TECHNICAL NOTE FOR APS 352MHz KLYSTRON REPLACEMENT

D. Horan and A. Nassiri

June 13, 2000

This procedure outlines the steps necessary to replace a 352MHz klystron with one of the same manufacturer and model. A minimum of 8 hours is required to complete this procedure.

Note: Significant modifications to the water system and klystron shield enclosure may be necessary to accommodate a replacement klystron of different manufacturer and model. If such modifications are required, the amount of time required to complete this procedure could exceed 16 hours. *Contact the Mechanical Engineering Group for assistance with the necessary modifications before installing the replacement klystron.*

Note: Refer to Procedure # 1110-001, "Safety Procedure for APS 352MHz Klystron Maintenance" for detailed information while performing steps 1-11:

1. Place the Universal Voltronics power supply system in LOCAL CONTROL by placing the "LOCAL/REMOTE" knob in the "LOCAL" position (see Figure1).

2. Turn off the magent-1, magnet-2, heater, and ion pump power supplies.

3. Electrically open the 13.2kV Fused-Disconnect Switch using the front-panel pushbutton, located on the front of Control Cabinet bay #2 (see Figure 1). Verify that the switch status indicator shows that the switch is now open, and that ALL of the 13.2kV line voltage meters indicate zero voltage after the switch is opened.

4. Disable the klystron power supply front panel control by pressing the "CONTROL OFF" pushbutton (see Figure 1).

5. Switch the control keyswitch on the klystron power supply control panel to the "DISABLE" position and remove the key (see Figure 1).

Figure 1

6. Using the klystron power supply control key, remove the padlocks on the klystron Pantak jack hasps (see Figure 2).

Figure 2

Note: EEV klystrons are shorter in length than Thomson klystrons; therefore the Pantak connectors on EEV klystrons will be positioned inside the klystron shield enclosure. The padlocks cannot be removed from the Pantak connectors on EEV klystrons until the klystron shield enclosure is opened.

7. Place the control key into the interlock grounding switch located on the side of the klystron power supply SCR cabinet (see Figure 3), and move the switch to the "GROUND" position. Lock out the switch in this position.

Figure 3

8. Shut down and lock out the klystron power supply control power by removing all 208 VAC Control Cabinet power. This is accomplished by opening all of the 208/120 VAC circuit breakers located on the front of the Control Cabinet bay #1 (see Figure 4), and by opening the 480 VAC disconnect switch, which supplies ac power to the Control Cabinet (see Figure 5).

Figure 4

9. Shut down and

Figure 5

lock out the ac power feed to the auxiliary klystron ion pump power supply, which is located in rack #2 of the klystron control rack island (see Figure 6 and Figure 7).

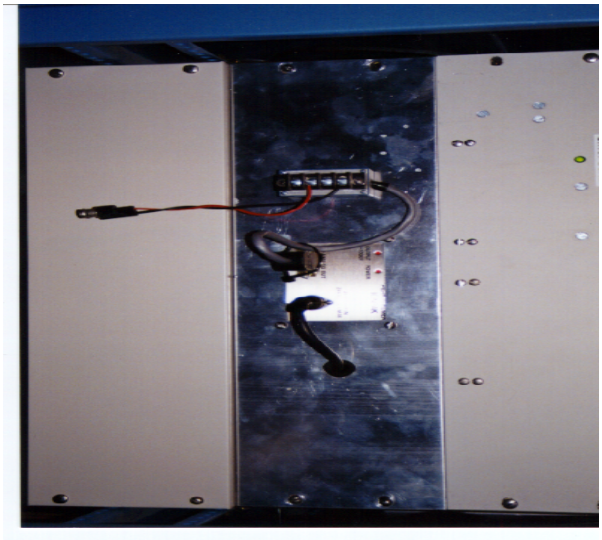

Figure 6

Figure 7

10. All personnel who will be involved in the klystron replacement activity shall follow LOTO procedures and lock out over the ground switch on the SCR cabinet, the 480VAC control power disconnect switch, and the 120 VAC power to the auxiliary ion pump power supply.

11. Shut down the ac power feed to the klystron shield enclosure by opening the appropriate breaker in the technical power panel for the station (see Figure 8).

12. Remove the klystron radiation shield enclosure interlock key from the key block located on the side of the power supply cabinet (see Figure #3) and release the chain lock on top of the enclosure (see Figure 9). Open the klystron radiation shield enclosure by releasing all four latches and rolling the moveable half of the enclosure away from the klystron.

