<u>RF TECHNICAL NOTE</u>

DETERMINING THE CATHODE HEATER OPERATING POINT ON APS 350MHz KLYSTRONS

This technical note outlines the steps involved to determine the cathode emission curve and correct cathode heater operating point on the APS 350MHz 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 350MHz 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 *(again, heater voltage times heater current, in watts)* is unique to each klystron, and represents the amount of cathode heat required for the cathode to produce a full-power beam (approximately 20A beam at 92-95kV) 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 to1000 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 lower beam powers, and therefore full emission from the cathode is not required. Based on the present typical operating point for the APS 350MHz klystrons (88kV @ 16A maximum), the following procedure can be used to determine the correct heater power operating point at RF1-RF5.

Note: Accurate metering of the heater voltage and current is required to properly determine the cathode heat operating point. The following procedure will begin with the steps necessary to verify readback calibration of the klystron heater voltage.

Refer to <u>APS Procedures #1110-00101, "Safety Procedure for APS 352 MHz Klystron Maintenance"</u>, and <u>#3104-00032, "Lockout/Tagout Procedures for the Synchrotron and Storage Ring RF Power Supplies"</u> when performing the following steps.

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

1. Shut down and LOTO the Universal Voltronics (UVC) power supply.

2. Open the klystron garage and remove the cap from the klystron oil tank.

   Note: On EEV klystrons, the entire tank lid must be removed.

3. Using the anode-tank ground stick, carefully ground the heater, cathode-heater, and mod-anode leads inside the klystron oil tank (see figure 1).

   Note: Clean the ground stick before inserting it into the oil to prevent contamination of the oil.

Figure 1 – Ground-sticking HV leads in klystron oil tank.

4. Attach long alligator-clip meter leads to the heater and cathode-heater terminals inside the klystron oil tank (see figure 2, figure 3, and figure 4).

Metering the heater voltage directly on the heater terminals inside the oil tank is necessary to determine the actual voltage applied to the heater. A measurement at this point in the system accounts for voltage drop in the Pantak cables between the anode tank and the klystron.

Note: Wear long rubber gloves to avoid unnecessary skin contact with the oil.

Figure 2 – Long meter leads with clips.

Figure 3 – Attaching meter leads to klystron heater terminals.

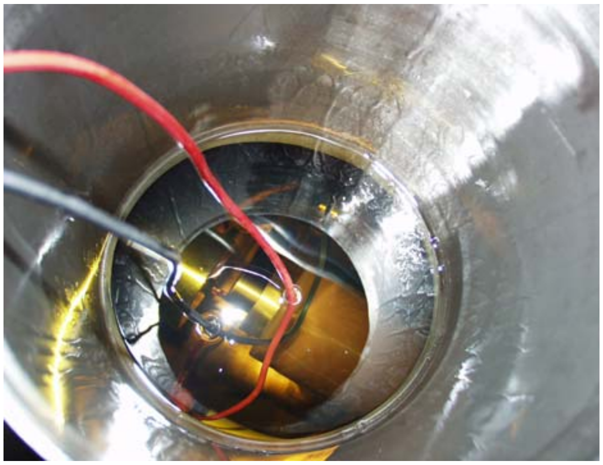

Figure 4 – View inside klystron oil tank.

5. Dress the meter leads so that they exit the klystron garage at the gun-end opening, and connect them to a calibrated ac voltmeter. Hang the voltmeter on the outside of the garage on the hook provided (see figure 5).

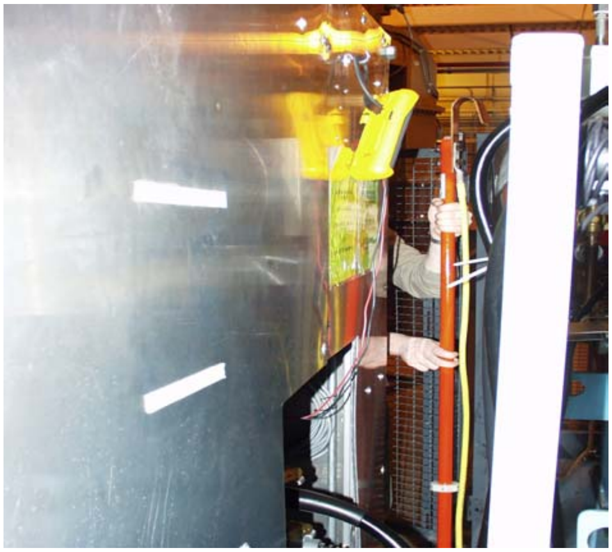

Figure 5 – Meter and leads outside of klystron garage.

