CLS Storage Ring Amplifier System Specification

5.4.32.2 Rev. 0

2000 January 16

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Canadian Light Source
107 North Road
University of Saskatchewan
Saskatoon, Saskatchewan Canada

	Signature	Date
	Original on File – Signed by:	
Author:	R. M. Silzer	
Reviewer #1:	Dan Lowe	
Reviewer #2:	Neil Johnson	
Approver:	M. de Jong	

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TABLE OF CONTENTS

1. INTRODUCTION

1.1 Purpose

This document specifies the requirements for the Canadian Light Source (CLS) storage ring RF amplifier system.

The Canadian Light Source requires an amplifier system to power the superconducting acceleration module for the CLS storage ring. The amplifier system is to be designed, fabricated, delivered to the CLS site, tested, and installed for use with the storage ring. An additional klystron tube to be held at the klystron manufacturers location is required to serve as a spare.

1.2 Scope

The amplifier system includes the drive amplifier, klystron, high voltage supply, modulating anode supply, all other auxiliary supplies and controls required for the klystron operation, WR-1800 waveguide, directional couplers, high-power circulator, full power water loads, and any additional waveguide components that are required.

This specification details the requirements for the design, fabrication, supply, and testing of the amplifier system. This work includes, but is not limited to:

- Materials
- Equipment
- Commercial components
- Detailed drawings
- Fabrication
- Assembly
- Testing and Inspections
- Quality Assurance /Quality Control documentation
- Delivery to site
- Installation

1.3 Background

The Canadian Light Source, CLS, is a national facility under construction on the University of Saskatchewan campus in Saskatoon, Saskatchewan. This facility will be a 3rd generation synchrotron light source, which will produce a high intensity source of infrared, visible, ultraviolet and x-ray radiation.

This facility will use a 500 MHz superconducting RF acceleration module installed into the CLS storage ring. The RF acceleration module will supply sufficient power to the electron beam to make up for power losses to synchrotron light in the dipoles and insertion devices, as well as power that is coupled through the ring impedances and dissipated in the walls of the vacuum chamber. The design current for the CLS storage ring is 500 mA.

The storage ring will be capable of circulating electrons with energies of up to 2.9 GeV. At this energy, the expected power loss of the beam will be approximately 110 kW per 100mA of circulating current. The CLS has decided to meet its design current through a two stage approach. All systems, excluding the RF system, will be designed for operation in excess of 500 mA. In phase one, the RF system will be sized to allow for a minimum of 200 mA of circulating beam. Phase two will be to reach 500 mA. Thus, the initial RF installation requires a minimum of 250 kW to facilitate operation over the 200 mA level.

Further background information can be seen in the attached report “CLS RF Design Note” (CLS 2.1.4 Rev 0)

2. AMPLIFIER GLOBAL REQUIREMENTS

2.1 Functional Requirements

2.1.1 The Proponent shall supply one complete RF amplifier station used to supply RF power to the RF cavity located in the CLS storage ring.

2.1.2 The amplifier system shall include all of the components shown in the attached drawing SR1/PFD/RF/0049100 Rev. A, excluding the RF cavity module. Additional components not shown in the figure may also be required to meet this specification and shall be the responsibility of the Proponent.

2.1.3 All large components of the amplifier system shall be equipped with crane attachments for lifting the components.

2.1.4 The Proponent shall supply all cooling water supply and return manifolds for the system.

2.1.5 Unless otherwise stated, the Proponent shall supply all monitoring transducers (e.g., temperature, flow) required for adequate monitoring of the system.

2.1.6 Provisions shall be made for remote control and monitoring by CLS computers. This shall include, but not be limited to, the system power supplies, RF drive amplifier, temperature and flow monitoring, and RF power monitoring.

2.1.7 The amplifier control system shall be designed to interface with the CLS Distributed Control System (DCS). The interface may use EPICS communication protocols, RS-232 or RS-485. The interface shall be reviewed and accepted by the CLS before being implemented.

2.1.8 If a PLC is used, it should be based on a Modicon or Siemens controller with a Modbus (Plus or TCP/IP) interface. Programmable logic controller (PLC) control software programs shall be provided by the Proponent.

2.1.9 Controller hardware and software must be reviewed and accepted by the CLS to verify adherence to the CLS standard control protocols and standards.

2.1.10 A local emergency off switch with mechanical latching shall be provided for the RF amplifier system. This system shall employ redundant and independent means of shutdown.

2.1.11 The amplifier system shall have a small number of clearly defined operational states. These states shall allow for monitoring of interlock status through all states, running of the klystron filaments without HV applied, running of HV and filaments without RF on, and states that allow for logical handling of RF trips and the easy commissioning of a new klystron. One possible set of operational states for the amplifier system is shown below:

RF ON	RF drive to the klystron is enabled.
HV ON	High Voltage is being supplied to the klystron. The application of RF is permitted from the HV ON state.
HV ENABLE	This state indicates that the klystron filaments have had sufficient run up time, and all other interlocks are satisfied to permit the application of high voltage to the klystron tube.
STANDBY, (FILAMENTS ON)	This state indicates that power is supplied to all systems except the HV power supply. The filament power is supplied but a sufficient warm-up time may not have elapsed. Interlocks permit the application of power to the filaments but not the application of HV to the klystron tube.
FILAMENTS OFF	This state indicates that a klystron ion pump over-current or a klystron over-temperature has occurred that has warranted the removal of power from the filaments A manual reset is required to reenergize the filaments.
OFF	In the OFF state, all AC load connections shall be disconnected. Control unit power shall not be de-energized in the OFF state; it will be used for status monitoring during the OFF state. 24 V shall be supplied to interlock sensors and

	indicators on the local control panel will indicate the status of these interlocks. The supply should be able to be turned off from any other state.

Transitions up the table enable more functions, while transitions down the table disable some functions. The FILAMENTS OFF state is a special state that is not to be entered from below but can be entered from above due to certain fault conditions or a user request. There are 20 possible transitions that can be permitted between the states listed in the table. These are:

UPWARD TRANSITIONS TO TURN ON THE SYSTEM

1. OFF to STANDBY

This transition will occur when a request is made to supply power to the filaments.

2. FILAMENTS OFF to STANDBY

This transition will occur due to a request for the application of power to the filaments from the FILAMENTS OFF state.

3. STANDBY to HV ENABLE

This transition will occur if the filaments have had sufficient time to warm up and no other interlocks are in a state to prevent the application of HV to the klystron.

4. HV ENABLE to HV ON

Request for the application of klystron HV.

5. HV ON to RF ON

Request for the application of RF.

DOWNWARD TRANSITIONS DUE TO FAULTS OR USER REQUESTS

6. RF ON to HV ON

The RF can be disabled with a RF DISABLE command. This may also occur from a trip that warrants the removal of RF but not the removal of the klystron HV.

7. RF ON to HV ENABLE

This transition will occur due to a trip that warrants the removal of the RF drive and the klystron HV, but not the removal of the power to the filaments. To move to the HV ENABLE state, all interlocks must be in a good state to permit the application of HV if requested. This transition may also occur due to a user request.

8. RF ON to STANDBY

This transition will occur due to a trip that warrants the removal of the RF drive and the removal of the klystron HV, but not the removal of power to the filaments. To move to the STANDBY state, some interlocks must be in a state that will not permit the application of klystron HV.

