Long Life for Your Transmitting Tubes

Here are some "housekeeping" rules that will help you achieve maximum tube life.

By William I. Orr,* W6SAI

Transmitting tubes represent a significant proportion of the money a radio amateur spends for his or her station, so it's prudent to reduce the cost-per-hour of operation by getting longer life from the tubes. Abuse of the power tube can be costly. Common sense tells the user to operate the tube in the manner recommended by the manufacturer. This article provides some insight into tube operation and provides information that will allow the operator to gain the maximum life from power tubes.

A data sheet covering operation of a specific tube type is available from the manufacturer.[1] It outlines the maximum ratings and provides typical operating conditions for the tube. Maximum ratings must never be exceeded, but some latitude exists in the typical operating conditions. The data sheet is a good starting point in the search for long tube life.

What is the Life of a Power Tube?

If a large number of power tubes of a given type are run in a life test, tube "death" will follow the same mortality curve as that used by insurance companies to determine policy rates. Thus, while it is impossible to determine when a particular tube will fail, it *is* possible to ascertain the *average* life of a number of tubes, which can be extended by proper care. The situation is akin to the Old-Timer who, after taking a physical examination, told the doctor, "If I knew I was going to live this long, I would have taken better care of myself!"

All things being equal, the better care an operator takes of a power tube, the longer it will last. It is possible to extend the life expectancy of an individual tube, just as clean living will help to extend *my* life expectancy (or so I have been told!).

Well-designed power tubes are very forgiving of abuse — more forgiving, for example, than TV type "sweep tubes" or rf power transistors. Nevertheless, the ultimate life of a particular power tube in a given piece of equipment depends on the care and expertise of the operator. Even in the best equipment, tube life can be shortened by the operator who believes in "all knobs to the right!" Tube life can be curtailed by the operator who does not read the instruction manual and doesn't know how to operate equipment properly. Heat is the enemy of long tube life, and an amplifier operated in an off-tune or overloaded condition can quickly damage the power tubes therein.

Filament-Voltage Management of Thoriated-Tungsten Tubes

Certain tubes, such as the 3-500Z, 4-1000A and others have a thoriated-tungsten filament. The filament is processed and heated in the presence of a hydrocarbon to produce ditungsten carbide on the surface of the wire. Life is proportional to the degree of carburization and the filament operating tempera-

[1]Information on most EIMAC tubes and other products may be obtained by writing: Application Engineering Department, Varian/EIMAC, 301 Industrial Way, San Carlos, CA 94070. Data sheets for the 3-400Z, 3-500Z, 3-1000Z and 8877 tubes may be obtained from Varian/EIMAC, 1678 South Pioneer Rd., Salt Lake City, UT 84104.

