RF Technical Note

Determing the Cathode Heater Operating Point On the APS 2856 MHz Klystrons

3/21/06, Revision 0

Prepared by: A. Cours, ASD-RF

This Note outlines the steps involved to determine the cathode emission (or "cathode filament") curve and correct cathode heater operating point on the APS 2856-MHz klystrons. This is a general procedure that will be adequate for most situations.

Periodic checks of cathode emission are necessary to maximize the useable lifetime of a klystron cathode. Excessive cathode heat *(the product of heater voltage and heater current)* will result in premature depletion of the cathode emission surface, and may also result in future dc and rf problems with the klystron due to excessive barium deposition in the gun and first cavity of the klystron. Insufficient cathode heat will hinder cathode emission, and therefore degrade klystron operation at high power levels. Severe cases of insufficient cathode heat could result in dc arcing in the gun area and possible cathode damage.

Unless operational problems preclude it, an annual check of cathode emission is adequate to insure that the cathode heat is set at the correct value. All APS 2856-MHz klystrons are assigned a factory-recommended value for heater power when they are conditioned and tested at the factory prior to delivery. This factory-recommended value of cathode heat power is unique to each klystron, and represents the amount of cathode heat required for the cathode to produce a full-power beam (approximately 295-300 A beam at 275-280 kV for 35-MW klystrons, and 345-350 A beam at 305-310 kV for 45-MW klystrons) at the time the klystron was tested to full rf output power at the factory. This value for heater power is then recorded in the factory acceptance test specifications document that is produced for each klystron, and should be used as a reference operating point for determining the status of the klystron cathode.

For the first 500 to 1000 hours of a klystron's operating lifetime, the cathode heat should be operated at the factory-recommended full-power value regardless of operating conditions. This aids in removing contaminants from the new cathode surface. However, at the end of this initial period, it is best to operate the klystron at cathode heat levels lower than the full-power setting if possible. In most cases, lower cathode heat is acceptable because the klystron is being operated consistently at a lower beam power, and therefore full emission from the cathode is not required. Based on the present typical operating point for the APS 2856-MHz klystrons (260 kV @ 270 A maximum), the

following procedure can be used to determine the correct heater power operating point at L1 through L6.

Note 1: Accurate metering of the heater voltage and current is required to properly determine the cathode heater operating point. In the APS Linac modulators, heater power is applied to the klystron filament through a 7:1 step-down filament auto-transformer (Fig. 1). Heater voltage and current are measured inside the heater power supply connected to the primary side of the filament transformer. Therefore, filament voltage and current values that may be read on the local and remote control screens are approximately 7 times higher (for voltage) or lower (for current) than real levels. Accuracy of the 7-to-1 ratio is having been periodically checked by the RF Group personnel. For determing the cathode heater operating point, the computer screen values of the filament current and voltage may be used.

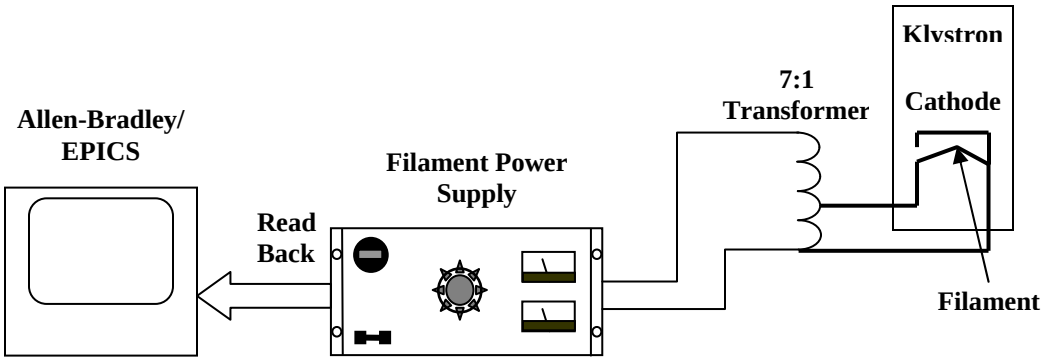


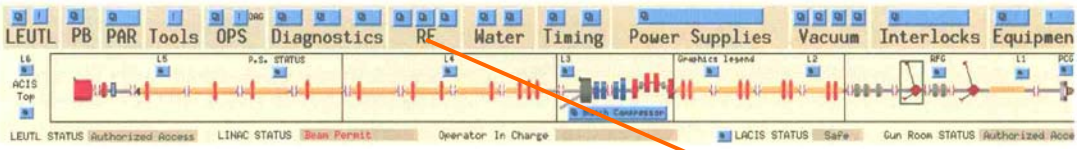
Figure 1. Klystron filament simplified block diagram.