9. RF ON to FILAMENTS OFF

This transition will occur due to a trip that requires that power be removed from the filaments as well as removal of the RF drive and the klystron HV.

10. RF ON to OFF

This transition can occur due to a major trip. Things such as power outages will require a trip right to the OFF state. The OFF state can also be entered due to a user request. The OFF state may be entered to reset any PLC's, reinitialise any registers, and reset any timers used for the filament warm up.

11. HV ON to HV ENABLE

This transition will occur due to a trip that warrants the removal of the klystron HV, but not the removal of the power to the filaments. To move to the HV ENABLE state, all interlocks must be in a good state to permit the application of HV if requested. This transition may also occur from a request to remove the klystron HV.

12. HV ON to STANDBY

This transition will occur due to a trip that warrants the removal of the klystron HV, but not the removal of power to the filaments. To move to the STANDBY state, some interlocks must be in a state that will not permit the application of klystron HV.

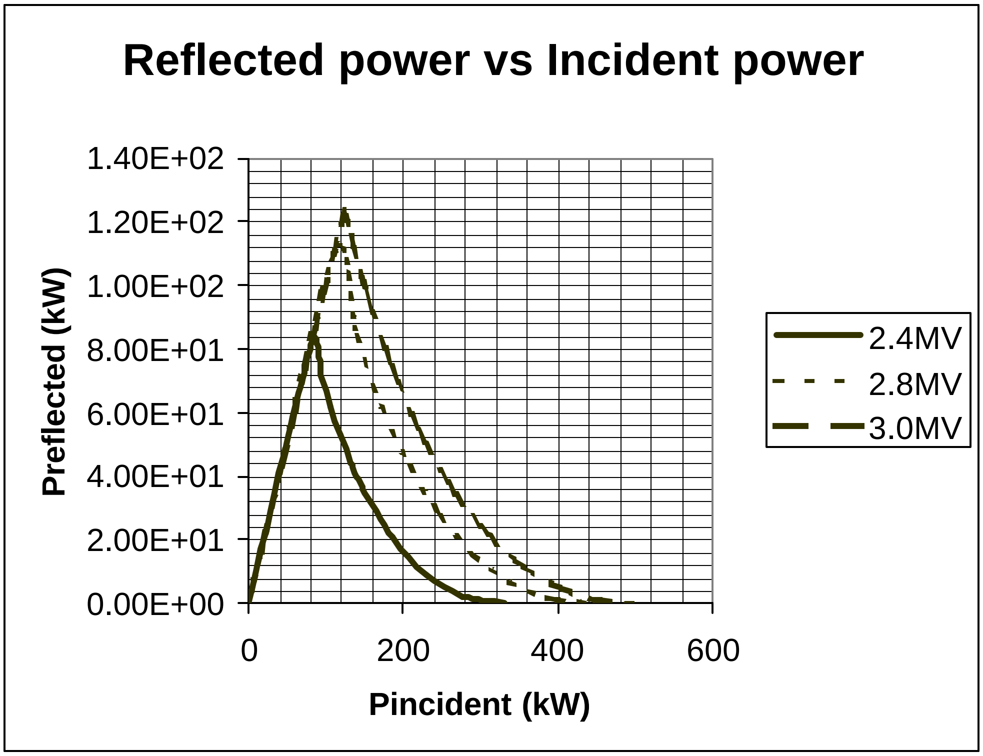
13. HV ON to FILAMENTS OFF
This transition will occur due to a trip that requires that power be removed from the filaments as well as removal of the klystron HV.
14. HV ON to OFF
This transition can occur due to a major trip. Things such as power outages will require a trip right to the OFF state. The OFF state can also be entered due to a user request. The OFF state may be entered to reset any PLC's, reinitialise any registers, and reset any timers used for the filament warm up.
15. HV ENABLE to STANDBY
This transition will occur when some interlock(s) have changed state to not permit the application of klystron HV.
16. HV ENABLE to FILAMENTS OFF
This transition will occur due to a trip that requires that power be removed from the filaments.
17. HV ENABLE to OFF
This transition can occur due to a major trip. Things such as power outages will require a trip right to the OFF state. The OFF state can also be entered due to a user request. The OFF state may be entered to reset any PLC's, reinitialise any registers, and reset any timers used for the filament warm up.
18. STANDBY to FILAMENTS OFF
This transition will occur due to a trip that requires that power be removed from the filaments or a request is made to remove power from the filaments.
19. STANDBY to OFF
This transition can occur due to a major trip. Things such as power outages will require a trip right to the OFF state. The OFF state can also be entered due to a user request. The OFF state may be entered to reset any PLC's, reinitialise any registers, and rest any timers used for the filament warm up.
20. FILAMENTS OFF to OFF
This transition can occur due to a major trip. Things such as power outages will require a trip right to the OFF state. The OFF state can also be entered due to a user request. The OFF state may be entered to reset any PLC's, reinitialise any registers, and reset any timers used for the filament warm up.

2.2 Performance

2.2.1 The amplifier system shall be capable of continuous operation at 500.00 MHz.

2.2.2 The amplifier station shall be capable of a maximum CW output power of:
OPTION 1: The installed output power shall have a maximum of between 275 kW to 350 kW.
OPTION 2: The installed output power shall have a maximum of between 475 kW to 600 kW.
In each case, the amplifier shall be able to operate continuously at output power levels ranging from 0 to 100% of the installed power level although normal operation will not exceed 90 % of the maximum output power.

2.2.3 The amplifier shall be designed for operation with a 500 MHz superconducting cavity. The operation of a superconducting cavity differs from a conventional cavity in that under normal operation, there is very little power dissipated in the cavity walls compared to the power that is transferred to the beam. For this reason, heavily beam loaded cavities require very strong coupling to achieve reflectionless operation. As a consequence, the cavity will appear as a highly mismatched load when operated at beam currents below the design limit. The target $Q_{external}$ for the CLS superconducting cavity is 2×10^5 giving an expected operation of the cavity characterized by the graph shown below:



2.2.4 The goal for amplitude and phase stability of the RF in the cavity is better than 1 percent and better than half a degree respectively.

2.2.5 The amplifier system shall operate at a frequency of 500.00 MHz, with a bandwidth of greater than +/- 400 kHz measured at the –3dB points.

2.2.6 No elements of the amplifier system should extend above a height of 4.0 m from the floor height.

2.2.7 Unless explicitly stated, all control and monitoring of the amplifier station shall conform with the "CLS Design Specification Control System Overview" (CLS2.42.39.002 Rev. 0).

2.2.8 The CLS will supply a phase stable RF reference to the amplifier system. The RF input to the acceleration module will be a signal of the order of 50 mW (17 dBm).

2.2.9 The total mass of any one component should be less than 2500 kilograms.

2.2.10 All control and interlock signal inputs shall be 24 V DC and shall require less than 50 mA drive. Interfaces with CLS equipment shall be designed to work with external optical isolators.

2.2.11 All control and interlock signal outputs shall be 24 V DC and shall be able to switch a minimum of 50 mA and use optical or some other form of isolation.

2.3 Safety and Environmental

2.3.1 The general layout of the main floor of the CLS can be seen in the diagram BLDG/ME/0035100 REV. N.

2.3.2 The RF amplifier system shall be capable of operation in an ambient temperature range of 10° C to 40° C. The normal ambient temperature of the main floor area at the CLS is 23° C. The expected temperature stability of the main floor will be +/- 1° C during normal operation.

