Thomas Jefferson National Laboratory Specification

CEBAF 8 kW CW KLYSTRON SPECIFICATION

EE0043, Rev. H

January 15, 1998

Approved by:

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CEBAF 8 kW CW KLYSTRON SPECIFICATION
EE0043, Rev. H (to 8 kW)

15-January-1998

CEBAF KLYSTRON: A 1.5 GHz, 8.0 kW, CW Amplifier

1.0 SCOPE

1.1 Introduction and General Description

1.1.1 Application

This specification establishes the requirements for new (replacement and spare) CW Klystron tubes for the CEBAF Accelerator. Klystrons are to exactly match the form, fit and function of the existing Varian (CPI) VKL-7811W and Litton L-4941 klystrons now in service at CEBAF. The various parameters required for these Klystrons are defined in this specification**.** These Klystrons are operated as the output amplifier for each of 338 RF drive chains used to energize the CEBAF superconducting accelerating cavities. ***Note that this revision to the specification calls for the tube to reliably deliver 8 kW CW when operated at a beam voltage of 14 kV. The original specification required 5 kW at a maximum beam voltage of 11.6 kV.***

The original CEBAF Klystron is rated at a nominal 5 kW saturated RF power, however, a large percentage of the CEBAF accelerator operation will be in the two to four kilowatt range, well below saturated output. Some operation will be required at RF output powers as low as 100 watts. The RF phase and gradient in the superconducting accelerator cavities must be regulated to a high accuracy. This requires that the Klystron be controlled in a broad band, high gain, feedback system. The Klystron must always be operated well away from saturation to maintain proper feedback system gain margin.

This revision to the specification is to insure that klystrons delivered will be capable of operating at up to 14 kV to provide and deliver an RF output power of 8 kW. While it is not foreseen that any major redesign of the tube will be required, special emphasis should be placed on the output window since this element has failed when some of the original tubes were operated at higher voltage and RF output power levels. It should also be noted that the tube supplied under this specification shall be guaranteed to operate at 14 kV and produce 8 kW output power.

As with previous revisions to the spec, an important power specification for this Klystron is at 4 kW output power (11.6 kV operation), where this Klystron must deliver an incremental gain, as defined in Paragraph 2.1.12, of at least 0.5.

Klystron Vendors are to respond with a proposed Klystron which will meet this CEBAF Klystron Specification #EE0043 Rev H requirements while operating into a microwave transmission system defined in section 2.1.29.

Figure 1.1.1-1 is a block diagram of the system supplying microwave power from the Klystrons through the accelerator shielding to the accelerator tunnel. Each klystron amplifier is connected to its superconducting cavity in the underground tunnel via WR650 waveguide. Each run has a length of about 10 meters, or roughly 40 wavelengths one way.

1.1.2 General Description

The requisite tube is to be a four-resonator, factory tuned, narrow band, high gain, efficient, long lived, water cooled klystron amplifier with integral, factory mounted PM beam focusing. A Modulating Anode and Isolated Collector are to be provided as part of the design. Design of the klystron must permit it to be rebuilt a minimum of three times during its operational life.

The tube should be fabricated without an integral or appended ion pump, though a proposal for these elements may be included. In any event, the tube will require advanced dual-vacuum, high temperature bakeout and exhaust processing. All-metal and ceramic construction practice is essential. The tube design may incorprate a getter.

1.1.3 System Duty

System duty profiles at CEBAF will range from multi-hour-long CW runs, approaching nearly 100% duty over an application period of several years. System overhead (power budget) permits overall machine operation to continue with a small number of failed or failing klystrons remaining socketed.

1.1.4 Klystron Warranty

The vendor shall provide a warranty for the CEBAF Klystron as defined in the Klystron proposal and shall cover both a Shelf Life Warranty and an Operational Warranty. The Warranty provisions will be incorporated in any ensuing klystron contract with CEBAF.

Shelf Life Warranty

Klystrons shall be warranted for 24 months after the tube is tested for full compliance with specification requirements and accepted at CEBAF. Any tube may be operated on our Test Stand up to 25 hours cumulative without nullifying the Shelf Life Warranty. Application of power under any other circumstances voids the Shelf Life Warranty and the tube warranty is then defined by the Operational Warranty.