Figure 8

Note: The process of opening the klystron radiation enclosure requires a minimum of two personnel, one positioned at each end of the moveable half of the enclosure to prevent damage to the garage and klystron during the opening process.

13. Remove the Pantak cables from the klystron oil tank jacks, using ground stick to discharge any stored energy in the cables before coming into contact with the Pantak cable center conductor. Stow the cables in a safe position on top of the power supply mod-anode tank.

14. Remove the ion pump power supply cables from the klystron (see Figure 10). Stow these cables on the inside wall of the fixed half of the shield enclosure.

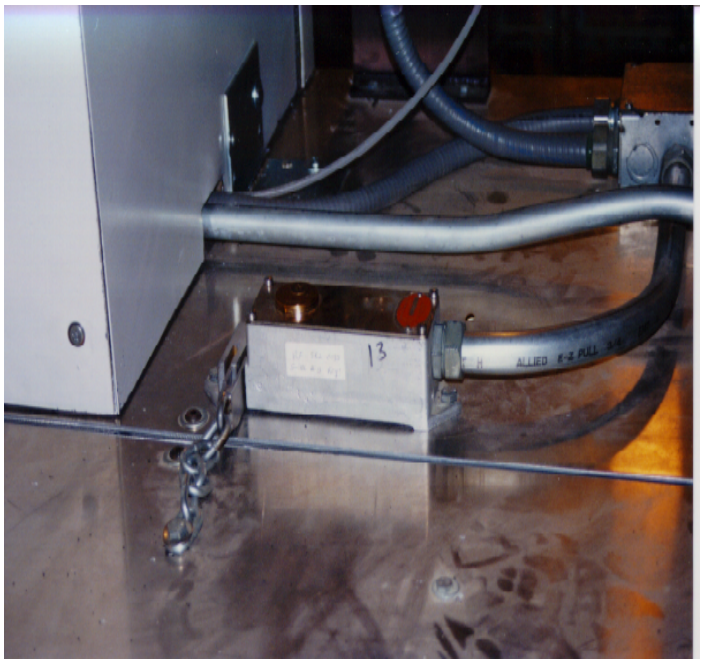

Figure 9

15. Remove the window cooling air hose from the klystron (see Figure 11).

16. Remove the rf drive cable from the klystron (see Figure 12). Stow this cable on the inside wall of the fixed half of the shield enclosure.

17. Remove the focus magnet-1 and focus magnet-2 connectors from the Klystron (see Figure 12). Stow these cables on the inside wall of the fixed half of the shield enclosure.

18. Disconnect the oil tank temperature alarm switch cable and stow it on the inside wall of the fixed half of the shield enclosure.

Figure 10

Note: *The oil tank temperature alarm switches are mounted differently on Thomson and EEV klystrons:*

<u>On Thomson tubes</u>, the oil tank temperature alarm switch is attached to a copper heatsink that is bolted to the oil tank using one of the tank flange bolts. This heatsink/switch assembly must be removed from the old klystron and attached to the new klystron being installed. The bolt used to attach the heatsink to the oil tank is slightly longer than the other bolts on the tank flange, and must be re-used on the new klystron.

<u>On EEV tubes</u>, *the oil tank temperature alarm switch is attached to an existing oil tank heatsink fin located on the left side (looking from the gun end) of the oil tank. Both EEV klystrons have been fitted with oil tank temperature alarm switches, so there is no need to remove the switch when replacing an EEV klystron.*

19. Disconnect the output window temperature thermocouple cable, located near the output window (see Figure 13). Stow the connecting cable on the inside wall of the fixed half of the shield enclosure.