2.3.3 The main CLS building will be equipped with an overhead sprinkler system. All components of the RF amplifier system shall be installed in a "weather-resistant" condition or housed in "weather-resistant" cabinets that are capable of withstanding modest exposure to water or other fluids.

2.3.4 The components shall be able to withstand a relative humidity range of 0 % to 90%. The expected relative humidity limits under operation are from 25% during the winter months and a maximum of 50% during the summer months. The expected relative humidity range for components under storage will be the same as previously mentioned.

2.3.5 No components of the RF amplifier system shall induce a vibration source to the floor greater than 0.4 microns at frequencies less than 100 Hz. All equipment/structures shall conform to the BKL report "Vibration Isolation Mechanical Equipment".

2.3.6 Low conductivity cooling water (LCW) will be supplied by the CLS. The supply water will have a conductivity of less than 600 μS/m.

2.3.7 The Proponent shall specify the expected consumption of low conductivity water for the normal operation of the amplifier system.

2.3.8 The Proponent should limit the consumption of low conductivity water to less than 1000 litres per minute.

2.3.9 The Proponent shall supply the CLS with its LCW consumption requirements within 80 days of the award of the contract.

2.3.10 Where water cooling is required, the cooling system shall operate at an input pressure of 1 MPa.

2.3.11 The pressure drop to achieved the required flows in the cooling water circuits shall not exceed 800 kPa.

2.3.12 Any cooling circuits should be designed so that under normal operation the velocity of the cooling water is maintained in the transition zone between laminar and turbulent flow. This corresponds to roughly 1.5 to 2 m/sec.

2.3.13 Supply temperature of the LCW will be nominally between 27 to 33 degrees Celsius. The maximum water inlet temperature is 40 degrees Celsius and the minimum water inlet temperature is 10 degrees Celsius.

2.3.14 The Proponent shall supply notify the CLS of any special cooling water requirements at the time of the bid.

2.3.15 The maximum temperature rise in the water cooling circuits should be kept below 20 K.

2.3.16 All small tubing water connections shall be American standard Swagelok fittings. All large water tubing shall use NPT treads.

2.3.17 AC input power will be supplied through a CLS-installed, external, manually operated disconnect switch, which is normally closed.

2.3.18 All supplies with an input supply requirement exceeding 2.5 kVA shall incorporate circuitry to reduce harmonic current components on the supply lines. As a minimum, this circuitry shall include the equivalent of 12 pulse rectification.

2.3.19 The electrical power supplied by the CLS will be 60 Hz AC. Each load connection shall be one of the voltage levels listed below and not exceed the current limits given in Table 1.

Table1: Load Connections

RMS voltage (V,+/- 10 %)	Single or Three Phase	Maximum RMS current (A)
120	Single	15
208	Single	15
208	Three	30
600	Three	1900

Line voltage will exhibit instantaneous (faster than one millisecond) fluctuations of +/- 1.5 % and gradual variations of +/- 10 %. Brownout conditions involving instantaneous drops and restorations of 10 % are also observed.

2.3.20 The use of liquid dielectrics (High Voltage oil) as an insulator should be avoided. The use of oil requires a more elaborate fire protection system to be implemented (CO_2 system). A second major disadvantage is the possible contamination of our UHV vacuum system when oil is used in close proximity. All fire protection systems shall be the responsibility of the Proponent. Any use of oil in the amplifier system shall be subject to review and acceptance by the CLS.

2.3.21 Every effort shall be made through careful design to keep the acoustic noise levels well below 60 dB. Noise levels above 60 dB limits effective communication and warning sounds such as sparking are masked.

2.3.22 The amplifier system shall be designed and assembled to avoid all holes, cracks, or defective joints that may allow RF power to radiate into the room. RF exposure limits shall follow the Radiation Health and Safety Regulations of the Saskatchewan Occupational Health and Safety, levels for continuous unprotected exposure to RF radiation for occupational workers shall be less that those outlined below:

Frequency Range (MHZ): 300 to 1,500
Power Density (W/m2): f/30
Electric Field Intensity (V/m): 3.46f
Magnetic Field Intensity (A/m): 0.0093f

f = frequency of source expressed in MHz

The Proponent should strive to achieve the radiation levels for the general public if it is not technically or cost prohibitive. The exposure limits for the public are one tenth of those mentioned above.

Where a microwave source is capable of producing power densities greater than the values mentioned the owner shall ensure that a sign bearing the microwave warning symbol and the words "MICROWAVE RADIATION" is prominently displayed in any area to which a person may have access. Supply of the warning signs is the responsibility of the Proponent.

The Proponent shall adhere to the guidelines outlined in the document “Industry Canada ICES-001 Industrial, Scientific and Medical Radio Frequency Generators” if they are more prohibitive.

2.3.23 Sufficient shielding shall be designed into the amplifier system to reduce the X-ray radiation to a safe level. For x-rays, the shielding should be provided to ensure that the effective dose equivalent is below ALARA levels of 0.5 uSv/hr (50 uR/hr) at a distance of 300 mm. The level outlined above may be allowed to increase up to 5 uSv/hr depending on the occupancy factor and cost for providing shielding to achieve 0.5 uSv/hr.

2.3.24 In general, the amplifier system can be set up and operated according to standard industrial practices. However, maintenance and testing in some cases may be expedited by deviating from standard practices provided extra precautions are taken to reduce hazard to an acceptable level before these deviations are permitted.

2.3.25 All equipment must be housed in a suitable enclosure to prevent contact with high voltage by personnel. These enclosures may be one of the following:

1. Permanent completely enclosed cabinets
   Permanent cabinets should be constructed of metal panels with plastic or safety glass for windows when necessary. They should be constructed so that it is impossible to touch high voltage from the outside with a thin conductor of reasonable length. These cabinets must provide protection for uninformed personnel and be suitable for unattended operation. Doors must be fitted with redundant and independent interlocks.
2. Permanent walk-in enclosures

Walk-in enclosures may be used for equipment that occupies large areas. The walls of such enclosures must be a minimum of 2 m high and should be higher than the equipment. They may be constructed of perforated metal with openings smaller than 1 cm or have solid walls with safety glass or plastic windows to allow for a clear view of the inside. Access doors must be fitted with redundant and independent interlocks. Local control panels are required outside the enclosure but close to it so that the operator can readily check that no one is inside during operation. They must provide protection for uninformed personnel and be suitable for unattended operation.

Cabinets or walk-in enclosures shall be equipped with grounding hooks to allow for the safe discharge of high voltage on equipment that may retain a charge. These grounding hooks should be positioned to prevent access without the hooks being moved.

2.4 Applicable Codes, Standards and Procedures

2.4.1 The following documents can be considered as part of this specification. All equipment shall be built in strict accordance with the following standards:

1. CSA Canadian Electrical Code 1998 Safety Standards for Electrical Installations.
2. ANSI/IEEE Std. 519-1992 IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
3. Industry Canada ICES-001 Industrial, Scientific and Medical Radio Frequency Generators
4. ANSI/IEEE Standard C57 Distribution, Power and Regulating Transformers.
5. NEMA Pub. No. SG 5 – 1995 Power Switchgear Assemblies.
6. Radiation Health and Safety Regulations of the Saskatchewan Occupational Health and Safety

2.4.2 Unless otherwise specified, the issue date or revision level shall be that in effect on the date of the Invitation to Quote. Exceptions to these standards shall be reviewed and accepted by the CLS.

