

EXTENDING TRANSMITTER TUBE LIFE

CPI Microwave Power Products Eimac Operation APPLICATION BULLETIN no. 18 revised Sept. 2010

A carefully followed program of filament voltage management can substantially increase the life expectancy of transmitter power grid tubes. With today's rising operating costs, such a program makes good financial sense.

One way to offset higher transmitter operating costs is to prolong tube life. For years station engineers have used various tricks to get longer operating life, with greater and lesser degrees of success. Success can be maximized, however, by understanding the various factors that affect tube life and then implementing a program of filament voltage management.

A few important factors that can aid in obtaining maximum tube life for your transmitter:

- Don't exceed the manufacturer's data sheet maximum ratings. Data sheets are available upon request from Eimac.
- Consult with Eimac's Application Engineering Department to assist in evaluating tube performance for a given application.
- Allow some headroom for the final power output tube so that the transmitter is capable of delivering power in excess of the desired operating level, without exceeding rated nominal filament voltage.

Figure 1 can be used as a basic guide to determine if a given transmitter and tube combination has a good probability of giving extended life service. Extended life service is defined as useful operating life beyond that normally achieved by operating at rated nominal filament voltage. The amperes/watt ratio is obtained by dividing average anode current by the product of filament voltage and filament current. If the amperes/watt ratio falls in the "good" to "excellent" range, excess emission is sufficient to permit filament voltage derating. At a lower filament voltage, the filament temperature is lowered, thus extending life. A typical FM transmitter on the market today may have an amperes/watt filament ratio of 0.002 to 0.003. This equipment would be considered an excellent choice to achieve extended tube life. On the other hand, if the amperes/watt ratio falls in the "poor" range, it is unlikely that filament derating is possible due to limited emission. Note that this guideline should be used for thoriated tungsten emitters only and **does not apply to oxide cathode-type tubes.**

Instrumentation

Are all tube elements metered in the transmitter?

Elements should be metered for both voltage and current, and meters should be red-lined to define operation within safe limits. Modern transmitters may incorporate a microprocessor-controlled circuit to monitor all pertinent parameters.

In addition, the following controls are necessary if effective filament voltage management is to be undertaken:

- Power output metering for an FM transmitter or a distortion level meter for AM equipment
- *Accurate* filament voltage metering; an iron-vane instrument is preferred over the more common average responding RMS calibrated type but true-RMS digital meters are acceptable.
- The filament voltage measurement must be made at the tube socket terminals and filament voltage control should be capable of being adjusted in 0.1 V increments.



- A filament current meter – desirable but optional.

A means must be provided to hold filament voltage constant. If the filament voltage is permitted to vary in accordance with primary line voltage fluctuations, the effect on tube life can be devastating. One acceptable solution is to use a ferroresonant transformer or a line voltage regulator. These accessories are offered by some transmitter manufacturers as an option and should be seriously considered if a tube life extension program is planned.