Figure 11

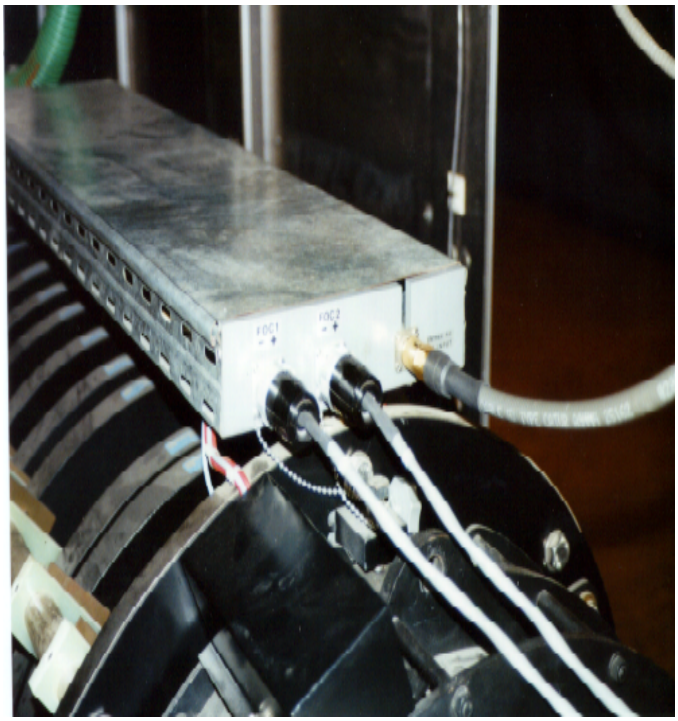

Figure 12

20. Remove the arc detector fiber optic cable from the fitting on top of the klystron output waveguide (see figure 14). Stow the fiber optic cable on the inside wall of the fixed half of the shield enclosure.