2.5 Quality Assurance

2.5.1 The Proponent shall maintain and apply a quality assurance program compliant with ISO-9001 for the design, manufacture and testing of all components.

2.6 Inspection, Testing and Commissioning

2.6.1 The installation of the amplifier system shall be done by the CLS staff with supervision from the Proponent. The CLS main hall is equipped with a 10 tonne overhead crane. The crane has coverage extending from the loading area to drop areas inside of the storage ring.

2.6.2 Installation and testing shall conform at all times to the local safety codes.

2.6.3 The CLS reserves the right to have access to the Proponent's facility at any time during the fabrication and testing procedures. The CLS shall have the right to witness any manufacturing or testing procedures upon request. When requested, the Proponent shall provide a minimum of 21 days notice in advance of any test date to allow for the CLS to make the necessary travel arrangements.

2.6.4 The CLS reserves the right to require additional or more extensive tests to be conducted in the event of marginal design or performance.

2.6.5 The Proponent shall formulate acceptance test procedures for all components and will provide the facility and instrumentation to perform all relevant tests to ensure compliance with this specification. The acceptance test procedures shall include but not be limited to all of the testing procedures specifically outlined in this document.

2.6.6 All items purchased or manufactured by a subcontractor used in the work shall be clearly identified to the CLS.

2.6.7 Review and acceptance of the CLS shall not release the Proponent from its responsibility to correct errors, oversights and omissions to ensure conformance to the specifications in this document.

2.7 Reliability and Maintainability

2.7.1 All elements of the amplifier system shall be designed and manufactured with strong consideration for both reliability and serviceability. Access to all external connection points must be incorporated into the overall design.

2.7.2 The Proponent shall supply documentation to the CLS outlining the expected maintenance requirements and schedules for all major subsystems of the RF amplifier system. A list of recommended spare parts along with cost information shall be supplied by the Proponent.

2.7.3 The amplifier system shall be designed and constructed to be in continuous use with only limited maintenance periods throughout the year. Major maintenance periods will be scheduled twice a year and have a duration of approximately 10 working days. Weekly maintenance periods will likely be scheduled to last for one 8 hour time period. Weekly maintenance should not be required for the amplifier system. The total maintenance time annually should not exceed 6 man-days. The target time limit for the replacement of the in-service klystron amplifier with the spare should be less than 2 working days after delivery of the spare, with a total manpower of less than 10 man-days.

2.7.4 All components shall have a minimum mean time between failure (MTBF) of 40,000 hours in the operational environment at the CLS as outlined in this specification.

2.7.5 The amplifier system shall be designed and constructed in such a way as to supply access to any system components that are expected to fail in the normal operating environment. This will facilitate easy replacement of such components upon failure or during scheduled maintenance periods.

2.7.6 The amplifier system shall be designed and constructed with an expected operational lifetime of greater than 20 years given that the klystron tube is considered as a replaceable item. The expected lifetime of the klystron should exceed 50000 operational hours at maximum RF output. Filament lifetime should exceed 75000 hours.

2.7.7 All threaded mechanical fasteners should be American Standard Thread. The use of metric standards is negotiable with the CLS. If metric standards are used, additional spare nuts and bolts shall be provided by the proponent.

2.8 Layout

2.8.1 The entire amplifier system including power supplies and all associated safety systems shall be located in the interior of the CLS booster ring. The CLS requires a 1.5 meter wide walk way extending from the shielding chicane to the central region of the booster. The area available for installing the amplifier system can be seen in the attached diagram SR1/ME/RF/0049000 Rev. A (SR1 RF Yard Plan View). Deviations from this specification shall be subject to review and acceptance by the CLS.

2.8.2 The amplifier system shall be positioned to allow easy connection to the WR-1800 waveguide run outlined in diagrams SR1/PPL/RF/0034304 Rev. B (SR1 RF Cavity Tunnel Cross Section) and SR1/ME/RF/0037100 Rev. D (SR1 RF Straight Section General Plan View). The Proponent shall supply any additional waveguide components required to connect to the proposed waveguide run outlined in the two diagrams.

2.9 Other Requirements and Constraints

2.9.1 The Proponent shall supply complete documentation of all components and subsystems contained in the amplifier system. This documentation shall include but be not limited to the following:

1. Users/operation manual for the amplifier system. These manuals shall contain, but not be limited to: specifications, operating instructions, hook-up instructions, circuit diagrams, block diagrams, PLC programs (also provided on CD-ROM), maintenance procedures (both operational and preventative), component data sheets, normal adjustments and calibration setup procedures.

2. A final parts list along with a list of recommended spare parts and their cost information.
3. A complete set of electrical and mechanical as-built drawings shall be supplied for each power supply.
4. Mechanical drawings of the klystron, circulator, water loads and all associated support stands.
5. Layout diagrams of the full amplifier system.
6. Mechanical layout diagram of all components including dimensions of all waveguide components.

All documentation should conform to the "CLS documentation specification" (CLS2.42.01.001 Rev. 1). Electrical diagrams should be presented in Orcad® 9.2 or Autocad® R14 or Autocad® 2000 or Cadsoft Eagle 3.5. Hardcopies shall be provided of all documentation along with copies on CD-ROM.

2.9.2 The Proponent shall provide the CLS with electronic copies of all custom developed source code, PLC programming and embedded logic in source and binary format on CD-ROM or equivalent media.

2.9.3 All measurement results shall be filed in hardcopy, on magnetic media, and archived at the Proponent's location in duplicate.

2.9.4 One set of measurements in hardcopy and an electronic copy on magnetic media shall be sent to CLS after all major assembly and measurement procedures. Frequent data transfer is encouraged.

2.9.5 All equipment/structures shall be labelled with a unique serial number with details to be worked out with the CLS.

3. AMPLIFIER COMPONENT REQUIREMENTS

3.1 Functional Requirements

KLYSTRON:

3.1.1 The main amplifier should be a klystron equipped with the capability of modulating anode power control.

3.1.2 The Proponent shall supply and implement all interlocks required by the klystron manufacturer.

3.1.3 The Proponent shall supply interlocks to prevent the application of beam voltage unless focussing magnet currents, coolant flow rates, and the klystron vacuum are within the specifications outlined by the klystron manufacturer.

3.1.4 When applicable, the Proponent shall provide coolant-flow interlocks to prevent the application of RF unless the klystron window air flow is at or above the minimum value specified by the klystron manufacturer.

3.1.5 The Proponent shall supply any dehydrators, blowers and or filters required for the klystron operation.

POWERSUPPLIES:

3.1.6 All power supplies used in the operation of the klystron shall meet or exceed the requirements set out by the klystron manufacturer.

3.1.7 The Proponent shall provide the coordination and all the hardware to implement the power supply operation, both interlocks and control.

3.1.8 Proponents may elect to control several power supplies with one PLC unit, provided the supplies are housed in close proximity to each other.

3.1.9 Unless explicitly stated in this document, all individual power supplies shall have a minimum of four operational control command states. These should be OFF, FAULT, STANDBY, and ON. The status of the power supply shall be displayed locally.