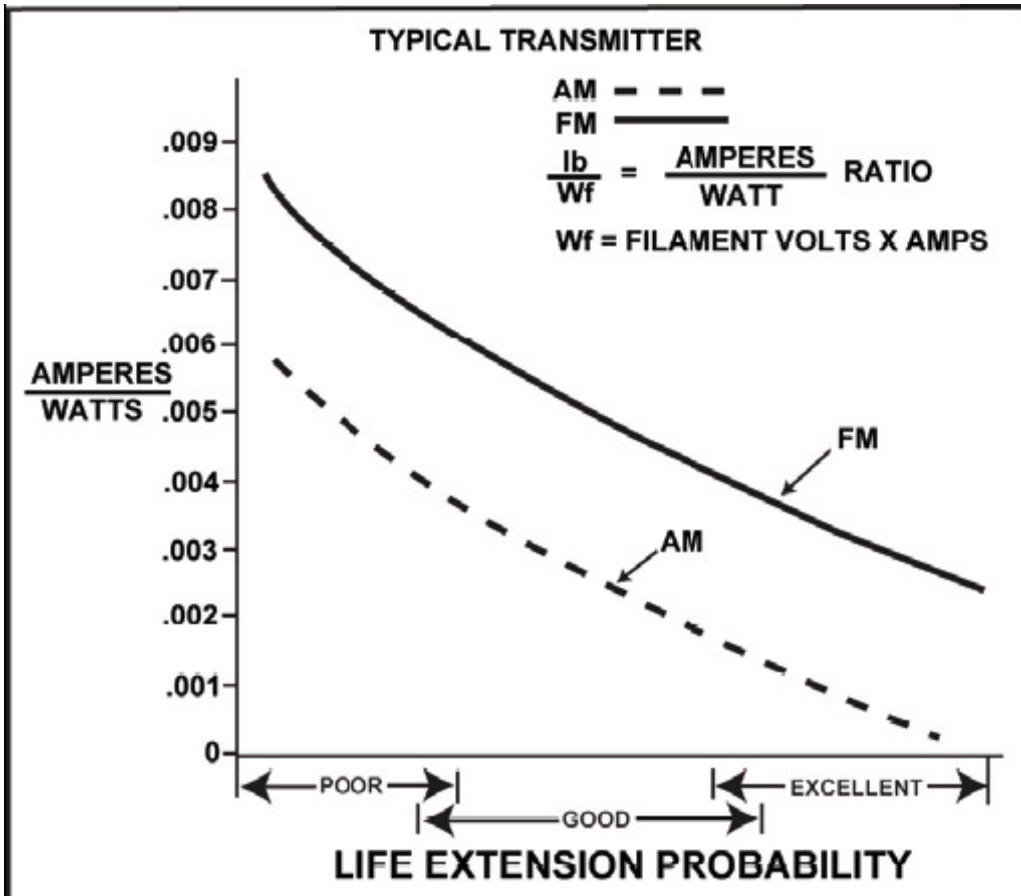


Figure 1. The probability of extended life service can be determined from this graph. Divide the average anode current in amperes by the product of filament voltage and current. The resulting amperes/watt ratio is projected horizontally to the appropriate curve. The vertical projection to the X-axis indicates the life extension probability.

Transmitter Housekeeping

Once the transmitter has been placed in operation, tube life is in the hands of the chief engineer. The first action to prolong tube life falls into the category of routine maintenance. Most transmitter manufacturers have a routine maintenance schedule established in the equipment manual. This procedure must be followed carefully if operating costs are to be held to a minimum. During routine maintenance it is very important to watch for tube and/or socket discoloration, either of which can indicate overheating. Look for discoloration around the top of the cooler near the anode core and at the bottom of the tube stem where the filament contacts are made. Review Figures 2, 3, 4 and 6 for examples of a tubes operating with inadequate cooling. It is possible for

discoloration to appear in the areas mentioned if the transmitter has to operate in a dirty environment. If this is the case, the tube should be removed and cleaned with a mild detergent. After cleaning, the tube should be rinsed thoroughly to remove any detergent residue and blown dry with compressed air. If the discoloration remains, this is an indication that the tube has operated at too high a temperature. Check inlet and outlet air ducting and filters for possible air restriction. It may also be necessary to verify that the air blower is large enough to do the job and that it is operating at rated capacity.

With the tube removed, the socket should be blown or wiped clean and carefully inspected. Any discoloration in the socket finger stock caused by overheating could contribute to early tube failure. Finger stock that loses its temper through prolonged high temperature operation will no longer make adequate contact with the tube elements (Figure 7). A well-maintained socket will score the tube contacts when the tube is inserted. If all fingers are not making contact, more current flows through fewer contacting fingers, causing additional overheating and possible burn-through of contact rings.

Filament Voltage Management

The useful operating life of a thoriated tungsten emitter can vary widely with filament voltage. Figure 8 describes the relative life expectancy with various filament voltage levels. Obviously, a well-managed filament voltage program will result in longer life expectancy. Improper management, on the other hand, can be very costly. For a better understanding of this sensitive aging mechanism, the filament itself must be understood. Most filaments in high-power, power grid tubes are a mixture of tungsten and thoria with a chemical composition of W + ThO₂. Filaments made of this wire are not suitable electron emitters for extended life applications until they are processed. Once the filament is formed into the desired shape and mounted, it is heated to approximately 2100°C in the presence of a hydrocarbon. The resulting thermochemical reaction forms di-tungsten carbide on the filament's surface. Life is proportional to the degree of carburization. If the filament is overcarburized, however, it will be brittle and easily broken during handling and transporting. Therefore, only approximately 25% of the cross-sectional area of the wire is converted to di-tungsten carbide. Di-tungsten carbide has a higher resistance than tungsten; thus, the reaction can be carefully monitored by observing the reduction in filament current as the carburizing process proceeds. As the tube is used, the filament slowly decarburizes. At some point in the filament's life, all of the di-tungsten carbide layer is depleted and the reduction of thoria to free thorium stops. The filament is now decarburized and can no longer be an effective electron emitter. The key to extending the life of a thoriated tungsten filament emitter is to control operating temperature, which reduces the decarburization rate of the filament. Emitter temperature is a function of the total RMS power applied to the filament. Thus, filament voltage control is temperature control, because temperature varies directly with voltage. As the emitter temperature rises, the de-carburizing process is accelerated and tube life is shortened. Figure 8 shows that useful tube life can vary significantly with only a 5% change in filament voltage.