<u>This work does NOT involve electrical safety.</u>

<u>NOTE: File an APS Work Request and have it approved before beginning this work.</u>

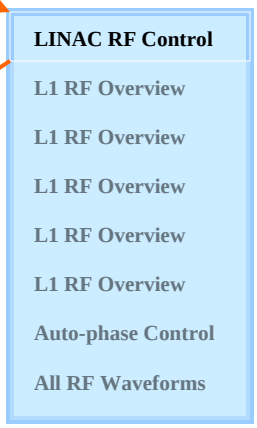
Procedure:

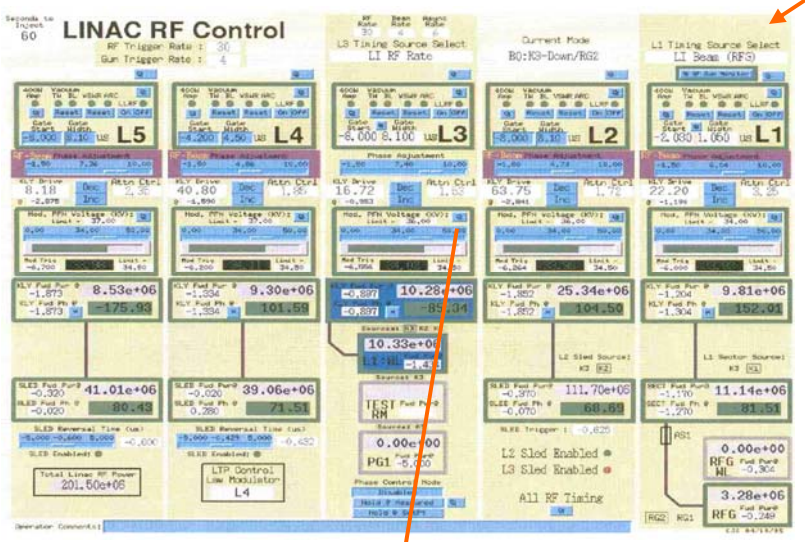
1. Open the EPICS Linac Control screen:



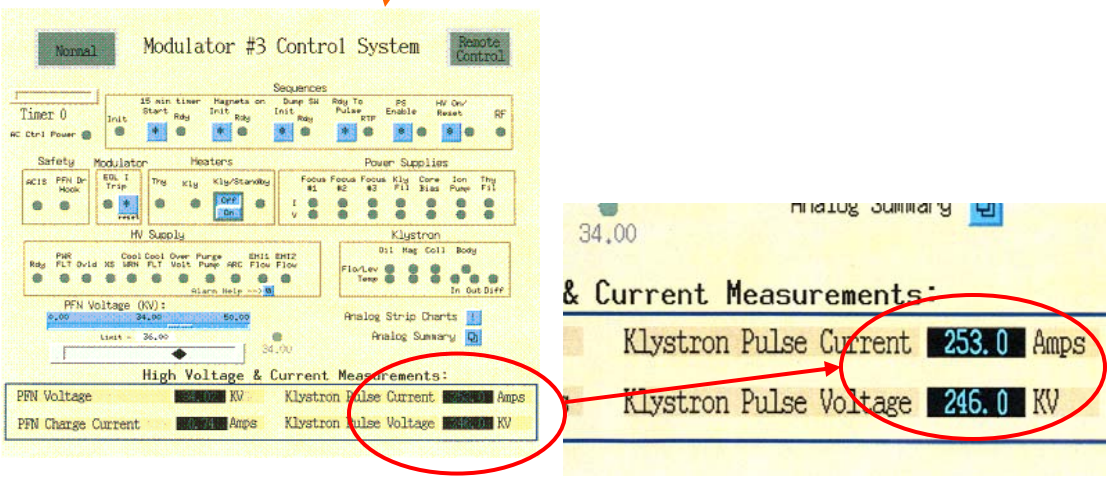
2. Open the middle **RF** menu box.

3. Chose "**LINAC RF Control**" option.





3. Open the Modulator control window.



4. Turn the modulator ON w/o RF. Set up the PFN voltage to 34 kV.

5. Read and record in the Log book initial values of the Filament heater voltage (Fil-V) and current (Fil-I) (local Allen-Bradley controller (AB) screen). Compare the values to the Filament power supply front panel meter readings. Record the difference.