Operational Warranty

When the Klystron is removed from the shelf and placed in service, the Operational Warranty becomes effective and shall cover the Klystron for 600 hours of operation or (6) months of operation, whichever occurs first.

Klystron Replacements

Klystrons provided as replacements for tubes failing during either the Shelf Life Warranty or Operational Warranty period shall meet all specifications and requirements and shall themselves have full Shelf Life and Operational Life warranties.

2.0 KLYSTRON SPECIFICATION

For convenience of reference in this and related documents the subject Klystron shall be known as CEBAF Klystron.

2.1 Klystron Parameter Specifications and Conditions

The following Klystron parameters and parameter tolerances are hereby specified. See Figure 2.1-1 for a summary of basic klystron design parameters. The following paragraphs describe these and other design criteria. A Klystron offered in response to this specification must meet all requirements defined herein. The term ***saturated RF output power*** is defined as the point where the curve plotted for RF output power versus RF input drive power deviates from the extension of the linear portion of the curve by three dB.

References to tube performance at RF output powers up to 5 kW are for operation of the klystron at a cathode voltage of 11.6 kV. References to performance at greater than 5 kW (up to 8 kW) are for tube operation with a cathode voltage of 14 kV.

2.1.1 Electron Gun Design

The electron gun shall utilize a long life (>100,000 hours) cathode and incorporate a modulating anode for control of the Klystron beam current. The perveance is 1.0 X 10^{-6}. (See 2.1.22).

2.1.2 Interaction Circuit

The RF interaction circuit shall consist of 4 cavities. The first two cavities define the pass band, the third cavity enhances the beam interaction (efficiency) and provides adjustment to the pass band, and the fourth cavity couples the RF output power to the RF coaxial output line. The second cavity is resistively loaded to reduce the sensitivity to beam loading. Cavities 1, 2, and 3 shall have an external tuning capability for precise adjustment of the tube. Factory tuning is required to be stable within specifications for the duration of the tube life.

Klystron band pass requirements are shown on Figure 2.1.10-1. Small signal Klystron gain requirement is defined in Paragraph 2.1.11.

2.1.3 Collector Design

The Collector for the CEBAF Klystron must be designed to dissipate full klystron beam power in the absence of RF drive, and should have a significant design safety margin. In actuality, the tube may have only a limited safety margin when operation is pushed to 14 kV for 8 kW output. The Vendor is to define the capabilities of the collector included with the proposed Klystron. Coolant pressure drop across the Klystron collector must not exceed 20 PSI with 5 GPM coolant flow.

The collector shall to be electrically isolated from the klystron tube body in order to allow monitoring of klystron body current. The insulating material used to isolate the collector from the tube body must also absorb microwave energy at 1497 MHz in order to reduce microwave leakage from the klystron.

2.1.4 Focusing

The CEBAF Klystron shall use an Alnico 5 (bowl configuration) magnet of standard design. The magnet is initially charged to saturation. During klystron test, the magnetic field may be trimmed if desired to lower body interception or to increase beam diameter and increase efficiency.

2.1.5 Layout and Hardware

Drawing K0066C01 is the CEBAF Klystron outline drawing. The collector is to fabricated from materials which will not react adversely with low conductivity water (iron, etc.). A steel sleeve is fitted over the collector to eliminate the magnetic field in the collector. This sleeve is never in contact with the Klystron coolant.

External tuners for cavities 1, 2, and 3 shall be provided. These tuners are to be used primarily during factory test and are not intended for routine field adjustment. The exhaust tubulation, which is to be pinched off and covered, shall be located opposite the external tuner in cavity 2.

The RF output assembly shall be a standard 1 5/8 inch rigid coaxial line with a Marmon Clamp fitting. The output RF window shall be 1 5/8 inches in diameter and operate reliably at 8 kW RF output. A support bracket and a clamp assembly are required to stiffen the RF output line and prevent damage from stresses that may result during handling and installation. The RF input connector shall be a standard type N female connector.