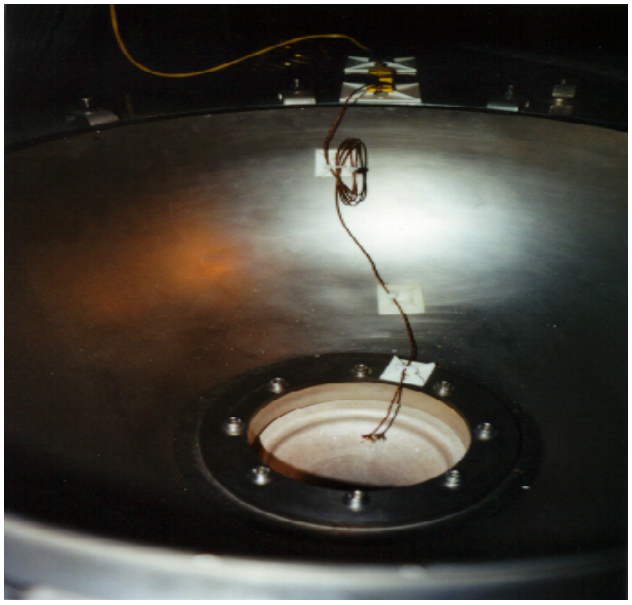

Figure 13

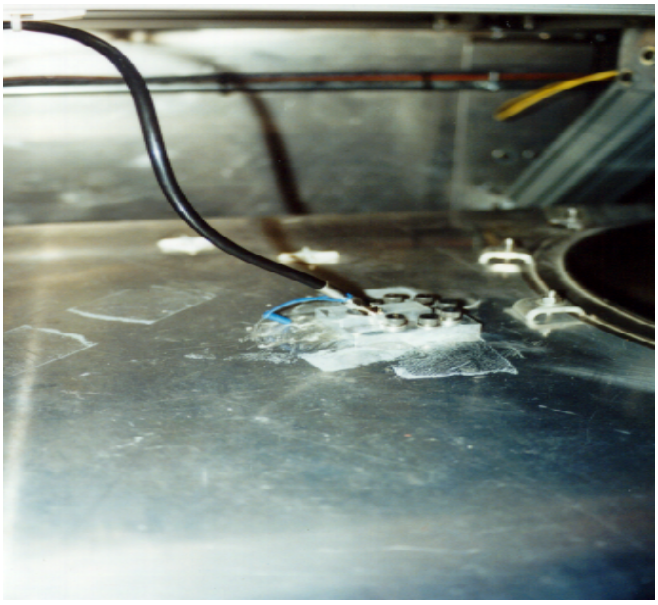

Figure 14

21. Remove all system grounding cables from the klystron (see Figure 15 and Figure 16).

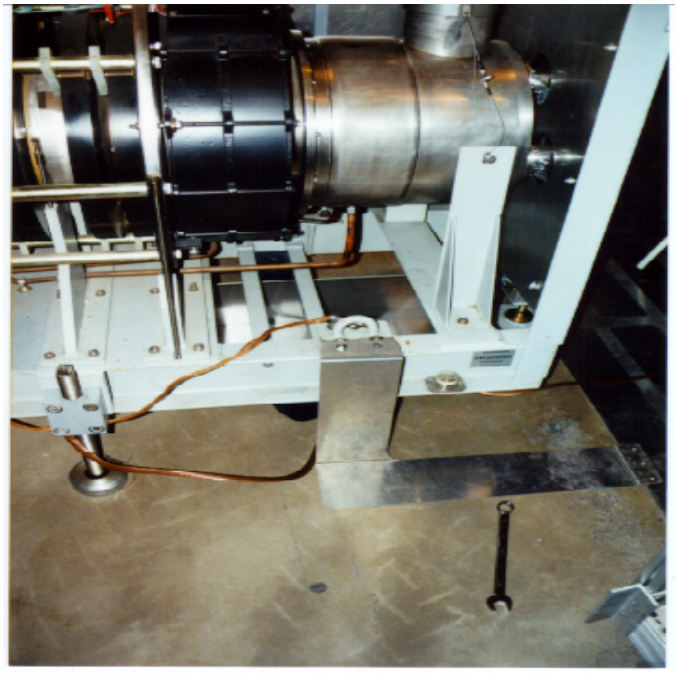

Figure 15

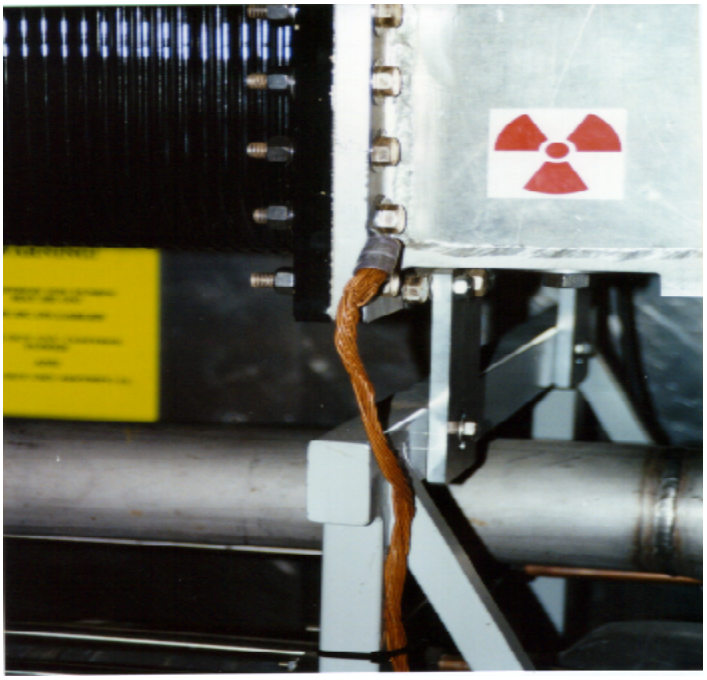

Figure 16

22. Disconnect the ac power cords for the klystron enclosure cooling fans (see Figure 17), and the oil tank cooling fans (EEV klystron only).

23. Remove the oil catch basin from beneath the klystron oil tank.

Note: All rf stations in Building 420 must be shut down and locked out before the following step is taken. All personnel working on the klystron replacement activity must participate in this rf system LOTO procedure. Unbolting a waveguide flange anywhere in the 352MHz waveguide system can result in excessive electromagnetic field radiation and will result in a Waveguide Air Interlock System trip, which will shut down all 352MHz rf systems.

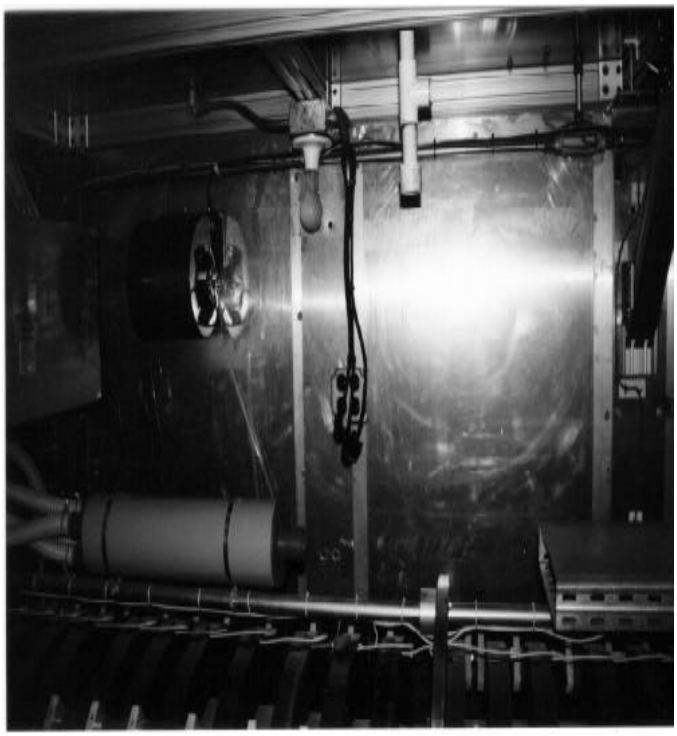

Figure 17

24. Remove the waveguide flex section immediately following the klystron output waveguide flange (see Figure 18).

25. Temporarily cover both waveguide flanges with a fiberboard or plastic sheet to prevent foreign material from entering the waveguide (see Figure 19).

