Superconducting Radio Frequency Acceleration Module Specification

CLS2.42.32.001 Rev. 0

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1. INTRODUCTION

1.1 Purpose

This document specifies the requirements for the Canadian Light Source (CLS) storage ring superconducting (SC) Radio Frequency (RF) acceleration module.

1.2 Scope

The Canadian Light Source requires a SC acceleration module for the CLS storage ring to be designed, fabricated, delivered to the CLS site, tested, and installed into the storage ring. An additional unit is required to serve as a spare acceleration module to be delivered and tested at the CLS site.

The SC acceleration module includes the Niobium RF cavity and tuner, the tuner drive control system, the liquid helium cryostat, the liquid helium control system, SC and non-SC waveguide run up to and including the high-power RF window and backup window, the higher order mode (HOM) loads, vacuum tapers, vacuum valves, “break-out” box, and all associated monitoring hardware. As well, the CLS will require a cryogenic valve box to regulate the flow of cryogens to and from the acceleration module. This valve box may also be supplied by the vendor.

This specification details the requirements for the design, fabrication, supply, and testing of the SC acceleration modules. This specification includes, but is not limited to:

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

1.3 Background

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

This facility requires a superconducting 500 MHz RF acceleration module to be designed, manufactured, and installation into the CLS storage ring. A second acceleration module is required to be tested and delivered to the CLS to act as a spare. 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 ultimate design current for the CLS storage ring is 500 mA. The initial operating design current is 200 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 initial RF installation will be a minimum of 300 kW to facilitate operation up to at least 200 mA.

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

2. ACCELERATION MODULE GLOBAL REQUIREMENTS

2.1 Functional Requirements

2.1.1 The vendor shall supply two acceleration modules used to supply RF power to the circulating beam in the CLS storage ring. Only one set of control hardware is required.

2.1.2 Each acceleration module shall include all of the components shown in the attached drawing SR1/PPL/RF/0034301 Rev. A. Additional components not shown in the figure may also be required to meet this specification and are the responsibility of the vendor.

2.1.3 The acceleration module shall be equipped with crane attachments for lifting of the entire module assembly. The gravitational centre of the whole superconducting acceleration module shall be marked on the cryostat.

2.1.4 The acceleration module shall be equipped with 360 degree moveable wheels to allow for its transport along the floor to its position in the storage ring tunnel.

2.1.5 The vendor shall provide a method for supporting and aligning the acceleration module from valve to valve. The vendor should incorporate vibration damping into the support design.

2.1.6 Unless otherwise stated, the vendor shall supply all monitoring transducers (e.g., temperature, flow, position, and pressure) required for monitoring of the system.

2.1.7 Unless otherwise stated, the vendor shall supply all cooling water supply manifolds for the system.

2.2 Performance

2.2.1 Each acceleration module shall be capable of producing a minimum acceleration voltage of 2.4 MV (at 500.00 MHz) in continuous operation in the storage ring.

2.2.2 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.

2.2.3 The cavity shall operate at a frequency of 500.00 MHz, with a tuneable frequency range of +/- 200 kHz.

2.2.4 The entire module assembly from valve to valve shall not exceed 3.3 m in length.

2.2.5 The beam height shall be 1.4 m. No elements of the acceleration module system shall be allowed to extend above a height of 2.5 m from the floor height.

2.2.6 No components in the acceleration module shall extend more than 1.0 m from the sagittal plane containing the beam centreline.

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

2.2.8 The input and output vacuum connections of the acceleration module shall mate with the vacuum chamber profile given in the attached drawing SR1/PPL/RF/0034303 Rev. A.

2.2.9 All vacuum components shall conform to the specifications outlined in the “CLS High Vacuum Specification” (CLS2.42.33.001 Rev.0).

2.2.10 The total mass of the entire superconducting acceleration module shall be less than 9000 kilograms.

2.2.11 When installed, the superconducting module shall be fixed in its position such that it can not be moved by an acceleration of up to 3.3 m/s^2.

2.3 Safety and Environmental

2.3.1 The CLS plan view is given in the attached drawing BLDG/ME/0035100 Rev. M. The layout of the RF Straight and the cross-section of the storage ring tunnel can be seen in the attached diagrams SR1/ME/RF/0037100 Rev. C, SR1/PPL/RF/0034300 Rev. C, and SR1/PPL/RF/0034304 Rev. A. The above mentioned diagrams can be used as a guideline for the layout of the acceleration module.

2.3.2 The acceleration module shall be capable of operation in an ambient temperature range of 10 to 40 degrees C. The normal ambient temperature of the SR1 tunnel is 27 degrees C. The expected temperature stability of the tunnel will be better than 1 degree C during normal operation.

2.3.3 The components shall be able to withstand a relative humidity range of 0 % to 95%. 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.

2.3.4 All components shall be designed for operation in a radiation environment. The vendor shall avoid all materials that are subject to damage by ionising radiation or provide adequate shielding incorporated into the design to allow for long service life of the component. All components shall have a minimum mean time between failure (MTBF) of 5 years in the typical radiation environment.

2.3.5 In the tunnel environment, there will be a small amount of production of radioactive air and noxious gasses. These are estimated to be:

1. For N-13,O-15, and C-11: 0.0002 Bq/cc.
2. For ozone: $5.6x10^8$ mol/cc.
3. Nitrogen dioxide: $2.7x10^8$ mol/cc.
4. Nitric acid: $0.8x10^8$ mol/cc.

2.3.6 The tunnel environment will have a maximum vibrational movement of less than 0.4 microns at frequencies less than 100 Hz.

2.3.7 All equipment/structures shall conform to the BKL report “Vibration Isolation Mechanical Equipment”.

2.3.8 The liquid He (L He) refrigeration system and L He distribution system will be supplied by the CLS. The CLS will also supply the required liquid nitrogen (L N_2).

2.3.9 Low conductivity cooling water (LCW) will be supplied by the CLS. The supply water will have a conductivity of less than 6 µS/cm.