ON	The ON state energizes the power supply main contactor and output power is made available. The supply should be able to enter the ON state from the

	STANDBY or the OFF state with an ON command.
STANDBY	In the STANDBY state, the low level regulation and control circuitry will be energized but not the main contactor. All interlocks (internal and external) must be satisfied for the supply to be in the STANDBY state. The supply is ready to be turned ON. The unit should be able to be changed from the ON state to the STANDBY state with a STANDBY command. A RESET should clear all latched faults that are specific to the power supply and allow the unit to enter the STANDBY state if all other external interlocks are satisfied.
FAULT	The FAULT state will indicate that a fault has occurred during the power supply operation. Alternately, if the supply is requested to enter the ON or STANDBY state from the OFF state, the supply will enter the fault state if all internal and external interlocks are not satisfied. All faults shall be displayed locally as an INTERNAL or EXTERNAL fault
OFF	Control unit power shall not be de-energized in the OFF state; it will be used for status monitoring during the OFF state. The supply should be able to be turned off from any other state.

Other operational states such as a WARNING state or a STARTUP state may be implemented by the Proponent. Deviations from this specification on the operational states of power supplies is permitted. The operational states of the power supplies implementation of the transitions between states is subject to review and acceptance by the CLS.

3.1.10 The Proponent shall provide hard-wired trip of the HV power supply to the FAULT or OFF state.

3.1.11 The design of the control system shall be fail-safe. On a loss of control power the power supply shall safely trip OFF. Upon return of power, the power supply shall remain in the OFF state.

3.1.12 Indicator lights and status bits shall indicate true operation, not just control activity.

3.1.13 A local emergency off switch with mechanical latching shall be provided for the HV supply. This system shall employ redundant and independent means of shutdown.

3.1.14 The protection devices and circuits on all power supplies shall be properly isolated from the main power circuits. All interlocks status and alarm information shall be latched and displayed locally on a local alarm panel and monitored by the internal power supply control system. Some interlocks shall be wired directly to the main contactor coil. These interlocks are indicated in section 3.1.15. The interlocks and indication circuitry shall be subject to review and acceptance by the CLS.

3.1.15 Where applicable, the following interlocks shall be incorporated in the power supplies and where indicated shall be used to de-energize the main contactor.

1. DC over current
2. Door microswitches – wired directly to main contactor coil: these should have a manual bypass capability which is automatically reset when the door is closed.
3. Cooling failure
4. Transformer/choke over temperatures – wired directly to main contactor coil
5. Semiconductor over temperature
6. Cubicle over temperature – wired directly to main contactor coil
7. Regulator failure
8. Ground fault – wired directly to main contactor coil
9. Control power failure – wired directly to main contactor coil
10. Local Emergency Off (mechanical latching pushbutton) – wired directly to main contactor coil
11. Two external (customer) interlock, with +24 V indicating main contactor can be energized.

3.1.16 The transformers used shall conform to the following specifications:

1. The rectifier power transformer shall be built with copper windings.
2. No splices shall be allowed.
3. The transformer shall be dry type.

4. The insulation shall be IEEE class 180 (class H)
5. The transformer shall be braced for rectifier service and shall be able to withstand the worst case fault currents that are available.
6. The units shall be air cooled, either forced or by convection.
7. It shall withstand input voltages of 110% of nominal without overheating.
8. Three phase primary windings shall be delta connected.
9. The transformer shall conform to applicable subdivisions of ANSI standard C57.

3.1.17 The junction temperature of any power semiconductors shall not exceed 100 ^{o}C with an ambient temperature of 40 ^{o}C.

3.1.18 All power supplies with greater than 2 kW output should be cooled using natural convection. Water-cooled semiconductors are allowed if other than convection cooling is required. Alternate cooling schemes shall be reviewed and accepted by the CLS. Manual reset snap action thermal switches shall be mounted on all heat sinks. These shall be placed adjacent to the power semiconductors, and shall open the primary contactor before the maximum junction temperature of 100 ^{o}C is reached.

3.1.19 Voltage limiting devices or snubber circuits shall be placed across each rectifier cell and power semiconductor device. The snubber circuits should be adequate to limit the voltage transients experienced by the semiconductors as a result of switching transient to no more than 60 % of the manufacturer's voltage rating.

3.1.20 If phase control SCR's are used the trigger circuitry should be pulse transformer or optically isolated from the high power circuitry.

3.1.21 Unipolar supplies should have a reverse connected diode across the DC output terminals. This diode provides a short circuit current path for the continuing inductive load current upon turn-off. The diode shall be capable of operating continuously at the power supply full rated DC current. This diode shall be mounted on an adequate heat sink to allow it to be operated at this maximum rating continuously without exceeding its thermal ratings. This diode shall not be fused.

3.1.22 Capacitors filled with flammable liquids shall limit the volume of the liquid to 14 litres or less and comply with the Canadian Electrical Code requirement 26-012 part (4). Unipolar capacitors shall be protected against reverse charging.

3.1.23 The Proponent shall supply the ion pump power supply/controller required for maintaining the klystron vacuum.

3.1.24 The Proponent shall supply the klystron cathode heater supply. This supply shall be lifted to a high voltage potential and receive its AC power via a high voltage isolation transformer also supplied by the Proponent. The heater supply shall have a current-limited output and conform to the specifications of the klystron manufacturer. If required, it shall be controlled by an optical fibre system.

3.1.25 The Proponent shall be responsible for supplying all magnetic focussing power supplies required for the operation of the klystron.

3.1.26 The Proponent shall supply the HV DC power source used to supply the klystron anode-to-cathode voltage.

3.1.27 If required by the klystron manufacturer, the Proponent shall provide an electronic crowbar on the HV supply. The crowbar shall exceed all requirements outlined by the klystron manufacturer.

3.1.28 The HV supply shall be equipped with a primary contactor. The contactor shall be operated from a variable threshold over-current sensing device and the safety interlock system in the power supply and shall be remotely operable from either of two remote inputs. One input shall be connected to the power supply control system so it can be monitored by external CLS computers. The other shall be brought to a terminal strip for CLS use. As well, if applicable, the contactor shall be operable from a load crowbar signal.

3.1.29 The Proponent shall supply a breaker (600 V) used on the AC line to the high voltage klystron power supply. This breaker should be located at the location of the HV power supply. The circuit breaker and contactor shall be mounted inside the unit, and barriered or in a separate compartment so that live connections on both line and load are not exposed

3.1.30 The Proponent shall supply the modulating anode supply for the klystron.

OTHER COMPONENTS:

3.1.31 A flex section of WR-1800 waveguide shall be used at the output port of the klystron to allow for ease of installation and replacement of the klystron.

3.1.32 If any mitred bend waveguide components are used, the Proponent shall use components designed for optimum operation at 500 MHz. The mitred bends shall have a maximum VSWR of 1.02 over a 10% band width.

3.1.33 The klystron output shall be protected by the use of a high-power circulator. The circulator shall be capable of continuous operation at the maximum design power under conditions of full transmission and full reflection at the forward port.

3.1.34 Arc detection is required in the waveguide, circulator and at the klystron window. The Proponent shall supply arc detection at these locations.