* c/o Varian/EIMAC, San Carlos, CA 94070

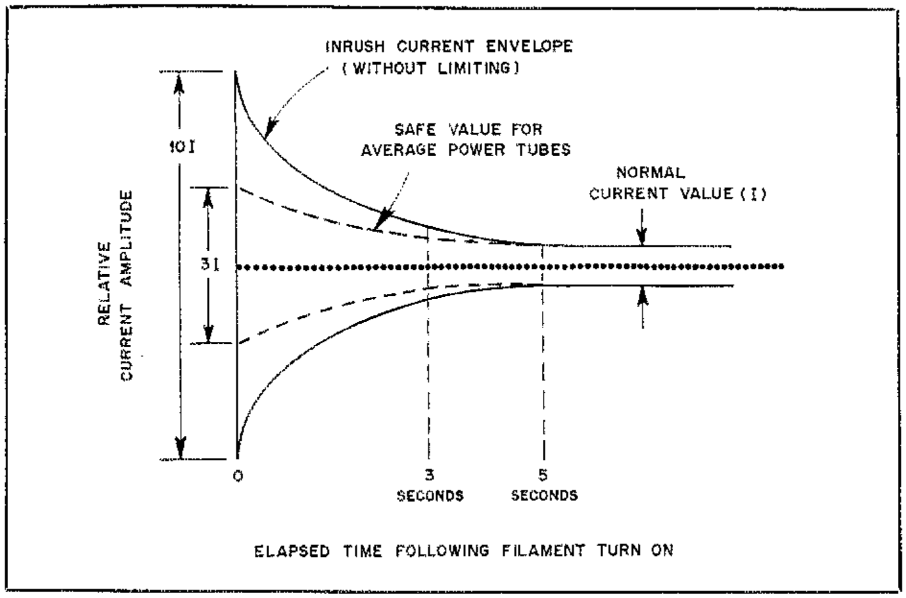

Fig. 1 — Graphic representation of filament inrush current. With no protection, filament inrush current may be as high as 10 times the normal value, for up to 5-seconds' duration (with tubes of the amateur power level). Most tubes are easily capable of withstanding three times the normal filament current; this is a good limiting value. Amateur type tubes can be run at 60% of nominal filament voltage for two to three seconds, after which the voltage is raised to nominal value. Filament voltage may also be brought up to nominal value by means of a variable-voltage transformer.

Table 1

Suggested Primary-Circuit Resistor for Limiting Filament Inrush Current

Tube Type	*Time Delay (Sec.)*	*Resistor*
3-500Z, 4-400A	2	50 Ω, 50 W
2 × 3-400Z, 2 × 3-500Z, 4-1000A	2	25 Ω, 50 W
8873/4/5, 4CX250B	4	150 Ω, 50 W
2 × 8873/4/5, 2 × 4CX250B	4	75 Ω, 50 W
8877, 4CX1000A	4	75 Ω, 50 W

ture. As the tube is used, the filament slowly decarburizes and finally is no longer an effective electron emitter.

The key to extending the life of a thoriated-tungsten filament is temperature control, which is a function of filament voltage. For most power tubes a nominal value is given on the data sheet, plus recommended variation limits (usually ±5% of the nominal voltage). The danger of operating the filament in excess of the high limit is that when electron emission is accelerated, the filament decarburizes more rapidly and life is shortened. The danger of operating beyond the lower limit is that a "cool" filament is in danger of being "poisoned" by gas ions in the tube (no vacuum is perfect), or by contaminants forced out of the other tube elements. These can be released during a period of high-temperature operation brought on by an overload.

Operation of the filament within the ±5% voltage range cannot be done without an accurate filament voltmeter. If your amplifier has such an instrument, its accuracy should be checked. If no internal meter is present, the filament voltage can be checked with an external instrument, and a correlation made between line voltage and filament voltage. Once this is done, it is only necessary to check the line voltage to know the filament voltage. Holding the filament voltage within the recommended range will pay big dividends in extended tube life!

Filament Voltage Management of Oxide-Cathode Tubes

Some smaller transmitting tubes, such as those in the 4CX250 family, the 8873/4/5 and the 8877 employ an indirectly heated cathode emitter instead of a thoriated-tungsten filament. The cathode is coated with a barium-strontium emitter that is brought up to temperature by a heater located within the cathode can. These tubes require a period of time for the cathode to reach operating temperature, and potential should never be applied to the tube until the cathode temperature is stabilized. Warm-up time is noted on the data sheet for each tube type.

As with the filament type tube, it is important to hold the heater of the oxide-cathode tube within the voltage limits set by the manufacturer. In the majority of cases, it is ±5%. Exceeding the recommended heater voltage in these tubes will tend to reduce tube life, and falling short of it will severely restrict electron emission.

Filament Inrush Current Protection

As in the case of the common light bulb, the filament or heater of a cold power tube has about one-tenth the resistance of a hot filament. Thus, at the instant of turn-on, inrush current can be up to 10 times the normal amount, until filament temperature rises to the proper value (Fig. 1). This large current surge overloads the filament structure and also creates a strong magnetic field. This field *can warp the filament and grid structures* in a very large power tube! Filament inrush current can be limited to some extent by the filament transformer, which should never be larger than necessary to do the job.