2.3.10 The vendor shall specify the expected consumption of low conductivity water for the normal operation of the acceleration module. The vendor shall limit the consumption of low conductivity water to 180 litres per minute.

2.3.11 The vendor shall supply the CLS with its LCW consumption requirements within 80 days of the award of the tender.

2.3.12 Water cooling systems shall be designed to operate at a maximum input pressure of 1 MPa.

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

2.3.14 The 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/s.

2.3.15 Supply temperature of the LCW will be nominally between 25 to 30 degrees Celsius.

2.3.16 The maximum temperature rise in the water cooling circuits should be kept below 10 degrees Celsius.

2.3.17 All small tubing water connections shall be American standard Swagelok™ fittings. All large water tubing shall use National Pipe Thread (NPT) threads.

2.3.18 The vendor shall supply the supply characteristics for the liquid nitrogen (L N_2) for review and acceptance by the CLS.

2.3.19 Compressed air (instrument quality) will be available in the tunnel at 827 kPa (120 psi). Consumption should not exceed 113.27 litres per minute (4 cubic feet per minute).

2.3.20 Vendor shall supply electrical load list to the CLS within 60 days of contract award. 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

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. B51-97 Boiler, Pressure Vessel, and Pressure Piping Code (CSA)
4. ASME Boiler and Pressure Vessel Code Section VIII divisions 1 2 and 3.

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

2.5 Quality Assurance

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

2.5.2 The vendor shall provide a copy of all its quality assurance procedures for review and acceptance by the CLS.

2.6 Inspection, Testing and Commissioning

2.6.1 The acceleration modules shall be designed for operation in the CLS storage ring (SR1). One acceleration module shall be delivered to the CLS site, moved to the location of the RF straight in the CLS storage ring tunnel and its performance shall be demonstrated. This acceleration module will then be removed to serve as a spare. The second acceleration module shall be delivered to the CLS site, installed in the RF straight, and its performance demonstrated. This module will be used for initial operations.

2.6.2 The installation of the accelerator module shall be done by the CLS staff, with supervision from the vendor. The CLS 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. There is no crane access into the interior of the storage ring tunnel. Access into the tunnel interior will be through chicanes and access doors in the storage ring shielding wall. The location of the access door into the RF straight can be seen in the attached diagram SR1/ME/RF/0037100 Rev. C.

2.6.3 The CLS reserves the right to have access to the vendor'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 vendor 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 vendor 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. The acceptance test procedures are subject to review and acceptance by the CLS.

2.6.5 An inspection sheet for the module assembly shall be designed by the Proponent, this sheet shall be reviewed and approved by the CLS.

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 Any review and acceptance process done by the CLS shall not release the vendor 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 acceleration module 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 vendor shall supply documentation to the CLS outlining the maintenance requirement procedures and schedules for all major subsystems of the acceleration module. A list of recommended spare parts shall be supplied by the proponent.

2.7.3 The acceleration module 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 acceleration module. The total maintenance time annually should not exceed 6 man-days. The target time limit for the replacement of the in-service acceleration module with the spare should be less than 10 working days with a total manpower of less than 40 man-days.

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

2.7.5 The acceleration module shall be designed and constructed with an expected operational lifetime of greater than 20 years.

2.7.6 All threaded mechanical fasteners should be American Standard. The use of metric standards can be negotiated with the CLS. If metric standards are used, additional spare nuts and bolts shall be provided by the vendor.

2.8 Layout

2.8.1 Refer to the attached diagrams SR1/ME/RF/0037100 Rev. C, SR1/PPL/RF/0034300 Rev. C., and SR1/PPL/RF/0034304 Rev. A. showing the RF straight and the cross-section of the storage ring tunnel. The above mentioned diagrams can be used as a guideline for the layout of the acceleration module.

2.8.2 Monitor signals shall be sent to a common location near the cavity. The CLS will be responsible for the distribution of these signals from this “break-out” point.

2.9 Other Requirements and Constraints

2.9.1 The vendor shall supply complete documentation of all components and subsystems contained in the acceleration module. All documentation should conform to the "CLS documentation specification" (CLS2.42.01.001 Rev. 1).

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

2.9.3 Two (2) sets 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.

3. COMPONENT REQUIREMENTS

3.1 Functional Requirements

3.1.1 The SC RF cavity and waveguide coupler shall be constructed of ultra-pure Niobium and based on the Cornell B-factory cavity design operating at 500.00 MHz. The basic cavity profile can be seen in the attached drawing SR1/PPL/RF/0034302 Rev. A.

3.1.2 All Niobium materials shall be made of Niobium that meets the "CLS Superconducting Cavity Niobium Specification" (CLS2.40.32.001 Rev. 1). The CLS will supply the niobium for the manufacture of the cavity. A list of the niobium material that will be supplied by the CLS is enclosed in this document.

3.1.3 The vendor shall supply all dies and jigs required to manufacture the cavities.

3.1.4 The internal cryostat vessel will provide a liquid helium (L He) bath to cover the Niobium cavity.

3.1.5 The Helium tank shall be produced from 316L (low carbon) stainless steel.

3.1.6 The vendor shall have the option of supplying the valve box used for regulating the flow of L He and L N_2 to the acceleration module. The design and implementation of this valve box will be subject to review and acceptance by the CLS. A possible schematic layout of the valve box can be seen in the attached diagram, SR1/PPL/RF/0034305 Rev. A.

3.1.7 The liquid cryogens will enter the valve box via a multi-channel transfer line, the specifics of which has yet to be determined. The line will supply L N_2 and L He, and will accept cold He gas for return.

3.1.8 The valve box will be capable of redirecting both the L He supply and the return cold He gas to a bypass line containing a heater to return warm He gas.

3.1.9 The valve box shall be equipped with a pump out port to establish an insulation vacuum. The valve box shall share a common vacuum with the distribution line and the transfer lines leading to the cryostat.

3.1.10 The valve box insulation is expected to utilized multiple layers of superinsulation and a liquid nitrogen shield.

3.1.11 The valve box shall be equipped with a Venturi meter or another device capable of providing a differential pressure reading to determine mass flow of the He cold gas return.