3.1.35 The Proponent shall provide a pin diode (or other electronic switch) that is capable of removing the RF drive with a rise/fall time < 10 µs (or faster if required by the klystron manufacturer). The faults that shall warrant firing of the pin diode include, but should not be limited to the following:

1. Arc detected at the klystron window, or the circulator.
2. Arc detected at another location in the cavity feed arm including the waveguide and cavity window. The Proponent shall supply capabilities of accommodating a minimum of 10 additional inputs with the capability of future expansion.
3. High VSWR at the klystron window.
4. Loss of air cooling at the klystron window.
5. Klystron magnet focussing currents out of specified range.
6. Bad klystron vacuum.

A second electronic switch is required to disable the RF drive. This switch will be used to increase the isolation and provide a redundant shut-down means for the RF. The characteristics and implementation of this switch are subject to review and acceptance by the CLS.

3.1.36 The Proponent shall provide 2 alternate hard-wired shutdown means for the RF input drive. The Proponent shall design the system to ensure that there is no single point of failure for disabling the RF.

3.1.37 In addition to the monitors and interlocks mentioned elsewhere in this document, the Proponent shall also supply monitoring and interlocks on the following where applicable:

1. Air flow under limit to the klystron gun (interlock).
2. Air flow under limit to the RF window (interlock).
3. Air inlet temperature on the RF window (monitor and interlock).
4. Air outlet temperature on the RF window (monitor and interlock).
5. Air inlet temperature on the klystron gun (monitor).
6. Air outlet temperature on the klystron gun (monitor).
7. Water flow under limit from the klystron collector (monitor and interlock).
8. Water flow under limit from the klystron body (monitor and interlock).
9. Water flow under limit from the klystron output cavity (monitor and interlock).
10. Water flow under limit from the circulator (monitor and interlock).
11. Water flow under limit from the RF load on port 3 of the circulator (monitor and interlock).
12. Water flow under limit from the RF test load (temporary) (monitor and interlock).
13. Water flow under limit for any other critical water flows (monitor and interlock).
14. Water inlet temperature on the klystron collector (monitor and interlock).
15. Water outlet temperature on the klystron collector (monitor and interlock).
16. Water inlet temperature on the klystron body (monitor and interlock).
17. Water outlet temperature on the klystron body (monitor and interlock).

18. Water inlet temperature on the klystron output cavity (monitor and interlock).
19. Water outlet temperature on the klystron output cavity (monitor and interlock).
20. Water inlet temperature on the circulator (monitor and interlock).
21. Water outlet temperature on the circulator (monitor and interlock).
22. Water inlet temperature on the RF load on the circulator (monitor and interlock).
23. Water outlet temperature on the RF load on the circulator (monitor and interlock).
24. Water inlet temperature on the RF testing load (temporary) (monitor and interlock).
25. Water outlet temperature on the RF test load (temporary) (monitor and interlock).
26. Forward klystron RF power (monitor).
27. Reflected RF power to the klystron (monitor and interlock).
28. Circulator load forward RF power (monitor and interlock).
29. Circulator load reflected RF power (monitor and interlock).
30. Circulator forward RF power (to test load or cavity feed arm) (monitor).
31. Circulator reflected RF power(from the test load or cavity feed arm) (monitor and interlock).
32. Current on the klystron focussing magnets (monitor and interlock).
33. Current to the klystron vacuum pump (monitor and interlock).
34. Drive amplifier output power (monitor).

All water flows shall be measured on the outlet side of the components being cooled. If parallel cooling circuits are used, a flow meter must be used on the outlet of each parallel circuit.
If a common supply manifold is used for a number of cooling circuits, a common temperature measurement may be implemented provided the manifold is in close proximity to the component inlet so that the expected temperature variation between the manifold and the inlet is less than 1 kelvin.

3.1.38 The water flow meters shall be ELETTA™ flow meters or CLS accepted equivalent with 4-20 mA analog outputs and either a dry contact which is closed or a +24 V output when water flow is above an adjustable limit.

3.1.39 The Proponent shall be responsible for supplying the analog outputs for all water flow rates associated directly with the amplifier system.

3.1.40 The Proponent should provide interlocks to ensure the proper operation of any dehydrator or electrostatic air filters used in the amplifier design.

3.1.41 Adequate temperature monitoring shall be provided by the Proponent. Temperature monitoring shall be accomplished with 100 ohm platinum resistive temperature detectors (PRTD) with an $\alpha = 0.00385$ (IEC) temperature coefficient. All temperature measurements shall be 3-wire measurements. The sensor elements should have a ¼ inch diameter stainless steel sheath, six inches long, to be compatible with other CLS sensors. The Proponent shall provide all thermal wells required for temperature measurement. The method, location, and number of temperature monitoring points shall be reviewed and accepted by the CLS. The Proponent shall supply the signal processing for all temperature readings. Provisions shall be made for monitoring by CLS computers.

3.1.42 WR-1800 dual-directional couplers are required at the following locations to allow for RF power monitoring.

1. Between the klystron and the circulator (port 1) to monitor the forward power from the klystron and the reverse power coming back to the klystron.
2. On the forward port of the circulator (port 2) to monitor the RF power transmitted from the circulator to the cavity feed arm.
3. On the load port of the circulator (port 3) to monitor the RF power reaching and reflecting from the RF load.

3.1.43 The circulator shall include arc detection and thermal compensation. Any power supplies or control required for the circulator operation shall be supplied by the Proponent.

3.1.44 The Proponent shall supply two RF loads. One load will be used to absorb the RF power reflected from the cavity feed arm and diverted by the circulator, and the second will be used in the cavity feed arm for high power testing of the amplifier station.

3.1.45 The RF loads should use standard WR-1800 waveguide flanges. The Proponent shall be responsible for providing any transitions if any thing other than WR-1800 is used. Deviations from WR-1800 shall be subject to review and acceptance by the CLS.

3.1.46 The RF loads should use deionised water for their operation. If any other coolant is required (e.g. a glycol system) the Proponent shall notify the CLS. In this case, the Proponent shall be responsible for supplying the additional equipment necessary to interface the system with the CLS deionised water system. Plans for such a system shall be subject to review and acceptance by the CLS.

3.1.47 The Proponent shall supply all racks, stands, mounts and enclosures.

3.2 Performance

KLYSTRON:

3.2.1 The efficiency of the klystron shall be in excess of 60 percent when operated at 500 MHz and maximum output power. Preference will be given to the use of a klystron with a higher efficiency.

3.2.2 The klystron tube shall not be damaged when operated at maximum rated RF input drive when the beam voltage is removed.

3.2.3 The klystron tube should not be damaged when operated at maximum beam voltage and current, and the RF input drive is removed. The collector should be able to dissipate the full beam power. Any deviation from this requirement shall be subject to review and acceptance by the CLS.

3.2.4 The klystron shall be able to be operated continuously without damage into a load with a VSWR of 1.2:1.

3.2.5 The klystron output shall be standard WR-1800 waveguide.

3.2.6 When installed, the klystron shall be fixed in its position such that it can not be moved without removing fasteners.

POWER SUPPLIES:

3.2.7 All power supplies shall perform in a stable fashion and exhibit no evidence of oscillation over its entire operating range.

3.2.8 Any power supply PLC shall respond to a change in the interlock status within 25 milliseconds unless faster response times are required by the klystron manufacturer. Response times to users input should be within 150 milliseconds so that the user perceives immediate response.