NOTE: If the filament voltage cannot be regulated to within $\pm 3\%$, the filament should always be operated at the rated nominal voltage specified on the data sheet. It should be noted that there is a danger to operating the emitter too much on the "cold" temperature side. It may become "poisoned." A cold filament acts as a getter; that is, it attracts contaminants. When a contaminant becomes attached to the surface of the emitter, the affected area of the emitter is rendered inactive, causing loss of emission. Should this happen, recovery is possible by operating the filament at full voltage for a period of time. Closely monitored operation of the filament at slightly below the rated nominal voltage, however, can extend tube life, if done properly. Note that these filament management techniques should not be applied to oxide cathode tubes, such as the 3CX1500A7/8877. Running oxide cathodes too cold will result in internal arcs and once that happens an oxide cathode tube is not recoverable.

Of equally great importance to long tube life is the temperature of the other tube elements and of the ceramic-to-metal seals. Element temperatures can be held within proper limits by observing the maximum dissipation ratings listed in the tube's data sheet. Tube seal temperatures should



be limited to 200°C at the lower anode seal under worst-case operating conditions. As tube element temperatures rise beyond 200°C, the release of contaminants locked in the materials used in manufacturing increase rapidly. These contaminants cause rapid depletion of the tungsten carbide layer



Figure 2. Improper cooling means short life. Discoloration of metal around the anode fins (left) indicates poor cooling or improper operation of the tube. A properly cooled and operated tube (right) shows no discoloration after many hours of use (note that some tarnishing of the plating may occur however).



Figure 3 Example of a severely overheated tube. The cooling fins are discolored and badly distorted. This type of overheating will cause premature tube failure.



Figure 4 Water cooled tube with evidence of overheating. Note the severe discoloration in the tube stem. This tube will have a very short lifetime. Base cooling is of equal importance as anode cooling.



Figure 5 This tube shows evidence of being well mounted in a socket for at least a year (note the marks on the contact ring from the finger stock). However, there is no discoloration of the stem and the anode fins have some discoloration (air flow could have been improved somewhat on this tube).



Figure 6 This tube appears to have been operated with low output efficiency (improper tuning or loading) or complete loss of air flow. Note the discolored stem and anode fins. This tube had a very short lifetime.

Eimac Application Bulletin No. 20, "Temperature Measurements of Eimac Power Tubes" describes methods for accurately determining operating temperatures on the base and anode cooler assemblies on power grid tubes. By using the techniques described in this paper, one can determine whether the cooling system in their equipment may be deficient or needs improvement. Occasionally something simple like air filters that have become plugged or a bearing failure in a blower may lead to overheated tubes. An exhaust air temperature measurement device will help spot abnormal temperature rise and prevent damage from overheating.



Figure 7. Bent and broken finger stock. Finger stock may become damaged due to effects of overheating or mishandling. Any broken finger stock must be repaired or replaced immediately to ensure long tube life.

Socket maintenance is an important part of regular transmitter system scheduling. Replacement parts are available for most Eimac sockets but having a spare socket on hand is the best advice for reducing down-time in case a failure occurs.