The electron gun (see 2.1.1) is a standard design. The gun leads are to be attached to heater, cathode, and mod-anode connection tabs by a combination of crimping and then welding, brazing, or hard silver soldering. See drawing K0066C01 for color codes of Klystron leads. The end of the electron gun, where the leads are attached, shall be vacuum potted with heat conducting, HV insulating, high temperature silicone compound. Emerson & Cuming's Eccosil 5952 should be used. The creep path shall be suitable for long term operation at **14 kV** in a dirty environment. Cathode cooling is by convection and radiation only. No forced air cooling of the cathode assembly shall be required.

The entire assembly is designed for reparability, with the collector, gun, and output window designed for easy removal and reassembly. Inductive brazing processes or TIG welding must be used for these assemblies thus avoiding the necessity of braze furnaces during klystron repair. The klystrons are to be repairable a minimum of three times. The proposed Klystron shall match the form, fit, and function of the existing VKL-7811 and L-4941 klystrons presently in service, with the exception of the revised requirement for higher output power.

2.1.6 Operating Duty: CW, uninterrupted.

2.1.7 Power Output: See output load definition in 2.1.29

Saturated output power from the Klystron shall be not less than 8 kW at when operated at 14 kV and 5 kW when operated at 11.6 kV. The tube shall meet specification requirements working into the RF load defined by 2.1.29 .

2.1.8 Operating Frequency, Mid band: 1.497 GHz.

2.1.9 Operating RF Efficiency: not less than 32.4 % (with beam current = maximum).

Efficiency with mod anode voltage adjusted to zero volts (see 2.1.19) and the tube operating at 11.6 kV with saturated RF output power (40% efficiency or higher preferred). Efficiency as used here shall be defined as the ratio of the total fundamental frequency, TE10 mode, RF power which the klystron delivers into an impedance matched, WR650 output waveguide (as per Section 2.1.29) to the total DC power of the Klystron beam excluding cathode heater power.

Considerable CEBAF operation is at reduced accelerator beam current requiring as little as 2 kW RF output power. To reduce the power consumption of the accelerator system on an average basis, the klystron RF efficiency shall be optimized for operation at the 2-3 kW RF output level to provide relatively good RF efficiency at these lower power levels. The efficiency at the 2 to 3 kW RF power level may be lower than the requirement at saturated RF output power. The mod anode voltage and RF drive power can be adjusted as required to provide improved operation at lower power levels. With optimum efficiency at reduced power, the RF beam efficiency at the 5 kW (8 kW) minimum saturated RF output shall not be less than 32.4%.

2.1.10 Instantaneous -1 dB and - 3dB Operating Bandwidth

With the Mod Anode volts adjusted to 0 volts (see 2.1.19), the -1 dB bandwidth shall be not less than 2.4 MHz above and 2.7 MHz below the center frequency of 1497 MHz when operated at 1 kW, 2 kW, 3 kW, 4 kW, and 5 kW power levels when operated at 11.6 kV and 8 kW when operated at 14 kV. The -3 dB bandwidth shall be not less than 3.0 MHz above and 3.3 MHz below the center frequency of 1497 MHz at 1 kW, 2 kW, 3 kW, 4 kW, and 5 kW power levels at 11.6 kV, and at 8 kW when operated at 14 kV. (see Figure 2.1.10-1). Reduced RF output levels are achieved by reducing either the input drive, beam current (by controlling mod anode and/or cathode power supplies), or both. Bandwidth requirements are to be met in all cases. Figures 3.3.1 - 3.3.5 were obtained with mod anode at zero volts and less than 2 watts of RF drive.

2.1.11 Small Signal Klystron Gain, Operating: 38 dB minimum

Klystron Gain is defined here to be the ratio of output to input power with output power defined as in 2.1.9 above. Input power is defined here to be the incident power to the Klystron. The maximum power input shall be less than 2 watts in any operating condition.

2.1.12 Klystron 4 kW (operating at 11.6 kV) Incremental Gain: At least 0.5.

4 kW incremental gain is defined as the ratio of the change in output power in dB to the change in the input drive power in dB. This is illustrated in figure 2.1.12-1.

2.1.13 Phase Pushing

2.1.13.1 Phase Pushing Versus RF Drive

Phase pushing due to change in RF drive shall not exceed 35 degrees for a change from the RF drive required for 250 watts output to the RF drive required for 5 kW RF output (mod anode at 0 volts, see 2.1.19).