Simple inrush current protection circuits are shown in Fig. 2. Any of these may be retrofitted into an amplifier. A variable-voltage transformer (Fig. 2A) in the primary circuit is a practical solution. Before the amplifier is turned on, the transformer is set at zero volts. Next, the amplifier is turned on and the filament voltage is brought up to normal. This simple operation need only take two to four seconds. With practice, the operation will almost become automatic.

Another effective inrush current protector is shown in Fig. 2B. A series-connected current limiting resistor is placed in the primary circuit of the filament transformer, or in the ac line. Once the power switch is thrown, the resistor is shorted out after two to four seconds. A time-delay relay or simple shorting switch may be used. The resistor should limit the filament voltage to about 70% of the nominal value (Table 1).

Simpler yet is a shorting type (make-before-break) rotary switch, connected as shown in Fig. 2C. In switch position 1, filament voltage is off. In position 2, voltage is applied through the limiting resistor. In position 3, full voltage is applied to the filament transformer. Passing through all the switch positions takes only a few seconds.

Line Voltage Regulation

A vexing problem to many radio amateurs is primary line voltage regulation. Line voltage can wander about during a 24-hour period, and may drop abruptly when a moderate load comes on the line. Unless the line is "stiff" and can withstand the full amplifier load, filament voltage will drop under peak input power conditions. This places a strain on the power tube filament, as voltage is lowest