6. Read and record in the Log book initial values of the Klystron Pulse voltage (Cath-V) and Current (Cath-I) (lower-right corner of the EPICS Modulator Control window). Compare the values with the corresponding signal levels at the oil tank lid scope (Fig. 2). While reading the scope signal levels, make sure that two ("read back" and "scope") cables are connected to each BNC connector (CT and VD) of the tank lid. Keep the cables connected at all times during the measurements and operation. If the EPICS window numbers are stable, and the difference between them and corresponding scope signals does not exceed 1%, you can use EPICS readings for further measurements. Otherwise, use the scope signals.

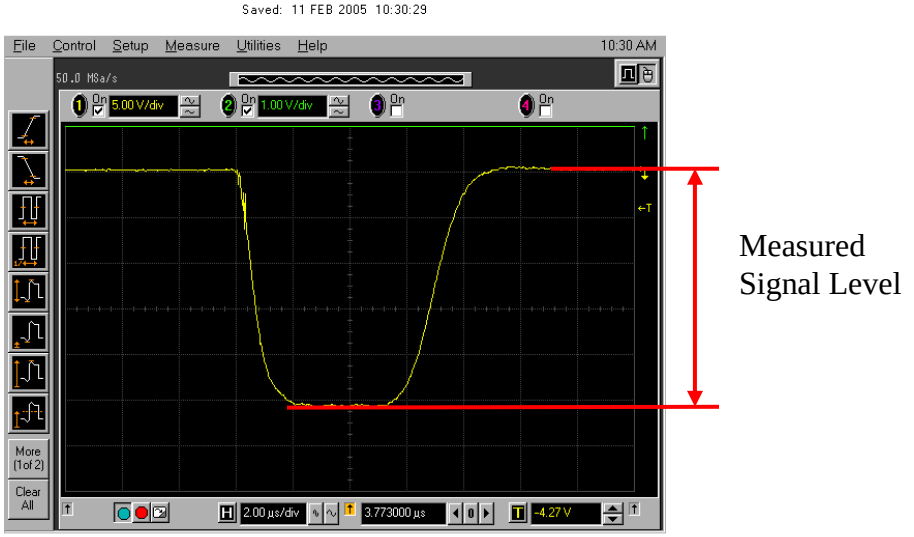


Figure 3. Typical scope signal of the Cath-V and Cath-I.

Note 2: A 10,000:1 voltage divider and 0.1V/A current transformer are used for measuring the cathode voltage and current. 25 V at the voltage scope channel means 250 kV on the cathode, and 25 V at the current channel means 250 A of the cathode current.

7. Manually increase Fil-V (monitor its value on the AB screen) by 3-4 volts. Wait 10 minutes or until the Cath-I and Cath-V stop changing.

Note 3: **Maintain constant Cath-V during the measurements.** Warmer cathode has higher electron emission (if saturation of the cathode has not been reached, yet). This results in higher cathode current, that in turn, means lower klystron impedance. If the PFN voltage is kept constant, you will observe drop of the cathode voltage. In order to maintain constant Cath-V, you will require adjusting PFN settings.

8. Adjust (if required) the PFN voltage in order to return Cath-V to the previously recorded initial value. Record Fil-V, Cath-V, and Cath-I in the Log book in form of a table (example):

Fil-V (V):	173	177	181	185	189	193	196
Cath-V (kV):	250	250	250	250	250	250	250
Cath-I (A):	230	233	236	239	242	244	244

Note 4: If after increasing the filament voltage, neither Cath-V nor Cath-I changed, the cathode saturation level (Vsat) has been reached. **Avoid overheating the cathode**. Do not exceed the filament voltage maximum level of

$$V_{max} = V_{sat} + (5\text{-}7)\ V.$$

7. If Vmax has not been reached, repeat steps 6 and 7 until Fil-V reaches Vmax.

8. If the maximum level of Fil-V has been reached, set up Fil-V to the initial level.

9. Reduce Fil-V by 3-4 volts. Wait for the cathode to cool down (10 minutes, or until the Cath-I and Cath-V stop changing).

10. Adjust PFN voltage in order to return Cath-V to the previously recorded initial **value**. Record Fil-V, Cath-V, and Cath-I in the Log book.