2.1.13.2 Phase Pushing Versus Mod Anode Voltage

Phase pushing resulting from changes in mod anode voltage shall not exceed 20 degrees for an RF power change of 2 kW to 4 kW. Start this measurement with a mod anode voltage of -2.5 kV and adjust the RF drive to produce 2 kW of RF output. End the measurement with a mod anode voltage of -800 volts and 4 kW RF power output. Make minor adjustments to the mod anode volts if required to produce the specified RF power.

2.1.13.3 Phase Pushing Versus Cathode Voltage

Cathode voltage phase pushing shall not exceed 0.088 degrees per volt at normal operating voltage.

2.1.14 Nominal Klystron Beam Voltages: -11.6 kV (for 5 kW) and -14 kV (for 8 kW)

CEBAF will operate eight klystrons in one HPA cabinet with cathode high voltage by a single power supply. It is necessary that the klystrons delivered under this specification operate at the specified -11.6 kV (14 kV) beam voltage. The klystron shall be capable of continuous operation with full input beam power and no RF drive.

2.1.15 Klystron Beam Current: 1.33 amps maximum and not less than 1.1 amps DC, with mod anode set at 0 volts (see 2.1.19) and beam voltage of 11.6 kV, and 1.76 amps maximum with beam voltage of 14 kV.

2.1.16 Klystron Harmonic Power Output: Less than -20 dBc. for total power summed in all waveguide modes and in all harmonic frequencies below the sixth. There is no requirement for harmonic numbers above five. This requirement applies for RF power outputs from 500 watts to 8 kW.

2.1.17 Spurious Emissions: 70 dBc for operating RF output of 100 watts to 8 kW.

2.1.17.1 Band Edge Oscillations: There shall be no Band Edge oscillations when operating from 0 to 8 kW RF power output.

2.1.17.2 RF Drive Induced Oscillations

There shall be no oscillations on the RF output for any setting of the mod anode voltage when the RF drive is increased to any level up to 2 watts

2.1.17.3 RF Drive Suppressed Oscillations

Under normal operating conditions from 0 to 8 kW RF output, when the RF drive is reduced to zero, there shall be no oscillations.

2.1.18 Klystron RF Leakage

RF leakage from the Klystron at any power from 1 kW to 8 kW saturated RF output into a VSWR of 1.5 at any phase shall not exceed 5 mW/cm^2 at 6 inches from the Klystron in any direction.

2.1.19 Modulating Anode Voltages: 0 to -7000 kV Max.

Mod Anode voltage is defined as the voltage between the Mod Anode and the tube body (ground). With the Mod Anode at -5000 volts, RF output power on the order of 400 watts is required.

2.1.20 Modulating Anode Beam Interception: To minimize excessive heating of the gun assembly and potting material, mod anode current shall not exceed 3 mA with a cathode voltage of -11.6 kV and the mod anode grounded, or 2.5 mA when operated at 14 kV with mod anode grounded. These values should not be exceeded during conditions of any RF level from 0 to full output power.

2.1.21 Isolated Collector Voltage: 0.0 volts

2.1.22 Klystron Operational Life: 20,000 hours, minimum

Improvements in the design are desirable to extend life beyond 40,000 hours. Cathode longevity data is of utmost importance as a tube life determinant. This element of the proposal will be carefully reviewed and will be a weighted element in rating the overall proposal. It is expected that tube life shall not be limited by the cathode lifetime, and, as such, it is required that cathode life be on the order of 100,000 hours. Cathode emission current density shall not exceed 0.8 amp/cm^2. The cathode operating temperature shall not exceed 1010^0C. End of klystron life is defined as the time at which RF output power with an incremental gain of 0.5 with an input drive power of less than 2 watts maximum, drops to 3 kW. No change in cathode design, chemistry, or operating parameters shall be made without the prior written consent of CEBAF.

2.1.23 Cathode Heater Voltage: 7.3 VDC +/- 5%

2.1.24 Cathode Heater Current: 4.5 Amps, Max.

2.1.25 Cathode Inrush Current: 7.0 Amps Max.

(Note: The heater power supply design presently limits inrush current to 7.0 amperes.)