3.2.9 All power supplies shall have a control set point resolution better than the regulation specification, with a minimum of 12 bit control. Feedback resolution shall be equivalent or better than control resolution to facilitate self testing of the control and regulation circuitry.

3.2.10 The klystron ion pump power supply/controller shall have a trip circuit used as an indicator of bad vacuum in the klystron. This circuit shall fire on an adjustable current limit. Once a fault is detected, this shall initiate a safe shutdown of the klystron and klystron filaments heater supply to avoid damage to the klystron tube.

3.2.11 The klystron ion pump supply/controller shall be oversized to allow for running at higher currents than those expected during normal operation. This is to take care of pressure increases than may occur after a long storage period upon start-up. The size of these supplies shall be subject to review and acceptance by the CLS.

3.2.12 The klystron focussing supplies shall be equipped with adjustable current and voltage limits. The focussing supplies shall be adjustable over the full range specified by the klystron manufacturer.

3.2.13 The klystron cathode heater supply shall be equipped with a voltage-run-up circuit. When the heater power is applied to a cold tube, the heater voltage should be adjusted from 0 V to its operating voltage over a period of time not less than 3 minutes. The voltage shall be increased in such a manner that it shall at no time allow the filament surge current to exceed the maximum surge current stated by the klystron manufacturer.

3.2.14 The high voltage power supply for the klystron shall use 60 Hz, three phase, 600V load connections.

3.2.15 The circuit breaker on the HV power supply shall have an interrupting capacity of at least 65,000 A AC symmetrical RMS for the 600 V inputs and 5000 A RMS for the 120/208 V inputs if applicable. The breaker should be a three pole, magnetically operated circuit breaker. This breaker shall provide the following protection:

1. Instantaneous trip on primary circuit faults (phase-to-phase and phase-to-ground faults).
2. Delay to avoid false trips on turn on in-rush current transients and crowbar actuations (if applicable).
3. Overload trips between 105-120% of rated load with a must trip level of 125% rated load.
4. AC shunt trip for remote tripping.

3.2.16 The circuit breaker for the HV power supply shall be provided with an auxiliary SPDT contact having a minimum rating of 1A @ 24V dc.

3.2.17 The contactor on the HV power supply shall be rated for greater than 10^5 operations.

3.2.18 The sum of voltage ripple and voltage regulation on the HV power supply shall be less than 1% at maximum output. The goal for the sum of voltage ripple and regulation is less than 0.5%.

3.2.19 All power supplies with an output greater than 1 kW shall have an efficiency in excess of 90 percent and a power factor in excess of 0.9. The Proponent shall provide information at the time of bid as to the expected efficiency of the HV power supply. Preference will be given to a supply with a higher efficiency. The Proponent shall also supply information of the expected heat loads to air and LCW water for the HV power supply.

3.2.20 The sum of voltage ripple and voltage regulation on the modulating anode supply shall be less than 0.5%. The goal for the sum of voltage ripple and regulation on the modulating anode supply is less than 0.1%.

OTHER COMPONENTS:

3.2.21 The dual-directional couplers shall meet or exceed the following specifications over a 10% bandwidth centred at 500MHz:

1. Maximum VSWR < 1.03
2. Directivity > 25 dB (> 30 dB preferred)
3. Coupling variation < +/- 1 dB
4. Insertion loss < 0.1 dB

The coupling factor should be 70 dB.

3.2.22 The circulator should have RF specifications that meet or exceed the ones listed below:

1. 20 dB Isolation bandwidth >+/- 2 MHz
2. Isolation at 500 MHz > 23 dB
3. Return loss at 500 MHz > 23 dB
4. Insertion loss at 500 MHz < 0.15 dB

3.2.23 The pin diode (or other fast electronic switch) on the RF drive shall provide a minimum isolation of 30 dB at 500 MHz (An isolation of greater than 40 dB is preferred). The second RF disabling switch shall have a minimum of 30 dB isolation at 500 MHz (An isolation of greater than 40 dB is preferred). .

3.2.24 The RF drive amplifier shall be sized so that the maximum drive power rating of the klystron is able to be exceeded by a minimum of 20 % at the klystron input coupler.

3.2.25 One RF load shall be sized to absorb 100 percent of the RF power. This load shall be used for amplifier testing on the forward power feed arm of the circulator to absorb the entire power of the amplifier system. This load may be configured out of two or more smaller water loads. The CLS would prefer the second load to be identical, provided that the cost is not unnecessarily prohibitive. The second RF load may be sized to absorb less than the full RF power provided there is adequate protection installed to limit the duration of time that the load will experience high RF power. This should include arc detection (10 µs), detection of high reflected power (50 µs), and excessive forward power into the circulator load (50 µs). The second load is to be used on port 3 of the circulator and must be capable of absorbing a minimum of 1/2 of the RF power at CW operation. The CLS will require a spare load to be on site during operation. The CLS would encourage the Proponent to investigate the use of common loads, and or modular designs to realize the water load requirements. The sizing of the high power RF loads shall be subject to review and acceptance by the CLS.

3.3 Safety and Environmental

3.3.1 The Proponent shall be responsible for providing a lead-shielded enclosure (or equivalent) for the klystron if necessary to meet all required safety standards under normal operation.

3.3.2 Asbestos or asbestos-type insulation, insulating or dielectric fluids containing PCBs shall not be used. Where a choice of materials is available (e.g. cables, support hardware), preference shall be given to materials or equipment exhibiting a higher level of fire resistance.

3.3.3 The power supplies shall be constructed with a view towards safety. All high voltages (greater than 30 V_{ac}) shall be barriered or compartmentalized. All high voltage shall be labelled with standard type labels. Controls shall be physically separated from the high power circuits.

3.4 Applicable Codes, Standards and Procedures

3.4.1 See section 2.4.

3.5 Quality Assurance

3.5.1 The Proponent shall provide QA/QC manuals for all components.

3.6 Inspection, Testing and Commissioning

3.6.1 All power supplies with a output power greater than 1 kW shall undergo initial component testing. This testing shall include but not be limited to the following:

1. Control functions shall be exercised through all states.
2. All interlock functions shall be checked for proper operation and indications. All fault status indicators shall latch until reset.
3. After the unit's warm up period, the line regulation, load regulation and reproducibility of the power supply shall be checked at a minimum of four output values spanning the power supplies working range over a period of 4 hours.
4. Heat checking shall be done on all critical components. The proponent shall temporarily install thermocouples on critical components and on power supply critical points. These points shall be agreed on between the Proponent and the CLS. A heat run shall be conducted at 110% load conditions, concluding after equilibrium temperatures have been reached.
5. Where applicable, static water tests shall be done at 2 MPa for a minimum of 1 hour with no indications of leaks.

The above mentioned test may be waived at CLS's discretion if a commercially available power supply is used.

3.6.2 Isolation testing shall be performed on all power supplies. These tests shall be performed at 60 Hertz for a one minute duration. The actual leakage currents shall be measured and recorded. These tests shall include the following:

1. Between input and output terminals to the frame–performed at 2500V RMS
2. Between the transformer primary and secondary to the frame–performed at 2500V RMS.