3.1.12 Indium seals shall be used to seal the internal vessel to the cavity.

3.1.13 Bellows shall be used to accommodate the differential expansion of the Niobium and the stainless steel, to allow for variations in the sizes within the dimensional tolerances, and to facilitate the assembly of the vacuum seals.

3.1.14 A liquid-nitrogen-cooled radiation shield should be used outside the L He vessel.

3.1.15 L N_2 should also be used to cool all intercepts between the areas of room temperature and L He temperature.

3.1.16 Superinsulation shall be located both internal and external of the heat shield. The design should incorporate as much superinsulation as is reasonably achievable in the design to minimize the static heat leak of the cryostat.

3.1.17 A small amount of the boil-off gas from the liquid helium (HEX gas) should be used in a heat exchanger on the waveguide transition pieces to reduce conduction and RF power loss to the helium.

3.1.18 L N_2 should also be used as a cooling media in the waveguide heat exchanger.

3.1.19 The HEX gas flow rate shall be controlled with a helium gas flow valve. Any L N_2 used in the waveguide heat exchanger shall be controlled with a flow valve. The vendor shall be responsible for the installation of these valves.

3.1.20 The HEX gas flow will be monitored with a gas flow sensor that shall be supplied by the vendor. The vendor shall also be responsible for monitoring the flow rate of any nitrogen used in the waveguide heat exchanger.

3.1.21 The vendor shall supply a heater for all warm gas return lines. This will include a heater for the He HEX gas return line and a heater on the nitrogen return line.

3.1.22 The vendor shall be responsible for the system to control the HEX gas flow and L N_2 flow rates through the waveguide heat exchanger.

3.1.23 The L He vessel and radiation shield shall be wrapped with layers of a highly permeable magnetic material to reduce the stray magnetic fields at the cavity location.

3.1.24 All stainless steel components, including nuts and bolts, that are on the interior of the magnetic shield shall be produced from non-magnetic 316 stainless steel.

3.1.25 The L He vessel should be lined with a 4.23 mm thick or greater (1/16 inch) rolled copper cylinder to minimize thermal gradients.

3.1.26 The area external to the L He vessel will be in a high vacuum environment.

3.1.27 The cryostat vacuum vessel pump out port will be on one end of the vacuum vessel.

3.1.28 The cryostat will be equipped with instrumentation and monitoring feed thru wiring.

3.1.29 The vendor shall provide a system to adjust the position of the cavity external to the cryostat assembly.

3.1.30 The vendor shall supply a “break-out” box where the monitor signals will be sent. The connectors used in the “break-out” box should be one of the following:

1. Terminal blocks for all DC interlocks.
2. Lemo connectors for all analog signals.
3. N connectors for all RF signals.

The connector configuration will be subject to review and acceptance by the CLS.

3.1.31 A sensor shall be used to measure the L He level in the cryostat.

3.1.32 The vendor shall supply the control system for the cryostat L He level. This system should employ 4-20 mA analog feedback.

3.1.33 The cryostat shall be equipped with a gas pressure transducer that will measure the He gas pressure in the cryostat.

3.1.34 The tuner will allow for adjustment of the resonant frequency of the RF cavity by longitudinally stretching the cavity along the beam axis.

3.1.35 The tuner should be capable of being adjusted locally in order to allow for frequency adjustment at the location of the cavity.

3.1.36 The tuner assembly shall be constructed sufficiently stiff to minimize frequency shifts in the cavity as a result of vibrations in the vicinity of cavity.

3.1.37 The vendor shall the control system for the operation of the tuner. This system should employ 4-20 mA analog feedback.

3.1.38 The tuner system will supply output signals including, but not limited to, the following:

1. Two limit switches to define the limits of the tuner travel.
2. Tuner force analog output.
3. Cavity displacement analog output.
4. Tuner displacement analog output.
5. Tuner position analog output.

3.1.39 All analog outputs should be 4-20 mA current loop with a burden less than 600 ohms.

3.1.40 All interlocks and digital control signals shall be 24 VDC.

3.1.41 Two ferrite HOM load assemblies located external to the cryostat will be required to damp the HOM spectrum that is transmitted outside the cavity.

3.1.42 The HOM loads are to be used in an ultra-high-vacuum (UHV) environment. Care must be taken to ensure that all exposed material is compatible with the UHV environment and that these components meet strict cleanliness standards. The vendor should use Trans Tech Inc. TT2-111 ferrite for its HOM load.

3.1.43 The water flow meters shall be ELETTA™ flow meters 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.

3.1.44 The CLS RF distribution is accomplished with WR-1800 waveguide components. The input flange of the acceleration module shall be WR-1800 waveguide.

3.1.45 A ceramic RF window shall be used to maintain the UHV region of the cavity.

3.1.46 The vendor shall take care to limit the infra-red transmission through the waveguide to the cryogenic environment. The vendor shall also take steps to limit the amount of “sharp” edges in the waveguide that can result in sites for field emission. The vendor shall provide test results or simulations to verify their design.

3.1.47 The Niobium cavity (or the Niobium beam tube directly adjacent to the cavity) shall be equipped with a minimum of two ports used to monitor the RF gap voltage, RF phase, and RF frequency.

3.1.48 The vendor shall supply the hardware and method to measure and monitor the RF power at key points in the acceleration module. This shall include, but not be limited to, measurement of the forward power at the RF window, the reverse power at the RF window, the power transmitted to the cavity, and the power reflected from the cavity. The vendor shall also supply a backup probe for measuring the transmitted power to the cavity.

3.1.49 RF probes shall be placed in the beam pipe and tapers of the acceleration module to monitor RF fields. The number and placement of these probes shall be reviewed and accepted by the CLS.

3.1.50 Pump out ports are required on the waveguide outside of the cryogenic region, preferably very near the RF ceramic window.

3.1.51 The vendor shall supply a backup window installed in the waveguide to protect the cavity in the event of a vacuum failure of the ceramic window. The region enclosed by the backup window and the ceramic window will be filled with dry nitrogen under normal operation. Thus, in the event of a crack in the ceramic window, the cavity will see a burst of dry nitrogen only. The backup window must be shown to be capable of withstanding the ring vacuum under a shock load.