2.1.26 Cathode Thermal Rise Time: 10 minutes, max.

2.1.27 Output Connector: Std. 1 5/8 in. EIA Rigid coax with Marmon Clamp fitting. (see Figure 2.1.27)

2.1.28 RF Input Connector: Standard type N female connector.

2.1.29 Klystron Load and Output Conditions

The CEBAF 8 kW Klystron is required to operate into the transmission system depicted by Figure 1.1.1-1. At the Klystron output, an immediate transition from 1 5/8" coaxial line to WR650 waveguide is made. Vendors are to propose a klystron meeting the specification requirements while operating into the transmission system shown. The Circulator has a minimum isolation of 18 dB. The VSWR into the circulator is 1.3:1 maximum, which represents the nominal match of the waveguide system, however, the klystron must operate and meet specification requirements into a worst case VSWR of 1.4:1.

2.1.30 Klystron Internal Arcing: None in lifetime.

2.2 KLYSTRON MECHANICAL SPECIFICATIONS

2.2.1 Klystron Outline and Mounting Dimensions

CEBAF drawing K0066C01 shows the overall Klystron dimensions, the required physical arrangement and the location of the mounting holes. Klystrons from all Vendors must mount interchangeably in the same socket within the tube volume shown. Shims, which may be an integral part of the tube, may be utilized to develop the required dimensions where applicable. Particular attention must be given to the relationship between the mounting surface and the RF coaxial output transmission line.

2.2.2 Output Coaxial RF Line Support

The output coaxial line shall be mechanically supported from the Klystron tube body to stiffen the output line and prevent damage from normal mechanical stresses occurring during tube installation, tube removal, and other operating procedures.

2.2.3 Overall Weight Klystron and PM: 100 lbs. max.

2.2.4 Cooling: Collector and body cooling circuits shall utilize low conductivity, de ionized water. Vendor shall specify the minimum coolant flow required for operation at 14 kV if different than the rates stated below.

Collector:	5.0 gallons per minute, nominal (11.6 kV operation) 8.0 gallons per minute, nominal (14 kV operation) Pressure drop across the collector shall be 20 PSI max. at 5 GPM.
Body:	0.5 gallons per minute, nominal (11.6 kV operation) 0.8 gallons per minute, nominal (14 kV operation) Pressure drop across body shall be 20 PSI max. at 0.5 GPM.

The collector and body cooling circuits will be operated as parallel paths. As installed in the completed RF system, the collectors of two tubes will be connected in series.

Pressure, maximum: 150 PSIG.

Minimum differential pressure at the manifold will be 50 PSIG.

2.2.5 Coolant Inlet Temperature: 95º F, +/- 1 degree F

2.2.6 Maximum Collector Coolant Temperature Rise, 25ºF rise per tube with maximum beam current and no RF drive power.

2.2.7 Cathode Cooling: Convection only, no forced air.

2.2.8 Coolant Connectors: Collector: 37º 1/2 JIC(½")
Body: 37º 1/4 JIC(¼").

2.2.9 Klystron Isolated Collector Connection

A standard #6 stud shall be provided for the isolated collector electrical connection (see CEBAF drawing K0066C01).

2.2.10 Klystron Body Ground Connection

A Standard #8 stud shall be provided for the Klystron Body ground connection (see CEBAF dwg. K0066C01).

2.2.11 Klystron Filament, Cathode, Mod Anode Connections

Insulated Flying leads, 18 inch length nominal, with round terminal lugs suitable for a connection with a #10 screw shall be attached. The end of the electron gun, where the leads are attached, shall be vacuum potted with heat conducting, HV insulating, high temperature silicone compound. Emerson & Cuming's Eccosil 5952 should be used. Adequate high voltage insulation and a creep path suitable for long term service in a dirty environment shall be assured.

2.2.12 Mounting Position, Orientation: Axis - vertical, cathode down.

Due to the restricted space in the regions above the penetrations into the accelerator enclosure, the CEBAF klystrons must be grouped in relatively tight proximity to one another, and close to supporting structures and other magnetic materials. The spacing of klystrons in the CEBAF configuration provides for klystron magnets to be located at least 12 inches from other magnets and 6 inches from magnetic material.