26. Contact the Water Group to turn off the pump supplying water to the klystron being replaced. Request a drain and removal of all water lines to the klystron.

27. If the front radiation shield is physically attached to the klystron, remove it at this time. Remove the rear radiation shield from the klystron only if the replacement klystron is not fitted with one (see Figure 20).

Figure 18

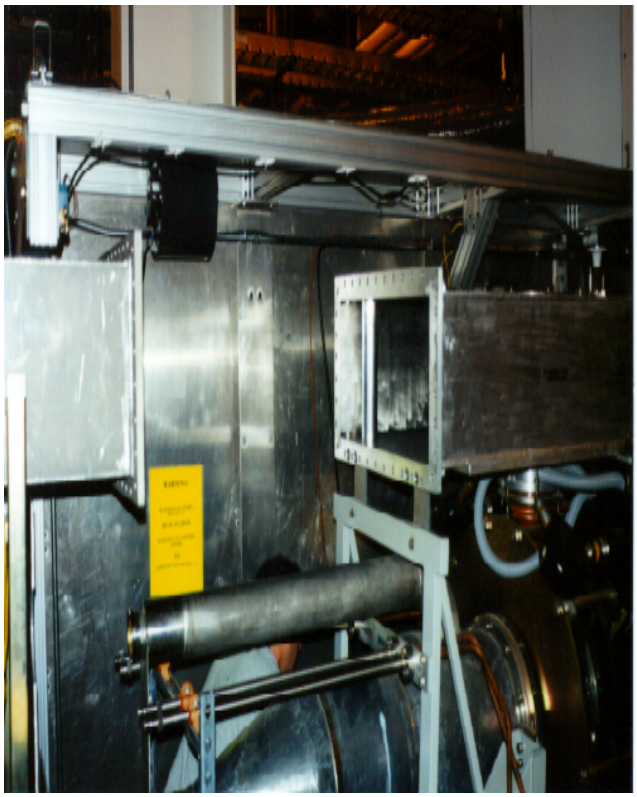

Figure 19

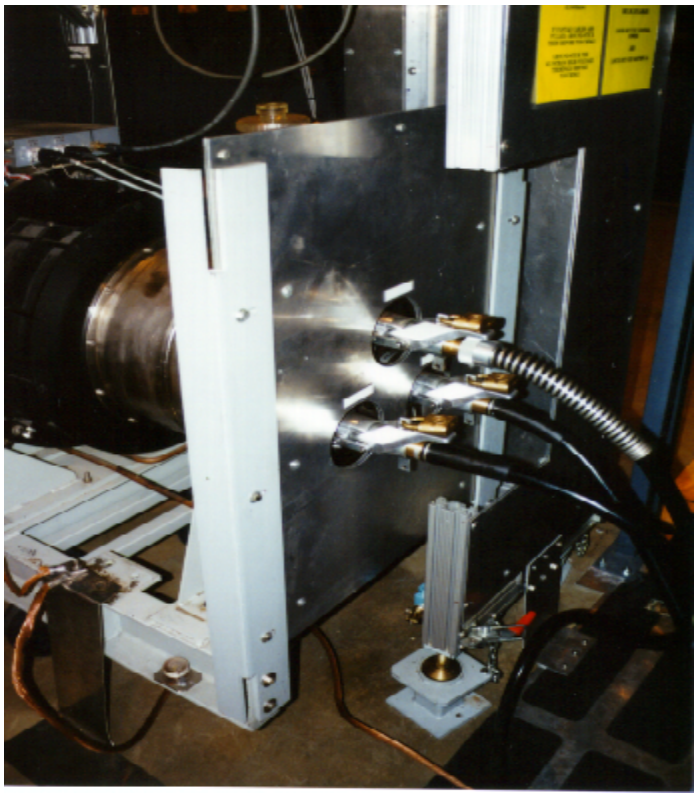

Figure 20

28. Mark the position of the klystron support feet on the floor with a permanent marker (see Figure 21).

29. Measure the distance between the floor and the top of the klystron girder at each support foot location, and write this measurement on the floor with a permanent marker (see Figure 21).

30. Lower the leveling screws on the klystron in an even fashion until all the klystron wheels touch the floor and the klystron is free to roll (see Figure 22).