6. Close and latch the klystron garage.

   Note: Pay close attention to the meter leads to prevent pinching them between the halves of the klystron garage when it is closed.

7. Turn the 5kV mod-anode bias supply off at toggle switch S1, located inside the Anode Tank Control Cabinet (see figure 6), and at the 120VAC switch located on the side of the Anode Tank Control Cabinet and LOTO the 120VAC switch (see figure 7).

Figure 6 -- 5kV toggle switch S1,
shown in the “off” position.

Figure 7 – LOTO applied to 5kV power supply
120VAC source switch.

8. Energize the UVC control power. ***Verify that the 13.2kV Fused-Disconnect Switch is open. It must remain open for the duration of this filament voltage calibration.***

9. Turn on the heater power supply, and verify that the ac voltmeter hanging on the klystron garage is indicating a voltage level (see figure 8). After the filament voltage has reached the maximum value (approximately 20 minutes), compare the voltage values read on the ac voltmeter with the heater voltage readback displayed on the UVC computer (see figure 9).

If the voltage values agree within 0.25 volts, no further adjustments are required, and proceed to step # 12.

If the voltage values differ by more than 0.25 volts, proceed with the next step.

Figure 8 – AC voltmeter reading actual heater voltage.

Figure 9 – Heater voltage readout on UVC computer screen.

10. Remove the UVC circuit card A8 and place it on an extender board (see figure 10).

Figure 10 – UVC card #A8, with trimpot for adjusting heater voltage readout.

Figure 11 – Adjusting heater voltage readout value.

11. Adjust the 10-turn pot on card A8 until the UVC readout of heater voltage agrees with the value read on the ac voltmeter (see figure 11).

12. Shut down and LOTO the UVC power supply system, and remove the ac voltmeter leads from the klystron oil tank (see figure 1).

    Note: Ground-stick the heater, cathode-heater, and mod-anode leads inside the klystron oil tank BEFORE attempting to remove the meter leads from the tank!

    Note: Wear long rubber gloves to avoid skin contact with the oil.

13. Turn on the UVC power supply, and verify that the heater power is adjusted to the normal recommended value (see local klystron logbook for the value) after the heater warm-up timer interlock has cleared.

14. Using a clamp-ammeter on the “heater” Pantak cable, verify that the UVC filament current readback agrees with the clamp ammeter.

    If the current values agree within 0.1A, no further adjustments are Required.

    If the current values differ by more than 0.1A, calibration of the UVC current readback is required.

15. Increase the collector return water temperature interlock trip point to 48° C. *Note the original trip-point value so that the meter can be reset to this value at the completion of this procedure.*

16. Put the collector interlock in "bypass" mode.

17. Operate the klystron <u>in diode mode</u> at 77kV/15A. Maintain this level of beam current with no changes for a period of 5 minutes.

    Note: The mod-anode voltage must remain constant throughout the entire test.

    Note: If the beam current begins to decrease with no corresponding decrease in mod-anode voltage, this may be an indication that cathode heat is insufficient.

18. Increase the heater current by 0.5A, and record the heater power and beam current value after a period of five minutes. *The klystron cathode structure has a significant thermal momentum, and a minimum of five minutes is required to reach thermal stability.*

    Note: Normally, increasing cathode heat will result in an increase in beam current. This increase is caused by a combination of two separate effects: [a] Increased cathode emission due to higher cathode temperatures, and [b] reduction in the physical space between the cathode surface and the mod-anode electrode, caused by expansion of the cathode structure due to the increased temperatures. The increase in beam current caused by increased cathode emission is the desired effect, and is normally much larger than the change in beam current caused by expanding mechanical structures in the electron gun.

    <u>*Further increases in heater current should not be made when corresponding changes in beam current are less than 0.02A.*</u>

19. Continue to repeat step #17 until the beam current increase at each 0.5A increase in heater current is 0.02A or less. <u>Under any circumstances, stop increasing the heater current when the heater current reaches 23A.</u>

20. Once no further significant increases in beam current are noted, return the heater power to the original setting and note the beam current value after a five-minute stabilization period.

21. Lower the filament current value by 0.5A, and record the beam current after a period of five minutes.

22. Continue to reduce the heater current in 0.5A increments as in step #20, and record the heater voltage and current and beam current at each step, until the beam current falls to approximately 13.7A.