3.1.52 The region enclosed by the backup window and the ceramic RF window shall be equipped with pump out capability as well as pressure gauging and a method to backfill the region with dry nitrogen gas. The design of this section shall be reviewed and accepted by the CLS.

3.1.53 The beampipe thermal transitions should be made of stainless steel and designed to have high thermal impedance along their length. They should be electroplated with copper on the interior to reduce wall-current heating from beam image currents. The details of these transitions shall be subject to review and acceptance by the CLS.

3.1.54 The vendor shall supply documentation outlining in detail the magnitude of the expected heat loading on the L He system in the acceleration module. This analysis should include, but not be limited to, the expected heat loading from:

1. Beampipe thermal transitions.
2. Waveguide thermal transitions.
3. Radiation from the L N_2 shield to the L He vessel.
4. Infra-red radiation from the beamline apertures.
5. Infra-red radiation from the waveguide duct.
6. RF wall dissipation in the RF cavity.
7. L He boil off gas in the waveguide heat exchanger.

3.1.55 The vendor shall also supply details of the heat loading on the L N_2 system in the acceleration module.

3.1.56 Transitional tapers shall be used to minimize the RF impedance effects resulting from the change in the vacuum profile from the cavity to the storage ring vacuum chamber.

3.1.57 The taper flanges shall be rotary for easy connection to the gate valves.

3.1.58 The tapers may act as synchrotron radiation absorbers. The details of this shall be worked out between the vendor and the CLS.

3.1.59 Ion pumps shall be used to maintain the UHV region of the acceleration module.

3.1.60 One ion pump shall be located as close as possible to the upstream taper which will experience a large amount of photodesorption due to the interception of synchrotron radiation. A second ion pump should be located at the downstream taper location. Additional vacion pumps should be located at the waveguide pump out box near the RF ceramic window.

3.1.61 All pumping ports located in the tapers shall be screen shielded.

3.1.62 The vendor shall be responsible for supplying the analog outputs for all water flow rates associated directly with the acceleration module. The monitored flows will include, but not be limited to, the ones listed:

1. RF window water flow.
2. Upstream taper water flow.
3. Downstream taper water flow.
4. One water flow rate for each cooling circuit in the upstream HOM load.
5. One water flow rate for each cooling circuit in the downstream HOM load.

3.1.63 Adequate vacuum monitoring is essential for the operation of the cavity. The CLS will supply the vacuum gauges. Vacuum monitoring should be accomplished through 2.75 inch Conflat™ flanges supplied by the vendor. Each vacuum monitor shall have its own port. The vacuum monitoring is required, but not limited to, the locations listed below:

1. 2 at each taper (a total of 4 per module).
2. 3 at the RF cavity window.
3. 3 connected to the cryostat insulation vacuum.
4. 2 at the valve box.
5. 1 port in the waveguide section enclosed between the ceramic window and the backup window.

The layout of the vacuum monitoring ports is subject to review and acceptance by the CLS.

3.1.64 Additional ports are required to accommodate RGA heads. The vendor shall supply one such port to look at the ring vacuum and one port to look at the cryostat insulation vacuum. The placement of these ports is subject to review and acceptance by the CLS.

3.1.65 Adequate temperature monitoring shall be provided by the vendor. Temperature monitoring should be accomplished with cryogenic linear temperature sensors (CLTS), T or J-type thermocouples, platinum resistive temperature detectors (PRTD), and graphite thermometers. The method, location, and number of temperature monitoring points shall be reviewed and accepted by the CLS. The vendor shall supply the signal processing for all temperature readings. The analog outputs of these signals should be 4-20 mA. Temperature monitoring shall be required, but not limited to, the locations listed below:

1. Inlet water temperature of the upstream HOM load.
2. One outlet water temperature for every water circuit in the upstream HOM load.
3. Inlet water temperature of the downstream HOM load.
4. One outlet temperature for every water circuit in the downstream HOM load.
5. Inlet water temperature for the upstream taper.
6. A minimum of 6 temperature points on the upstream taper.
7. Inlet water temperature for the downstream taper.
8. A minimum of 6 temperature points on the downstream taper.
9. One temperature of the upstream taper flange.
10. One temperature of the downstream taper flange.
11. RF window inlet temperature.
12. RF window outlet temperature.
13. A minimum of one temperature on the upper equator of the cavity.
14. A minimum of one temperature on the lower equator of the cavity.
15. Liquid nitrogen inlet temperature.
16. Liquid nitrogen outlet temperature.
17. A minimum of 3 temperatures at the RF coupling tongue at the interface of the cavity and the superconducting waveguide.
18. A minimum of 2 temperatures along the superconducting waveguide.
19. A minimum of 4 temperatures sequentially along the He gas waveguide heat exchanger.
20. A minimum of 2 temperatures along the upstream cavity thermal transition.
21. A minimum of 2 temperatures along the downstream cavity thermal transition.
22. A minimum of one temperature on each of the cavity flutes and cavity beam pipe.

The vendor is encouraged to add redundancy of temperature signals, and include additional temperature points beyond those mentioned in the above specification.

3.1.66 If the vendor supplies the valve box, adequate temperature, pressure and flow monitoring inside the box is essential. Temperature monitoring should be accomplished with cryogenic linear temperature sensors (CLTS). The method, location, and number of temperature monitoring points is subject to review and acceptance by the CLS. A possible schematic layout of the valve box can be seen in the attached diagram, SR1/PPL/RF/0034305. The vendor shall supply the signal processing for all temperature readings utilizing CLTS. The analog outputs of these signals should be 4-20 mA. Temperature monitoring shall be provided at, but not limited to, the locations listed below:

1. L He supply to the cryostat.
2. At two points of the Venturi meter located in the cold Helium gas return line.
3. At one point in the cold helium gas return line after the Venturi meter.
4. At a minimum of one point in the LN_2 shield of the valve box.
5. At a minimum of two points in the Helium gas bypass lines feeding the warm Helium gas return.