Figure 21

Note: While the klystron is being lowered to wheel contact with the floor, a minimum of two personnel at each end of the klystron shall be positioned to prevent the klystron from suddenly rolling when it rests on the wheels. Be aware that the klystron could suddenly roll slightly when all of its weight is transferred to the wheels. Do not position any personnel between the klystron and the fixed half of the enclosure until it has been demonstrated that the klystron will remain stationary while supported on it's wheels.

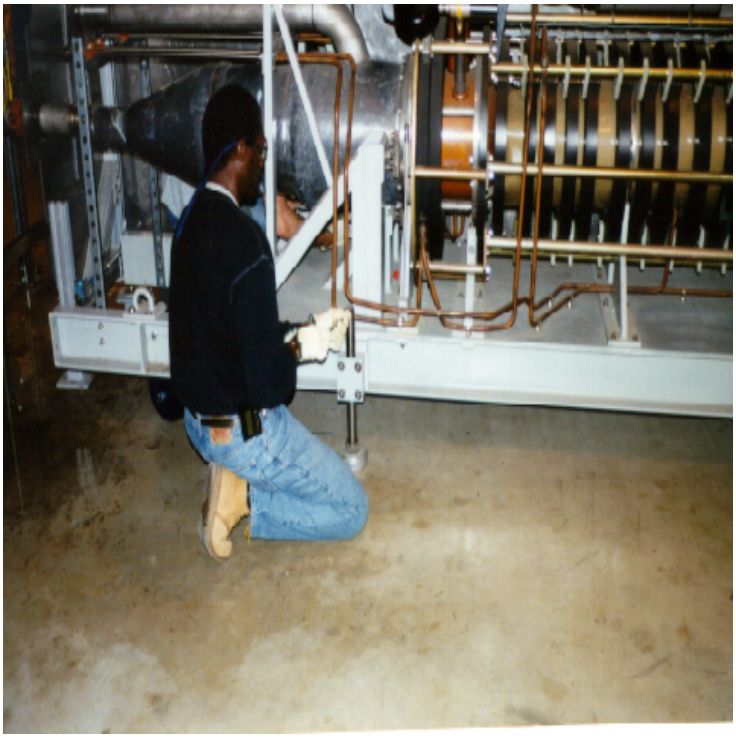

Figure 22

31.Using a minimum of two personnel at each end of the klystron, slowly roll the klystron out of the shield enclosure and to a safe stowage area. When the tube is stowed, a minimum of two leveling screws shall be cranked down to contact with the floor to prevent the klystron from rolling about while stored.

32. Using a minimum of two personnel at each end of the klystron, roll the replacement klystron into the garage, collector-end first. Position the klystron so that its leveling screws are positioned above the corresponding marks on the floor.

33. Position the klystron so that the distance between it's output waveguide flange and the system waveguide flange is within is within ½ of the length of the flex section. Simultaneously, position the klystron so that it's output waveguide flange is in alignment with the system waveguide flange in the vertical plane, and that parallelism of the vertical waveguide flange faces is within ½ Once this alignment is achieved, lock the klystron in position by screwing the support feet down until they are in hard contact with the floor. The support feet should be in the same approximate floor position as the corresponding reference markings.

Note: Do not position the klystron support feet directly on the foot reference markings. Experience has shown that no two klystrons are mechanically alike to the degree necessary to use these markings as absolute placement for a replacement klystron.

The alignment between the klystron and system waveguide flanges is the critical factor in the actual position of the klystron on the floor.

Note: This alignment can be done using the naked eye by viewing the outline of the waveguide flanges from the gun-end of the tube, and by using a ruler to check for parallelism of the flange faces.

34. Crank the klystron support feet down in an even fashion until the top of the klystron girder at each support foot location is the same height above the floor surface as was measured on the original klystron.

35. Check for parallelism of the mating waveguide flanges. They should be within ½ of parallelism in all planes.

36. Using a conventional bubble level on the top of the output waveguide, check that the klystron is level in both horizontal axes.

37. Insert the flex waveguide section into the gap and check for fit. If the flex piece can be inserted with no more than hand force to slide it into place, then the klystron floor position with respect to the system waveguide flange plane is correct.

38. Install the waveguide flex section and torque the bolts to 35 ft-lbs.

Note: When installing Thomson klystrons, longer bolts are necessary at two locations on the klystron output waveguide flange where a waveguide support block is attached to the backside of the flange.

Note: Log all waveguide flange activity in the Waveguide Flange Logbook.

39. Contact the Water Group to re-connect the klystron water lines and restore normal water pressure and flow through the tube.