3. Between the transformer primary and the transformer secondary–performed at 2500V RMS.
4. Between the low voltage control and interlock circuits to the frame–performed at 750V RMS.
5. A turn-to-turn test shall be performed at 400 Hz or higher frequency on the transformer. This test shall apply or induce a primary voltage of: 420V RMS on the nominal 208V terminals; 900V RMS on the nominal 600V terminals for a duration of 7200 cycles of the applied frequency.

3.6.3 The klystron HV supply shall undergo additional testing including the following:

1. Testing of the crowbar circuit (if applicable), including characterization of the voltage and current waveforms upon firing of the crowbar.
2. Measurement of the stored energy available to the klystron tube at full power operation.

3.6.4 The Proponent shall supply test results for the high-power circulator. These test shall include measurements of:

1. 20 dB Isolation bandwidth
2. Isolation at 500 MHz
3. Return loss at 500 MHz
4. Insertion loss at 500 MHz
5. Stray magnetic field at a distance of 1 meter.

These measurements shall be done at 10%, 25%, 50%, 75%, and 100% of the maximum rated power of the RF amplifier system. This will characterize the power dependence of the high-power circulator.

3.6.5 Successful high-power testing shall be done at the Proponents location prior to shipping to the CLS. These initial high-power tests shall include but not be limited to those outlined in section 3.6.6 of this specification.

3.6.6 Final acceptance of the RF amplifier system shall require a successful high power test to be performed at the CLS. The high-power test shall include the following:

1. Operation of the klystron at maximum output power for a period of no less than 24 hours. The power output of the amplifier shall be measured and it must meet the power acceptance requirements outlined by the klystron manufacturer. As well, the output power shall be in excess of 100% of the power requirements outlined in this specification (275 kW for Option 1 and 475 kW for Option2), as measured after the forward port in the circulator.
2. Measurements of the amplitude and phase stability during a 4 hour period while running at maximum output power and at half power by varying the RF drive power.
3. Operation of the modulating anode power supply to control the klystron at a minimum of 5 operating points with full drive power applied. This shall include using the modulating anode power supply to drop the amplifier output to 90%,75%,50%,25%, and 10% of its maximum value. During these test the amplitude and phase stability of the amplifier shall be measured at each operating point over a duration of 4 hours.
4. Measurement of the voltage regulation of the HV supply under a varying load. For a minimum of 5 different cathode voltages, the voltage regulation shall be measured while the modulating anode is adjusted to vary the output power of the klystron from 100% to 0% and back to 100% over a time scale of 10 seconds unless this exceeds the specifications given from the klystron manufacturer.

3.6.7 The Proponent shall supply plots of power output versus drive power for the amplifier system for each of the following cases:

1. A minimum of 5 curves (approximately equally spaced) are required at cathode voltages ranging from 50% to 95% of the maximum cathode voltage with the klystron running in a constant perveance mode. In this test, the modulating anode voltage should be set for maximum power output. For each voltage, the klystron beam current shall be recorded.
2. A minimum of 5 curves are required at cathode voltages ranging from 50% to 95% of the maximum cathode voltage with the klystron running in a constant beam impedance mode. In this test, the modulating anode voltage should be set for maximum power output. For each voltage, the klystron beam current shall be recorded.

3. A minimum of 5 curves (approximately equally spaced) are required to characterize the operation of the modulating anode with the cathode voltage running at 95% of its maximum value. The klystron operation should be determined at a minimum of 5 different modulating anode voltages that will limit the output from 10% to 100% of the value obtainable without modulating anode control. For each voltage, the klystron beam current shall be recorded.
4. A minimum of 5 curves are required to characterize the operation of the modulating anode with the cathode voltage running at 75% of its maximum value. The klystron operation should be determined at modulating anode voltages that will limit the output from 10% to 100% of the value obtainable without modulating anode control. For each voltage, the klystron beam current shall be recorded.

The spare klystron tube shall also be characterized by the test mentioned above.

3.7 Reliability and Maintainability

3.7.1 The CLS requires access to a spare klystron tube. The spare klystron tube should be stored at the location of the klystron manufacturer until required by the CLS. The warranty agreement on this spare tube shall be between the CLS and the klystron manufacturer. It is required that the delivery time for a spare klystron tube be less than 7 days.

3.7.2 All power supply units shall be manufactured with strong consideration for unit reliability and serviceability. Any units that need to be removed from cabinets or racks for service shall be mounted on slides. Access shall be made available to all components, especially solid state power components, fuses, and printed circuit boards. The Proponents drawings shall show the positions of the major components in the power supply.

3.7.3 When assembling any waveguide components it is important to assure proper alignment of the waveguide flanges to maintain proper inner surface continuity across each junction. All waveguide assemblies shall follow the procedures recommended by the manufacturer including the use of alignment tools, torque wrenches and the proper bolt tightening sequences. The assembly procedures shall be provided to the CLS prior to equipment arrival at the CLS.

3.8 Other Requirements and Constraints

3.8.1 All equipment supplied will bear the approval of the Canadian Standards Association (CSA). Where CSA approval is not available, the Proponent will secure approval of the Technical Safety Services Branch of the Department of Industry and Labour, Province of Saskatchewan prior to shipment of equipment to site. Evidence of such approval will be presented to the Owner, prior to shipment of the equipment from the factory.

3.8.2 The Proponent shall package all components to insure acceptance and safe delivery by a common or other carrier, and so components can be delivered in an undamaged condition.

3.8.3 All power supplies shall have a stainless steel or aluminium nameplate on each unit that shall include the following information:

- Manufacturer’s name and address
- Power supply type and serial number
- Input ratings
- Output ratings
- Gross weight of the unit
- Date of manufacture
- Cooling requirements (if required)
  - LPM
  - Maximum Temperature Rise

3.8.4 All shipping containers shall be marked or tagged with the following information:

1. CLS purchase order number.
2. Shipping address as specified within the contract.
3. Proponent’s name.

4. Components contained within each package.
5. “Top-side up” if required.
6. “Fragile” if required.

4. REFERENCES

Drawings

1. RF Amplifier Station, SR1/PFD/RF/0049100 Rev. A
2. SR1 RF Yard Plan View, SR1/ME/RF/0049000 Rev. A
3. Global Plan View, BLDG/ME/0035100 REV. N.
4. SR1 RF Cavity Tunnel Cross Section, SR1/PPL/RF/0034304 Rev. B
5. SR1 RF Straight Section General Plan View, SR1/ME/RF/0037100 Rev. D

Documents

1. “CLS Design Specification Control System Overview” 7.4.39.1 Rev. 0 (previous known as: 2.42.39.002 Rev. 0).
2. “BKL report “Vibration Isolation Mechanical Equipment”.
3. “CLS documentation specification” 0.4.1.1 Rev. 1 (previously known as:2.42.01.001 Rev. 1).
4. “CLS RF Design Note” 8.2.32.1 Rev. 0 (previously known as 2.1.4 Rev. 0
5. CSA Canadian Electrical Code 1998 Safety Standards for Electrical Installations.
6. ANSI/IEEE Std. 519-1992 IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
7. Industry Canada ICES-001 Industrial, Scientific and Medical Radio Frequency Generators
8. ANSI/IEEE Standard C57 Distribution, Power and Regulating Transformers.
9. NEMA Pub. No. SG 5 – 1995 Power Switchgear Assemblies.
10. Radiation Health and Safety Regulations of the Saskatchewan Occupational Health and Safety