The vendor is encouraged to add redundancy of temperature signals, and include additional temperature points beyond those mentioned in the above specification.

The vendor shall supply a Venturi meter to monitor the He cold gas return flow rate.

Pressure monitoring shall be provided for, but not limited to, the following points.

1. Differential pressure of the Venturi meter in the He cold gas return line.
2. L He supply pressure.
3. He cold gas return pressure.

3.1.67 Crane attachments should be designed into all the cryostat assemblies as required in order to facilitate assembly, shipping and final installation.

3.1.68 The vendor shall provide the gate valves located at each end of the acceleration module. These valves shall be RF shielded VAT™ valves. The design shall be subject to review and acceptance by the CLS.

3.2 Performance

3.2.1 The SC cavity must be able to provide an acceleration voltage of greater than 2.4 MV to the circulating beam. This indicates a guaranteed acceleration gradient greater than 8 MV/m. To ensure this level of operation for the cavity under normal operation, testing criteria shall be in excess of these numbers, refer to section 3.6.1, (Inspection, Testing and Commissioning) of this specification.

3.2.2 All longitudinal HOM's should have a maximum allowable R/Q*Q (where Power = V*V/R) of 250 ohms. All transverse modes should have a maximum allowable R/Q*Q of 5 ohms.

3.2.3 The required L He volume of the cryostat should be kept below 550 litres.

3.2.4 The superinsulation and cryostat design must be sufficient to ensure that the static heat load of the assembled cryostat and cavity is kept less than 35 W load on the L He system.

3.2.5 At a cavity operation of 2.4 MV, the vendor shall guarantee a dynamic heat load of the cryostat to be less than 65 W.

3.2.6 The magnetic shielding shall be sufficient to ensure that the magnetic field at the cavity cell under operating conditions is below 75 microtesla. The attenuation shall be at least a factor of 25 with respect to the field external to the cryostat under cavity operating conditions. It is acceptable to extrapolate room-temperature measurements of the magnetic field to cryogenic temperatures.

3.2.7 Attached to the copper L He vessel liner shall be two 200 watt heaters, each of 75 ohms. These heaters will be wired separately to allow for separate operation.

3.2.8 The width of the cryostat body should be less than 1.25 meters.

3.2.9 The exterior of the cryostat shall have no less than 6 fiducial points. This includes 4 fiducials located towards the top of the unit and 2 more on the side facing the interior of the ring to enclose the volume of interest.

3.2.10 Fiducial bushings should be welded in place and have an internal diameter of 8 mm, and an external diameter of 25 mm.

3.2.11 The vendor shall provide data to relate the position of the cavity to the fiducials on the exterior of the cryostat.

3.2.12 The position of the cavity axis shall be capable of being adjusted to a height of 1.4 m with a precision of better than +/- 5 mm. The horizontal position of the cavity shall also be adjustable to a precision of better than +/- 5 mm.

3.2.13 The tuner shall be capable of adjusting the resonant frequency of the cavity over a range of +/- 200 kHz without permanent deformation to the cavity.

3.2.14 The goal for phase stability of the cavity is better than 0.5 degrees. This indicates a tuner resolution of better than 10 Hz. The resolution of the tuner should be better than 10 Hz.

3.2.15 Each ferrite HOM load should be capable of dissipating in excess of 2 kilowatts of power under vacuum.

3.2.16 Each ferrite HOM load shall have a loss factor for a sigma = 1cm bunch of less than 0.15 V/pC. The vendor shall supply evidence of this to the CLS for its review and acceptance.

3.2.17 The infra-red transmission from the RF window to the position of the Niobium waveguide section should be less than 10 %.

3.2.18 The RF window shall be capable of delivering a minimum of 300 kW continuously to the RF cavity and beam. The power handling goal of the RF window is in excess of 500 kW continuous.

3.2.19 The RF vacuum tapers should employ a slope of no greater than 5:1 (11.3 degrees) in either the horizontal or vertical planes.

3.2.20 The valve box should not add a heat load to the distribution system greater than 10 watts.

3.3 Safety and Environmental

3.3.1 There should be provisions made for locking down the helium vessel within the vacuum vessel during shipment that can be removed without disassembly of the vacuum vessel.

3.3.2 The vendor should provide an appropriate (in compliance with codes listed in section 2.4.1) adjustable helium vessel safety vent that releases helium pressure above a preset level and is self sealing when the pressure drops below that pressure level.

3.3.3 In addition to the helium vessel safety vent, the vendor shall supply a burst disk that will rupture if the pressure in the cryostat is reaching an unsafe level.

3.3.4 The waveguide shall be equipped with arc detection. The system shall include, but not be limited to, a minimum of 3 arc detectors at the RF window. These arc detectors shall be used to look at the ceramic and both the pressure side and vacuum side of the window. The arc detector placement will be subject to review and acceptance by the CLS.

3.4 Applicable Codes, Standards and Procedures

3.4.1 During cavity production, thinning of the material in the immediate vicinity of the welds, in order to facilitate full penetration electron beam welds, is permissible but the thickness must be >1.5mm and must be specified in the proposal.

3.4.2 Before final welding, the cavity parts must be treated as follows:

1. Degreasing.
2. Rinsing with ultra-pure demineralised, submicron-filtered water.
3. Chemically etched with 1:1:2 BCP acid mixture (HNO_3:HF:H_3PO_4)removing 30 microns of material. The etch shall be done by dipping into an acid bath and agitating the acid at five minute intervals. The acid mixture must at all times be < 15 degrees C to minimize the amount of hydrogen contamination on the cavity surface.
4. Cavity interior surface shall be high pressure rinsed with ultra-pure water in a class-100 clean room or better. The water used for the high pressure rinsing should be submicron-filtered and have a resistivity of >18 Mohms/m.
5. Drying in a clean room of class 100 or better.

