G3SEK 'In Practice' columnist for RadCom (RSGB)
Editor, 'The VHF/UHF DX Book'