2.2.13 Lifting Devices. Lifting Handles suitable for the weight of the Klystron shall be provided.

2.3 Klystron Ambient Conditions

2.3.1 Ambient Temperature: 33 to 120 ºF

2.3.2 Temperature Change Rate: 0 to 10 ºF per hour

2.3.3 Ambient Relative Humidity: 10% to 100%, non-condensing.

2.3.4 Relative Humidity Change Rate: 0 to 10% per hour

2.3.5 Acoustic Background: 60 dB above 10^{-16} watts/cm^2

2.3.6 Microwave Radiation Ambient from adjacent Klystrons each side, mounted 12 inches between tube surfaces. See section 2.1.18.

2.3.7 Bremstrahlung Ambient: Nominally none

2.4 Serial Numbers for Klystron Tubes. The serial number shall be permanently engraved on the outside of the tube body only, before final assembly. The serial number shall be of the following format: S/N XXXX.

The serial number of a tube that has been repaired or remanufactured under warranty and has new or alternate subassemblies incorporated shall remain the same as that of the RF body. Should the RF body of a tube not survive repair or remanufacture, that tube number shall be discontinued and not reissued for any other tube authorized for manufacture under this specification. Note: during original manufacturing should a tube fail and be scrapped, the serial number may be assigend to a subsequent tube.

When a tube is repaired, an R1, R2, or R3 will be added to the serial number. For example, if Klystron serial 0001 was returned for the first time for repair, the serial number would be changed to 0001R1. If this same tube were returned a second time for repair, the serial number would be changed from 0001R1 to 0001R2, etc.

3.0 Test Requirements for Production Klystrons

SCOPE. The Klystron shall meet all the requirements of this specification, however, the Vendor is only required to perform the tests defined in this section as required for production tubes. CEBAF reserves the right to test any of the specified parameters at any time or to make arrangements with the Vendor to test parameters other than those required tests defined by this section. The Vendor is required to prepare a Test Procedure based upon his facilities and recommendations to perform tests to adequately test the CEBAF Klystron. The Vendor Test Procedure shall be submitted to CEBAF within 60 days of contract award and requires written approval by CEBAF before implementation following contract award. Test results should be presented on a Test Data Sheet and/or appropriate graphs as required.

The Test Procedure defined by this section should be used as a guide by the Vendor. The tests and testing procedures are considered to be a minimum requirement for the manufacturing inspection of CEBAF Klystron Tubes. The procedure is to be applied without delay to every CEBAF Klystron tube as it becomes available for inspection following initial fabrication, repair or remanufacture.

Having satisfactorily completed all of the initial inspection and test procedures, the klystron, together with copies of all test data sheets and graphs, may be shipped to CEBAF for final testing, evaluation and acceptance. A klystron shall be deemed accepted if it passes the criteria established in CEBAF specification EE033 Rev. E, CEBAF Klystron Test Specification.

Variances encountered in the results of tests together with other matters pertaining to CEBAF klystrons shall be referred to the Klystron Review Panel maintained for this

purpose. The Klystron Review Panel shall consist of representatives of both CEBAF and the Vendor, as well as such outside expertise as may be required by CEBAF. CEBAF will call Panel meetings when it deems it necessary.

3.1 Klystron Longevity Data

CEBAF does not intend to conduct any Klystron tube life improvement or measurement program. However the nature of CEBAF operations will be such that considerable tube life data will become available through responsible operational records keeping. This data will be accumulated and may be made available to klystron manufacturers.

3.2 Required Klystron Tests and Data

The items defined in this section are to be performed on each klystron. Any klystron not meeting specified requirements is not acceptable for service in the CEBAF accelerator and must be rejected.

The following list of tests together with a data sheet of required discrete quantities and a mechanical conformance to CEBAF control drawing #K0066C01 comprise the complete test procedure to normally be performed on each klystron submitted under this specification. Additionally, any klystrons submitted as First Articles shall also undergo the tests listed in Attachment 01 of this specification.