3.4.3 In preparation for a vertical test the niobium cavity (refer to section 3.6.7) should be chemically cleaned and prepared as outlined below:

1. Degreasing.
2. Rinsing with ultra-pure demineralised and submicron-filtered water.
3. Chemically etched with 1:1:2 BCP acid mixture removing 120 microns of material.. The acid mixture must at all times be < 15 degrees C.
4. Rinsing with ultra-pure demineralised and submicron-filtered water.
5. Cavity interior surface shall be high pressure rinsed with ultra-pure water in a class-100 clean room or better for at least one and a half hours with 6.2 to 6.9 MPa (900 to 1000 psi) water. The water used for the high pressure rinsing should be demineralised and submicron-filtered.
6. Drying in a clean room of class 100 or better.
7. Cleaning and rinsing of end plates, waveguide hat, and antennas to remove grease and particulate contamination.
8. Assembly of end plates, waveguide hat, and antennas in a class-100 clean room or better.
9. Bracing of the cavity, evacuation and leak check. The cavity must be bagged in a helium atmosphere for the final leak check.

3.4.4 After completion of a vertical test, the cavity shall be prepared for integration into the system in the method outlined below:

1. Removal of all indium on flanges.
2. Etching of the cavity volume with nitric acid (HNO_3) for a minimum of 45 minutes to remove indium contamination.
3. Chemically etched with 1:1:2 BCP acid mixture removing 5 to 10 microns of material.. The acid mixture must at all times be < 15 degrees C.
4. Rinsing with ultra-pure demineralised and submicron-filtered water.
5. High pressure rinsing with ultra-pure water in a class-100 clean room or better for at least one and a half hours with 6.2 to 6.9 MPa (900 to 1000 psi) water. The water used for the high pressure rinsing should be demineralised and submicron-filtered.
6. Drying in a in a clean room of class 100 or better.

3.4.5 The vendor shall supply complete details of the chemistry, rinsing, and drying procedures used on the cavity for CLS review and acceptance.

3.4.6 Prior to the total system integration, the HOM loads, thermal transitions, sliding joints, beam tubes, tapers, gate valves, and waveguide components on the vacuum side of the RF ceramic window shall be degreased, cleaned with ultra-pure solvents and assembled/evacuated in a clean room of class 100 or better. The components shall then be baked for at least seven days. The baking temperatures for all components, except of the HOM loads, shall be 150 degrees Celsius. The vendor shall submit the bake-out procedure for the HOM loads. This procedure shall be subject to review and acceptance by the CLS. After bake-out, the system shall be leak checked prior to final integration.

3.4.7 During any leak testing, if a leak occurs that requires the disassembly of an indium seal (except probe seals) the cavity must be completely disassembled and retreated as outlined below:

1. Removal of all indium on flanges.
2. Etching of the cavity volume with nitric acid (HNO_3) for a minimum of 45 minutes to remove indium contamination.
3. Rinsing with ultra-pure demineralised and submicron-filtered water.
4. High pressure rinsing with ultra-pure water in a class-100 clean room or better for at least one and a half hours with 6.2 to 6.9 MPa (900 to 1000 psi) water. The water used for the high pressure rinsing should be demineralised and submicron-filtered.
5. Drying in a in a clean room of class 100 or better.

Should a probe seal or a conflat seal require replacement the cavity shall be slightly pressurized with 0.3 micron filtered dry nitrogen as the seal is disassembled. The cavity shall also be braced and rotated so that the sealing surface that is to be broken is facing downwards.

3.4.8 Any assembly step that will affect the cavity volume shall be done in a class-100 clean room or better. Final assembly of all UHV vacuum components shall be done in a class-100 clean room or better.

3.4.9 The cavity and vacuum components should be kept under vacuum at all times until the time of their installation into the storage ring at the CLS.

3.4.10 The RF window should be stored under vacuum until its final assembly into the acceleration module.

3.4.11 The manufacturing and assembly procedures of any ferrite tile assemblies used in the HOM loads should be submitted for review and acceptance by the CLS.

3.5 Quality Assurance

3.5.1 The vendor shall provide monthly status reports to the CLS including progress reports and updated schedules.

3.5.2 The vendor shall provide written reports to the CLS after every major testing procedure has been performed. At this time, updates to the schedule shall be provided by the vendor if the test results warrant a schedule change. Major tests that require such reports are located in sections 3.6.4 to 3.6.10 inclusively, and 3.6.12 in this document.

3.6 Inspection, Testing and Commissioning

3.6.1 The vendor shall be responsible for the supply of all auxiliary equipment used in the testing of the superconducting acceleration modules unless otherwise specified in this document. This includes such things as cavity braces, a niobium waveguide shorting hat that will blank the cavity waveguide and allow resonant excitation of the cavity with a beta = 1.0, niobium end plates, a copper cavity, RF source, monitoring equipment etc.

3.6.2 Original cavity testing may be accomplished in a vertical cryostat, but cavity performance shall only be accepted once a full assembly into the horizontal cryostat is done and a high power acceptance test is passed.

3.6.3 The vendor shall perform leak tests on all water cooling circuits. These include the HOM loads, tapers and RF window. The water cooling manifolds in the HOM loads and tapers and RF window should be pressure tested at 2 MPa.

3.6.4 The vendor shall perform tests on the RF ceramic window to ensure their operation. The vendor shall be responsible for the high-power processing of the RF window. The windows shall be tested up to the following conditions:

1. The vacuum shall be better than 1.33×10^{-6} Pa (10^{-8} torr)
2. The window shall be run at 500 kW RF power transmitted in travelling-wave operation, at a 50% duty cycle.
3. The window shall be run in cw travelling-wave operation at 300 kW.
4. The window shall be run at 125 kW cw operation at full reflection of the power with the voltage maximum placed on the window.
5. The temperature gradient across the window shall be a maximum of 65 degrees Celsius while running at 125 W cw standing-wave operation. The temperature gradient across the window shall be a maximum of 65 degrees Celsius at 500 kW cw travelling-wave operation as extrapolated from measurements at 300 kW cw travelling-wave operation.
6. The window leak rat shall be better than 26.7×10^{-9} Pa L/s (2×10^{-10} torr L/s) following the RF power test.