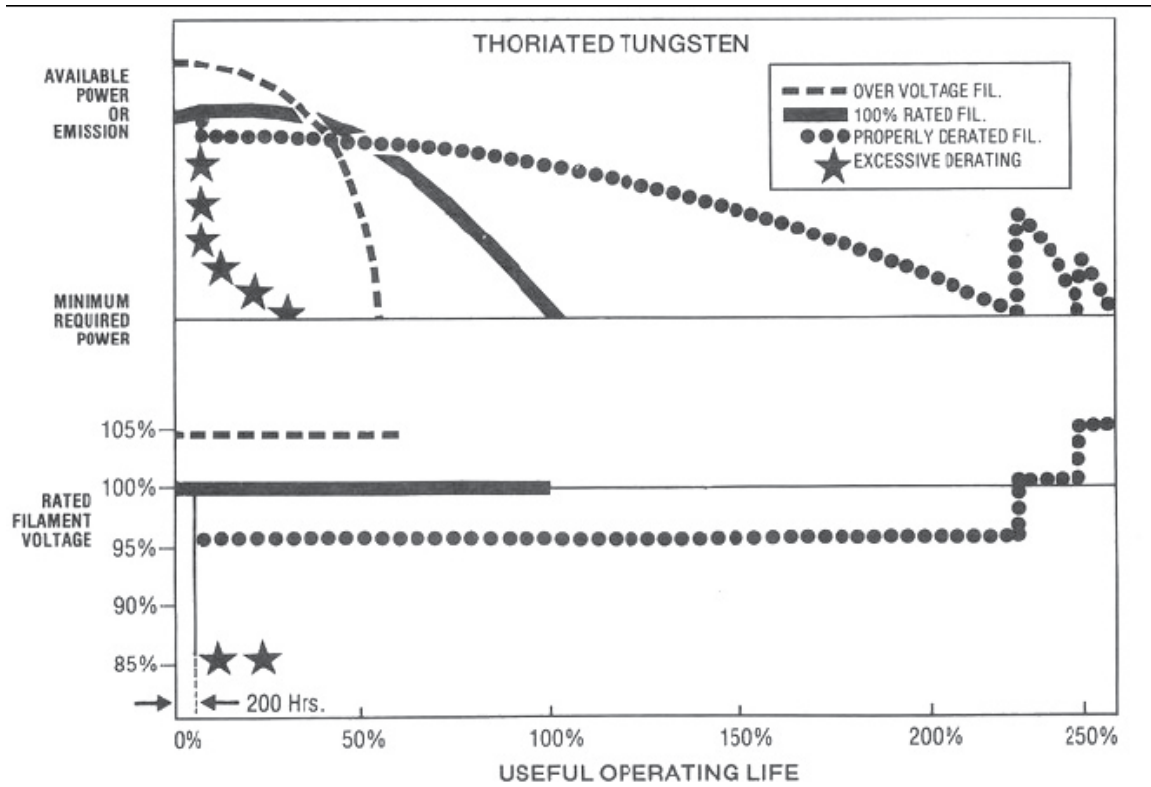


Figure 8 Filament voltage management allows extended tube life when accompanied by a continuing housekeeping program. When filament voltage is too high (dashes), power tube loses emission rapidly and normal operating life is not achieved. When filament is operated at rated voltage (solid curve, normal tube life is achieved in a majority of cases. With a filament voltage management program (bullets), extended tube life may be achieved. When the minimum required output power level is finally reached (right-hand portion of curve), the filament voltage may be raised to rated value, or above, to achieve additional useful operating life. If the filament is run "cool" (stars), extremely short life will result. Note that the filament voltage management program does not take effect until about 200 hours of operating time have passed.

When a noticeable change occurs in the output power or if the distortion level changes, the derating procedure must stop. Obviously, operation at and beyond this point is unwise since there is no margin allowed for a drop in line voltage. The voltage should be raised 0.2V above the critical voltage at which changes are observed to occur. Finally, recheck power output or distortion to see if they are acceptable at the chosen filament voltage level. Recheck again after 24 hours to determine if emission is stable and that the desired performance is maintained. If performance is not repeatable, the derating procedure must be repeated.

Continuing the Program

The filament voltage should be held at the properly de-rated level as long as minimum power or maximum distortion requirements are met. Filament voltage can be raised to reestablish minimum requirements as necessary. This procedure will yield results similar to those shown in the illustration (Figure 8), to achieve as much as 10% to 15% additional life extension. When it becomes necessary to start increasing the filament voltage in order to maintain the same power output, it is time to order a new tube. Filament voltage can be increased as long as the increase results in maintaining minimum level requirements.

However, when a voltage increase fails to result in meeting output level requirements, filament emission must be considered inadequate and the tube should be replaced. Don't discard it or sell it for scrap! Put it on the shelf and save it. It will serve as a good emergency spare and may come in handy some day. Also, in AM transmitters, a low-emission RF amplifier tube can be shifted to modulator use where the peak filament emission requirement is not as severe.

Start planning for longer tube life now! Review the following steps you can take:

- Investigate the manufacturer's ratings on the power tubes in your present equipment, or the transmitter you plan to buy.
 - Check that your transmitter has sufficient headroom. Is there a margin of safety in tube operation?
 - Look for important instrumentation in the next transmitter you buy. Are all tube elements monitored for voltage and current in the transmitter?
 - Whether your transmitter is new or old, start a filament life extension program.
- Remember that each time you replace a power tube, the recommended derating procedure must be rerun. Voltage levels required with one tube do not apply to a replacement tube.

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