Note: Most tests apply with 11.6 kV beam voltage and heater voltage adjusted to 7.3 VDC +/- 5%. Reference to 4.0 kW in these tests means: beam voltage at 11.6 kV, mod anode voltage set to 0 volts (see 2.1.19) and drive level set to 2 watts or less to achieve 4.0 kW output power and klystron incremental gain not less than 0.5. Tests to verify performance at 8 kW shall be made with beam voltage set to 14 kV and other conditions as previously stated.

3.2.1 Test List:

a) Static Heater Current at 7.3 volts DC.
Record Heater current, 4.5 Amperes DC maximum.

b) Static Beam Current versus Beam Voltage (Fig.3.3.1-1).
Plot curve with Beam Volts at values 1 kV to 12 kV.
At 11.6 kV beam volts, record beam current 1.33 amps max and 1.1 amps min.
At 14 kV beam volts, record beam current 1.76 amps max.

c) Static Beam current versus Mod Anode voltage (Fig.3.3.1-2).

Plot curve of Beam Current versus Mod Anode voltage with the Mod Anode voltage at values 0 to 7 kV.

d) Output pass band at 8.0 kW (14 kV), 5.0 kW, 4.0 kW, and 2 kW. (Fig.3.3.1-3, 3.3.1-4, and 3.3.1-5)
Plot curves with mid band 1497 MHz at 8 kW (14 kV), 5 kW, 4 kW, & 2 kW.
Output pass band requirements must be met with not more than 2 watts incident klystron input drive at any phase and klystron input VSWR.

e) Power Output Versus Drive Power. Mod anode set for 0 volts.(Fig. 3.3.1-6) Plot curve.
Do not exceed 2 watts RF drive. Record saturated RF power or maximum RF power, both at 11.6 kV and 14 kV.
Record maximum Klystron body current during this test. Body current must not exceed 150 milliamperes.

f) Incremental Gain- Set mod anode voltage to 0 volts (see 2.1.19) and RF klystron input incident drive of 2 watts maximum for 4 kW RF output (11.6 kV). (Fig.2.1.12-1).
Measure Incremental Gain: 0.5 minimum Record Incremental Gain.

g) Proper coolant flow verification.
Collector Flow: 5 GPM with pressure drop across the collector not more than 20 PSIG.
Record coolant flow and pressure drop.
Body Flow: 0.5 GPM with pressure drop across body not more than 20 PSIG.
Record coolant flows and pressure drops.

h) A four hour Heat Run (burn in) at 8 kW (14 kV) CW power output. Record completion.

i) Emission Test. At the end of the 4 hour Heat Run in h) above, record the klystron cathode current and reduce klystron heater voltage 10%. After operation at reduced heater voltage for 10 minutes, klystron cathode current shall not decrease by more than 10%. Record the klystron cathode current percent reduction.

3.3 Visual Inspection (Required for all Klystrons, see K0066C01). Record any discrepancies and completion.

3.3.1 Prior to potting the klystron gun assembly, the gun ceramic surfaces, connections, and leads shall be carefully examined.

3.3.2 A CEBAF klystron which becomes available for production inspection shall first be visually inspected for detailed conformity with CEBAF Drawing # K0066C01. Record when Complete.

3.4 CEBAF Klystron Production Inspection and Test Data Sheets

Production Inspection, Test Data Sheets and graphs shall be supplied with each klystron when the tube is delivered to CEBAF.

3.5 Klystron Failure Analyses and Remanufacture Histories

The klystron Vendor is to provide failure analyses, and, where applicable, remanufacturing histories to CEBAF for tubes returned to the Vendor for failure, or for those that failed during manufacture or during the warranty repair.

3.6 Engineering Changes to Klystron Design

The klystron Vendor shall supply, to CEBAF, copies of all Engineering Change Orders (ECO's), or their equivalent, pertaining to the construction of the CEBAF klystrons prior to any such change being implemented. CEBAF shall have 48 hours to reply to the ECO's. Approval of the ECO's will be contingent on their having no adverse effect on the form, fit, or function of the klystron. Identification of an "Emergency" will cause CEBAF to conclude a review within 24 hours for an ECO addressing a minor variation. The CEBAF designated point of contact for ECO review is Richard Nelson, with Jock Fugitt as alternate.