40. Install the oil catch basin beneath the klystron oil tank.

41. If necessary, attach the rear radiation shield to the klystron girder.

42. Attach all system ground connections to the klystron.

Note: System ground conductor attachment locations are not the same on all klystrons.

Thomson TH2089A klystrons require the main system ground connection be made on the klystron girder at the gun-end of the tube, using the rigging fixture bolts and

mounting holes for connection. A secondary ground cable is also attached at this point and routed to any bolt on the output waveguide flange.

EEV K3513A klystrons require the main system round connection be made on the rear of the oil tank, using the welded stud tab provided for this purpose. A secondary ground cable is also connected to this stud tab, routed under the klystron, and attached to a grounding stud provided for this purpose located on the girder top surface under the collector.

43. Connect the window arc detector fiber optic cable to it's fitting on top of the klystron output waveguide.

44. Connect the output window thermocouple to the thermocouple connecting cable. Check to see that the window outlet air indicator reads room temperature.

45. Connect the focus magnet-1 and focus magnet-2 lines to the appropriate inputs on the klystron.

46. Connect the rf-drive cable to the klystron. Check the tightness of all connectors in the rf driveline.

47. Connect the ion-pump output cables to the klystron.

48. Check for proper oil level in the klystron oil tank.

49. Carefully clean the klystron Pantak sockets and their mating connectors, looking for any signs of damage or deterioration. If no abnormalities are found, grease the Pantak connectors and insert them in the appropriate sockets.

Note: When installing Thomson TH2089A klystrons, the Pantak cables can be inserted to the klystron sockets with the shield enclosure closed.

When installing EEV klystrons, the Pantak cables must be inserted into the klystron sockets only with the shield enclosure open, as the klystron is shorter in length.

Note: The Pantak connector surfaces MUST be absolutely clean of foreign material and free of any surface damage before being mated. Mating dirty or damaged connectors can result in immediate failure of the connector under high-voltage operating conditions.

*Note: When inserting a Pantak connector, the proper insertion fit of the connector is achieved when the connector is dry (no grease or oil), the bayonet lever of the connector closes to 45-degrees with **NO** resistance, and the connector can be closed completely with the pressure of only **ONE FINGER.** When the connector is then greased, it will fit together noticeably tighter.*

Failure to properly fit a Pantak connector will result in damage to the plug, socket, or both.

50.Install the control-keyed padlocks on the klystron Pantak hasps.

51.Plug in the klystron enclosure ventilation fans.

52.Re-attach the output window cooling air hose to the klystron.

53.Re-energize the klystron shield enclosure ac power feed and check to see that the window airflow is normal, and that all the enclosure ventilation fans are operating normally.

Note: Normal window airflow is indicated by a normal indication on the window Photohelic airflow gauge on top of the klystron shield enclosure (see Figure 23).

Figure 23

54.Once the water flow and pressure are restored to normal values, check all klystron water connections for leaks.

55. On Thomson klystrons, replace the desiccant in the oil tank breather lid and fill the breather cap well to the correct level with Dow 200 high voltage insulating oil.

56. Inspect the interlock switch assemblies on the rigid half of the klystron enclosure for mechanical rigidity and correct operation. Tighten any related hardware if necessary.

57. Inspect the interlock switch striker plates on the movable half of the shield enclosure for mechanical rigidity. Tighten any related hardware if necessary.

58. On Thomson klystrons, check to make sure that the sample loop connectors on cavities 2, 3, and 4 are terminated with a type-N short, and that the connectors are tight.

59. Perform one last quick inspection of the klystron garage interior, double- checking all electrical and mechanical connections.

Note: During this inspection, make sure all tools and other foreign metallic objects are removed from the klystron structure. Foreign metallic objects in the vicinity of the klystron focus magnets can distort the focusing magnetic field and possibly affect the operation of the klystron.

60. Close the klystron garage and remove the captive interlock key from the tumbler on top of the klystron garage. During this process, monitor the appropriate indicator lights on the rf station Personnel Safety Interface Box to see that they turn from red to green when the enclosure is closed and the captive interlock key is removed.

61. At this time, all LOTO devices can be removed from the 420 rf stations.

62. Determine that the rf station where the klystron has been replaced is switched properly to drive it's appropriate accelerator (see the mode selected on the Waveguide Switch Control Screen). If the operating mode is not correct, switch to the correct mode now.

Note: The remaining steps in this procedure involve rf operation of the klystron into the accelerator. Careful attention must be paid to system settings, operating parameters and readbacks while the klystron is initially brought up to power. A complete set of operating data should be taken during this initial start-up period so that trends and abnormal behavior can be identified and tracked.