3.6.5 The vendor shall perform tests to ensure the proper operation of the HOM loads. Each HOM load shall be tested and shown to dissipate a minimum of 2 kW of power under vacuum. If individual ferrite panels are used in the HOM loads, they should be tested before assembly into the load. In this case an infra-red temperature test to look for thermal hot-spots on individual panels under a dissipating load is suggested. The results of this testing may be used as evidence to verify that each load is capable of dissipating a minimum of 2 kW average HOM power under vacuum. Testing may be done in air. Alternate testing procedures can be used depending on the HOM load configuration. The vendor shall supply the testing procedures for the HOM loads to the CLS for review and acceptance.

3.6.6 After completion of the cryostat-component production the vendor shall perform a nitrogen cold test on the cryostat. This test shall be done with a copper cavity. The procurement of this cavity is the responsibility of the vendor. This test will be used to detect leaks in the L N_2 lines as well as in the L He vessel. The vendor shall supply its testing procedures to the CLS for review and acceptance.

3.6.7 The vendor shall perform an initial cavity RF test at 4.2 Kelvin that may be performed in a vertical cryostat (this shall be referred to as a vertical test). The vertical tests shall be performed after the cavity has been prepared as outlined in section 3.4 of this document. The test shall include, but not be limited to, the following:

1. A thermometer array shall be attached to the equator and iris welds of the cavity to allow for temperature measurements during the vertical test.
2. Before cooldown, the cavity vacuum shall be better than $1.33X10^{-4}$ Pa (10^{-6} torr).
3. The cavity shall be cooled in a L He bath to 4.2 K.
4. With the cavity immersed in L He, the quality factor (Q_o) versus acceleration gradient (E_{acc}) shall be measured in a range from 1.0MV/m to the limit of the cavity or to the limit of the available RF power. The available RF power should be a minimum of 200W.

5. The thermometer array shall be used to diagnose the weld regions of the cavity in the event of a quench.
6. The testing shall reach the values of: E_{acc} > 10 MV/m ; Q_o (10 MV/m) > $8X10^8$. This may be accomplished after RF and or Helium Processing.
7. The external coupling Q_{trans} of the transmitted-power antenna on the cavity shall be checked and be in the range $5 X 10^{10}$ to $2 X 10^{11}$.
8. The vendor shall also measure the resonant frequency at 4.2 K. This shall be shown to be compatible with the final cavity operation of 500.00MHz, with a tuneable range of ± 200 kHz.
9. The cavity shall then be warmed to room temperature, wrapped in heat tape and baked for 48 hours at a temperature not exceeding 140 degrees Celsius. The cavity indium seals shall remain below 70 degrees Celsius.
10. Retesting of the cavity shall be done. The following values shall be reached to result in a successful vertical test. E_{acc} > 12 MV/m ; Q_o (12 MV/m) > $1X10^9$.

3.6.8 The vendor shall perform a cryostat-insert leak test using the niobium cavity. In a class-100 clean room or better the niobium cavity shall be connected to the thermal transitions and waveguide heat exchanger and mounted in the L He vessel. With the cavity braced and the entire assembly bagged in a liquid helium atmosphere, the cavity shall be evacuated and leak checked. The following leak rates shall be achieved:

Cavity to ambient	< 2×10^{-10} torr L/s (2.67×10^{-8} Pa L/s)
Cavity to helium tank	< 2×10^{-10} torr L/s (2.67×10^{-8} Pa L/s)
Cavity to insulation vacuum	< 2×10^{-8} torr L/s (2.67×10^{-6} Pa L/s)

If a leak is detected that requires the disassembly of an indium seal (except a probe seal) the cavity shall be completely disassembled and retreated as outlined in section 3.4.7 of this document.

3.6.9 The vendor shall achieve the following test results before shipment of the acceleration modules to the CLS.

1. The vacuum in the cavity shall be 10^{-6} torr (1.33×10^{-4} Pa) or better at room temperature. The residual pressure shall be achieved with as oil-free pumping system before switching to the ion pumps of the acceleration module.
2. The acceleration modules shall be leak tight at room temperature to the values listed below:

Cavity to ambient	< 2×10^{-10} torr L/s (2.67×10^{-8} Pa L/s)
Cavity to helium tank	< 2×10^{-10} torr L/s (2.67×10^{-8} Pa L/s)
Cavity to insulation vacuum	< 2×10^{-8} torr L/s (2.67×10^{-6} Pa L/s)
Helium tank to insulation vacuum	< 2×10^{-8} torr L/s (2.67×10^{-6} Pa L/s)
Insulation vacuum to ambient	< 2×10^{-8} torr L/s (2.67×10^{-6} Pa L/s)

The leak test shall be done using the following procedure:

1. Evacuate the cavity and then the helium vessel with an RGA head looking at the cavity vacuum. Check for changes of nitrogen and oxygen partial pressures in the cavity vacuum as the helium vessel is being pumped.
2. Using the RGA head in the helium-leak-check mode, spray helium around the cryostat and check for ambient to cavity leak. If a leak is found, the leaking region must be flooded with an ≈ 100% helium atmosphere to determine the leak rate.
3. Fill the helium tank with helium gas to a pressure of 82.7 Pa (12 psig) and check for helium tank to cavity leak.
4. Pump the insulation vacuum and have a helium mass detector on the insulation vacuum (does not have to be an RGA).
5. Fill the helium tank with helium gas to 82.7 Pa (12 psig) and check for helium tank to insulation vacuum leak.
6. Spray helium gas around the cryostat and check for ambient to insulation vacuum leak. If a leak is found, the leak region must be flooded with an ≈ 100% helium atmosphere to determine the leak rate.
7. Continue to pump on the cavity and have an RGA monitor the cavity vacuum.
8. Spoil the insulation vacuum with either neon or argon while leak checking the cavity with the RGA for neon or argon to leak check the insulation vacuum to cavity leak. The vendor

shall not use helium as it will compromise any future leak checking. The vendor shall not pressurize the vacuum vessel beyond room pressure.