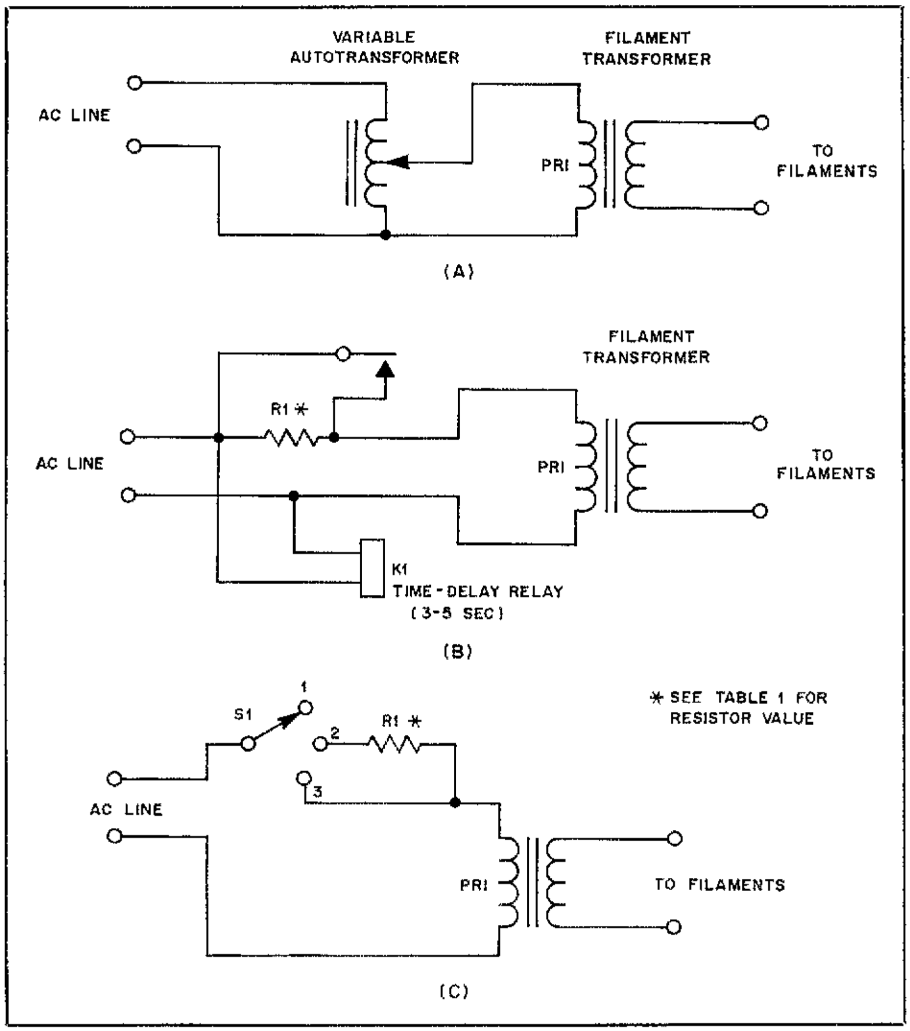

Fig. 2 — A variable-voltage transformer is used to bring the filament voltage up to nominal value over a period of two to three seconds (A). At B, series-connected resistor R1 is shorted out by time-delay relay K1 or a hand-operated switch. In circuit C, make-before-break rotary switch S1 is used to turn on the filament transformer. Switch position 2 introduces the current-limiting resistor.

when electron demand is highest.

On the other hand, filament voltage can rise during periods of low primary power utilization. Line-voltage fluctuations of 10 V or more are common; this is equivalent to a 0.4-V variation on a 5-V filament line powered from a 117-V primary transformer.

When voltage regulation is a problem, it is wise to set nominal filament voltage in the key-up (standby) condition, and permit less than a 5% drop in voltage at maximum power output. This can best be achieved by operating the amplifier on a 234-V line, as opposed to a 117-V line. When long-term voltage variations are pronounced, the only practical solution is to utilize a primary voltage control device, such as a rheostat or variable-voltage transformer, and maintain an "eyeball" check on the filament voltmeter.

Cooling

A high-power amplifier generates plenty of heat. Sources of this are the tube filament, plate and ohmic losses in the amplifier circuitry. Most amateur amplifiers of the 2-kW-PEP class incorporate a ventilation system to move the hot air out of the cabinet. The operator should make sure this system is in proper order and that air intake and exhaust vents are clear to allow free passage of air. Don't place books or pieces of equipment atop an amplifier if the air passes through this part of the cabinet. And don't push the amplifier back against the wall if the air intake is on the rear of the cabinet. Always allow free circulation of air around the amplifier. While manufacturers have been able to miniaturize equipment, nobody has been able to miniaturize the watt. The smaller the cabinet for a given size power amplifier, the more important it is to extract the heat from it. Make sure your equipment runs cool by providing the tubes with an unimpeded flow of cooling air. In a hot climate, or at an elevated altitude (Denver, for example), an additional cooling fan that forces air *into* the amplifier cabinet may help.

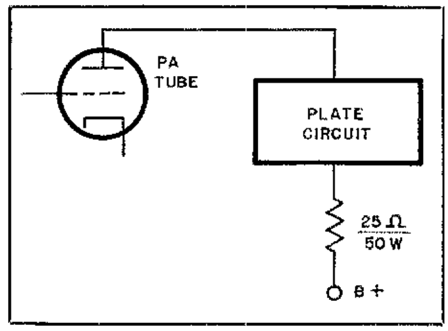

Fig. 3 — A series resistor in the B+ lead protects the tube and related components in the event of a flashover.

Arc Protection

It is possible for a power tube to internally flash over after a period of disuse. Similarly, other components in the plate circuit of an amplifier can flash over on occasion. Since the power supplies in many modern amplifiers use a large filter capacitor, a tremendous amount of energy can pass through a flashover, damaging the tube and associated equipment. A series resistor will dissipate a large portion of this energy, and can be placed in the plate lead to the power tube (Fig. 3). For retrofitting existing equipment, a 25-Ω, 50-W resistor in the B+ lead, *after* the power supply filter capacitor and before the plate rf choke and bypass capacitor, should do the job.

Finally, make sure that the socket contacts for your power tube are clean and make good contact with the tube pins. Also, check that the cooling system is clear of dust and lint. These simple "housekeeping" rules will help you achieve maximum tube life!

Acknowledgments

Thanks to William Barkley, Dick Rasor, W6EDE, William Sain, Bob Tornoe and Bob Sutherland, W6PO (all of Varian/EIMAC) for their help. Also thanks to Robert Artigo, KN6J, formerly of Varian/EIMAC, who prepared a paper on extended tube life for *Broadcast Management/Engineering Magazine* (April 1982). Some of this material has been extracted from that article.

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