63. Energize the main and auxiliary klystron ion pump power supplies. Note the vacuum reading.

64. Determine the nominal values for filament and focus magnet power for the new klystron.

Note: This information is available in information binders in Doug Horan's office. There is a binder for each klystron in the APS inventory, and the nominal values for all tube parameters are listed in these binders.

65. Check all klystron-related dc and rf interlocks for proper operation and trip-point setting.

66. Turn off the rf drive to the klystron.

Note: The magnet currents for EEV and Thomson klystrons are radically different. If you are replacing a tube of different manufacturer, the upper and lower magnet current interlocks in the UVC control system must be adjusted properly for the tube being installed.

67. Energize the filament, magnet, and ion-pump power supplies and adjust their parameters to the values listed in the klystron data sheet.

68. After the 20-minute filament warm-up time is completed, apply 10kV cathode voltage to the klystron, and slowly raise this voltage to 50kV, in 10kV steps over a five-minute period of time.

Note: There should be no klystron beam current indicated at this time.

69. Bypass the Collector Interlock.

70. Enter a mod-anode voltage setpoint of 20kV, and turn on the mod-anode.

Note: At this time, the klystron beam current should be approximately 5A.

71. If the klystron vacuum and body losses are normal, increase the klystron cathode voltage to 60kV. Hold this beam power for 5 minutes.

72. If the klystron vacuum and body losses are normal, increase the klystron beam current to 8A.

73. Set the AGC setpoint for the rf drive power to 0.0v, and turn on the rf drive.

74. Increase the rf drive to the klystron until the rf output power is 10kW.

75. Using the Narda electromagnetic radiation monitor, sniff the area around the output flange of the klystron for any signs of excessive rf radiation. If no radiation is detected, the klystron operation can continue.

Note: If significant rf radiation is detected during this test, the klystron must be shut down immediately. Contact the RF Group Engineer in Charge for further instruction on how to determine the source of the rf radiation.

Note: Log the results of the rf sniffing test in the sniffer logbook.

76. Increase the rf drive to the klystron until the forward rf power output reaches 50kW. Note the klystron output reflected power. If it is greater than 1kW, adjust the circulator bias to reduce the reflected power to a minimum.

77. Increase the klystron cathode voltage to 75kV. The beam current should change very little with this increase in cathode voltage, and the rf power output of the klystron should decrease slightly.

Note: The following increases in beam power and rf drive will result in significant increases in klystron rf output power. The ultimate goal of this slow increase in klystron power is to determine the conditioning level of the klystron and to condition it to the required power levels if necessary. Maintain a conditioning pace that will keep the klystron ion pump currents below 2mA. Monitor the body and output cavity losses closely for signs of over-dissipation.

78. Slowly increase the rf drive to approximately 50 watts in setpoint steps of 10mV. The klystron rf output should be approximately 200kW. If necessary, adjust the circulator bias to reduce the klystron output reflected power to less than 1kW.

Note: If you are using accelerator cavities as an rf load for the klystron, be aware of the klystron rf power output so that you do not over-drive the cavities.

79. Increase the mod-anode voltage until the klystron beam current is 10A.

80. Increase the cathode voltage in 1kV steps to 88.0kV.

Note: The rf output power should fall slightly as the cathode voltage is raised.

81. Set the Collector Interlock and take it out of bypass.

Note: If the Collector Interlock cannot be set, increase the klystron beam current until the rf output power is sufficient to set the Collector Interlock.

82. If the klystron is driving accelerator cavities as a load, increase the rf output power of the klystron to the nominal power level of the cavities with without beam. If no malfunctions such as vacuum bursts or excessive body dissipation occur, the klystron should be ready for service within one hour.

83. Monitor the operation of the klystron under full-load conditions (Storage Ring, 100mA stored) and record all klystron parameters in the rf station logbook.

Note: An abnormal condition exists if, while running under full-load condition, the klystron beam current decreases over time without a corresponding decrease in mod-anode voltage. A slow, gradual decrease (over hours) could indicate a condition of insufficient cathode heating. A very rapid decrease could possibly be a sign of overheated internal surfaces of the klystron (melted copper). If either condition exists, it should be investigated immediately!

84. Record the serial number, filament voltage and current, and the magnet voltages and currents on the klystron information sheet posted on the side of the UVC control cabinet. These values should also be recorded in the rf station logbook.

85. Drain the remaining water out of the collector of the old klystron, and store the klystron in a safe location. Place it under ion pumping as soon as possible, and record the reading of the ion pump.