11. Repeat steps 10 and 11 until Cath-I drops to the value that is (5-7) % lower than the saturated level (see Fig. 2).

12. Return Fil-V to the initial level.

13. Using Microsoft Excel, plot the klystron Filament Curve (Fig. 2). Print it out and stick it in the Log book. Mark the Operating level of the filament voltage (the cathode saturation level or 1-2 volts lower).

14. If newly determined operating level of Fil-V is different from the initial value, adjust filament voltage to the new level.

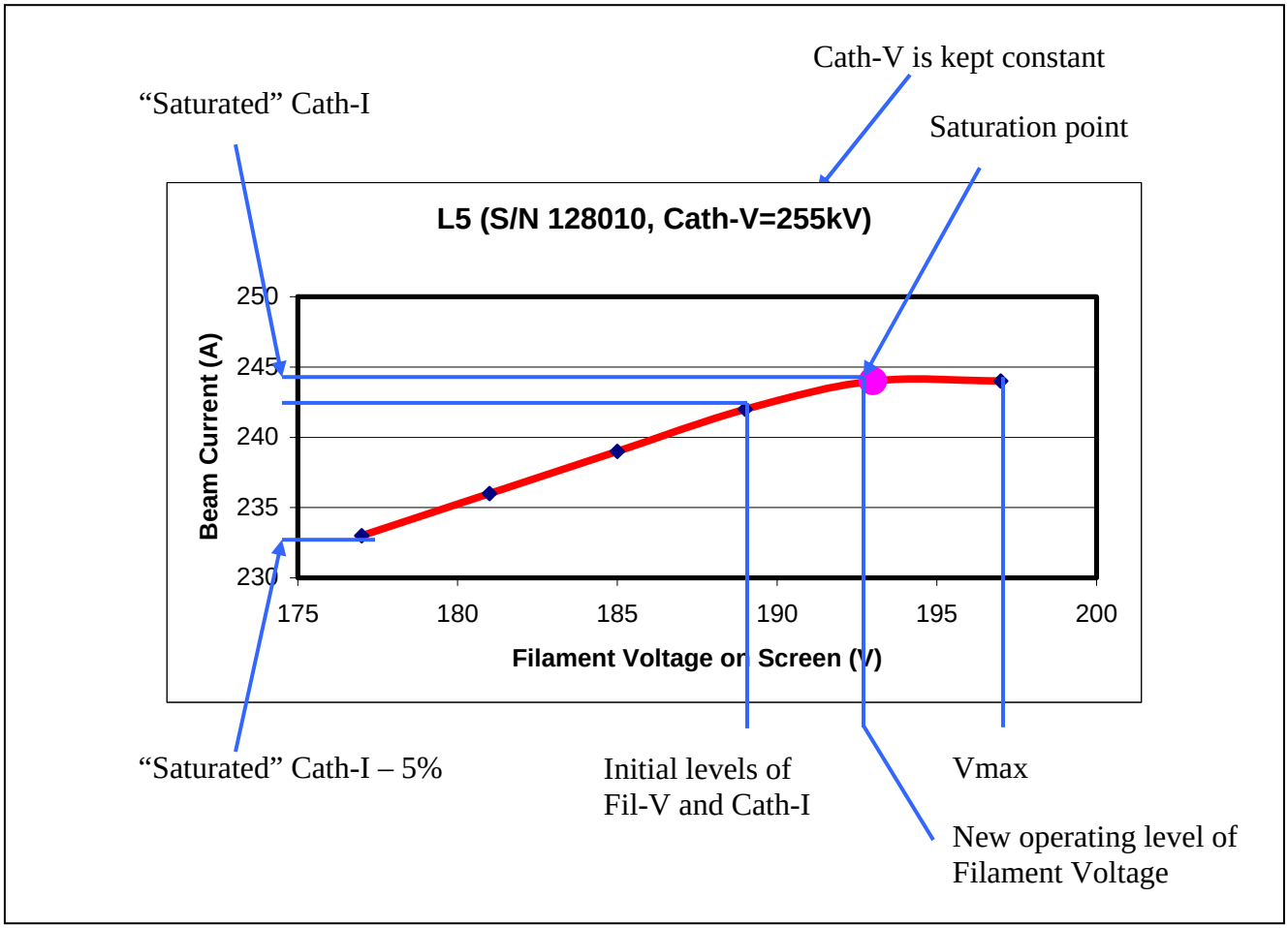


Figure 2. Example of the Klystron Filament Curve