23. Return the heater power to the initial pre-test value.

24. On linear graph paper, plot the data points taken at each heater current step, as shown in figure 12.

    Note: The curve plotted should have a relatively sharp knee, as shown. However, it is possible that the knee where emission drops off may be very subtle or missing entirely. This is quite often the case in new or newly-refurbished klystrons, were not enough operating time has elapsed to allow the cathode surface to clean itself of impurities.

    If no sharp knee is seen on "new" klystrons, operate the klystron heater power at the factory-acceptance test level and attempt another cathode heat curve after another 500 hours of operation. If the knee is not clearly present in an older klystron with many thousands of hours of operation, it may be a sign of previous or ongoing cathode damage.

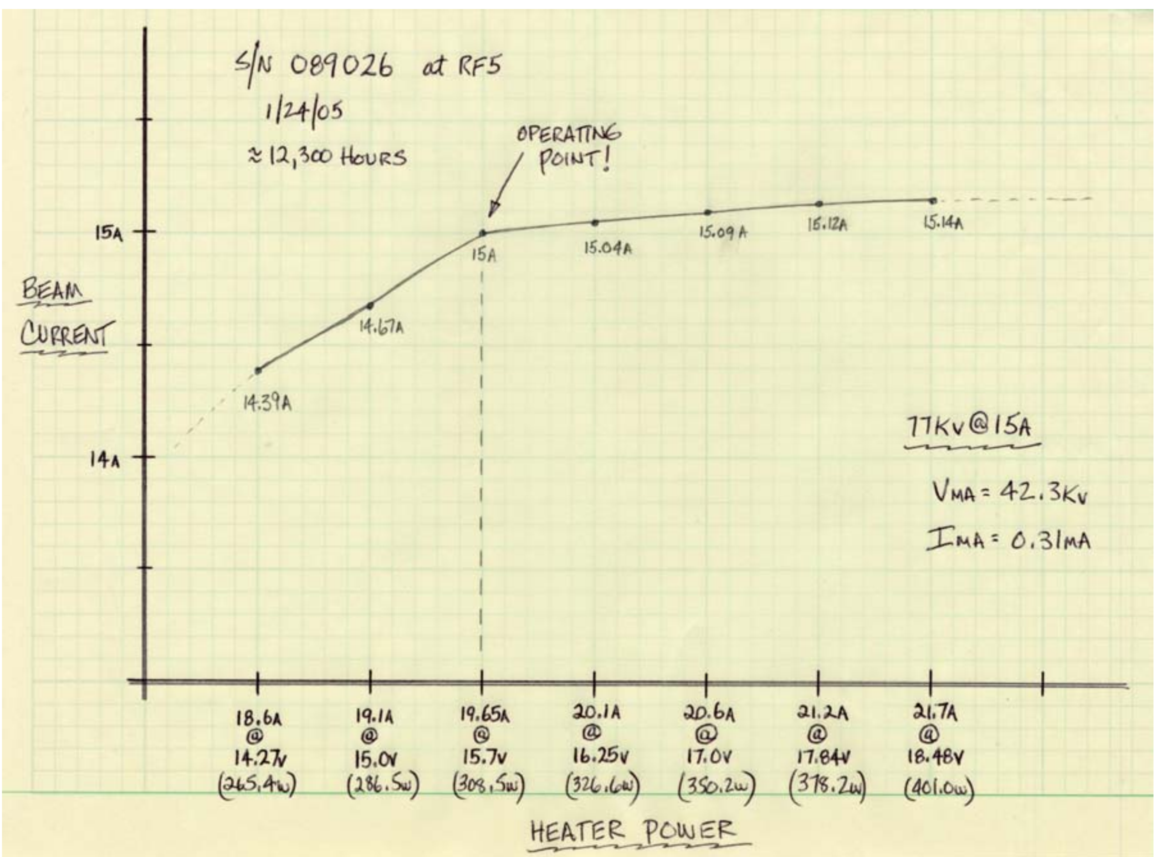

Figure 12 – Typical cathode heat-vs-emission curve.

25. The correct operating point for heater voltage is where the beam current falls by approximately 2% from it's highest value on the curve. Set the heater current to a value as close to this operating point as possible.

    Do not pick an operating point on the curve where the slope increases rapidly.

26. Take the collector interlock out of bypass, and adjust the cathode voltage and current to the normal ”diode standby” levels.

27. Reset the collector return water temperature interlock trip point to the original value (see step #15).

28. Return the klystron to normal service.