If a leak is detected that requires the disassembly of an indium seal (except a probe seal) the cavity shall be completely disassembled and retreated as outlined in section 3.4.7 of this document.

3. After a successful leak test, the acceleration module shall be cooled down to L He temperatures. The vacuum in the cavity shall be better than 1.33×10^{-4} Pa (10^{-6} torr) before the start of a cooldown. A 10 % fill of L He is sufficient. The module shall be checked again for leak tightness and the same values achieved. The insulation vacuum to cavity leak test should not be done until the cavity is again warmed up to room temperature. This test shall be performed and the same values achieved.
4. During cooldown, the vendor shall achieve a Q_{ext} of the input coupler of $2.5 \times 10^5 \pm 0.5 \times 10^5$.
5. During cooldown, the vendor shall demonstrate the function of the tuner. The vendor shall tune the cavity resonant frequency of the cavity to ± 200 kHz around the centre frequency of 500.00 MHz with a resolution of 10 Hz or better.

3.6.10 Final acceptance of the superconducting acceleration modules shall require a successful high-power test to be performed at the CLS. These tests will be performed without an electron beam. The high-power test includes the following:

1. The acceleration modules shall be leak tight at room temperature to the values listed below:

Cavity to ambient	$< 2 \times 10^{-10}$ torr L/s (2.67×10^{-8} Pa L/s)
Cavity to helium tank	$< 2 \times 10^{-10}$ torr L/s (2.67×10^{-8} Pa L/s)
Cavity to insulation vacuum	$< 2 \times 10^{-8}$ torr L/s (2.67×10^{-6} Pa L/s)
Helium tank to insulation vacuum	$< 2 \times 10^{-8}$ torr L/s (2.67×10^{-6} Pa L/s)
Insulation vacuum to ambient	$< 2 \times 10^{-8}$ torr L/s (2.67×10^{-6} Pa L/s)

2. After a cooldown, the leak rates shall not exceed the values at room temperature.
3. At 4.5 Kelvin operation, the following values shall be achieved:

E_{acc}	> 8MV/m (goal is 12 MV/m)
Q_o (E_{acc} = 8MV/m)	$> 1 \times 10^9$
Qext of input coupler	$= 2.5 \times 10^5 \pm 0.5 \times 10^5$

4. During cooldown, the vendor shall demonstrate the function of the tuner. The vendor shall tune the cavity resonant frequency of the cavity to ± 200 kHz around the centre frequency of 500.00 MHz with a resolution of 10 Hz or better. The vendor shall supply calibration results of the cavity tuner throughout the entire tuning region.
5. The vendor shall perform test to verify the cryogenic losses of the acceleration module. The following values shall be achieved:

   With the RF off and the L He vessel filled to the level of normal operation, the static heat load will be measured to be < 35 W.

   The RF dynamic heat load shall be measured at E_{acc} = 8 MV/m operation. The waveguide heat exchanger shall be operating and no electron beam. The RF dynamic heat load shall be < 65 W.

   Total losses shall be less than 100 W at E_{acc} = 8 MV/m operation.
6. During operation at Eacc = 8 MV/m, the following values shall be achieved:

Cryostat pressure fluctuation	< ± 2 torr (267 Pa)
Cryostat level fluctuation	< 1%.

7. Following a warmup of the acceleration module the resonant frequency of the cavity shall be measured at room temperature. Another leak test shall be done and the following values shall be achieved:

Cavity to ambient	$< 2 \times 10^{-10}$ torr L/s (2.67×10^{-8} Pa L/s)
Cavity to helium tank	$< 2 \times 10^{-10}$ torr L/s (2.67×10^{-8} Pa L/s)
Cavity to insulation vacuum	$< 2 \times 10^{-8}$ torr L/s (2.67×10^{-6} Pa L/s)
Helium tank to insulation vacuum	$< 2 \times 10^{-8}$ torr L/s (2.67×10^{-6} Pa L/s)
Insulation vacuum to ambient	$< 2 \times 10^{-8}$ torr L/s (2.67×10^{-6} Pa L/s)

3.6.11 The CLS shall require that all vacuum testing and assembly procedures be submitted to and approved by the CLS. The vendor is strongly encouraged to perform leak checks on all subcomponents prior to their integration into the full assembly. This should include the performance of vacuum tests on single components as well as smaller component assemblies prior to total system integration.

3.6.12 The vendor shall perform testing to determine the HOM spectra of the niobium cavity. The testing shall be done at 4.5 K operation. The vendor shall supply the testing procedures to the CLS for review and acceptance.

3.6.13 The vendor shall perform testing to determine the IR transmission of the waveguide from the location of the RF window to the cavity location. The test procedures shall be submitted to the CLS for review and acceptance.

3.6.14 The vendor shall do testing to ensure the adequate function of the backup waveguide window. Under testing, the backup window must be shown to be capable of withstanding a high vacuum shock load The vendor shall supply the testing procedures for the backup waveguide window for review and acceptance by the CLS.

3.6.15 If the valve box is supplied by the vendor, the vendor shall do testing to ensure its proper function. The testing procedures shall be submitted to the CLS for its review and acceptance.

3.7 Reliability and Maintainability

3.7.1 All elastomer O-ring grooves shall be provided with appropriate relief or access to the atmosphere side of the groove to facilitate leak checking.

3.7.2 At least one extra flanged port shall be provided into the vacuum vessel in addition to the ports required for vacuum pumping, vacuum monitoring, instrument wiring and RF coax feed thru and heat exchanger helium gas discharge.

3.7.3 Pusher bolts should be provided for breaking all Indium seals.

3.7.4 The vendor shall supply a unit price for spare ferrite elements for the HOM load assemblies. The vendor shall also make a recommendation as to the number of spare elements that the CLS will require.

3.7.5 The requirements of the ion pumps needed shall be supplied by the vendor to the CLS and the CLS will make a recommendation as to what pump is to be used. The requirements for the turbo pump and roughing pump for the cryostat vacuum shall be given to the CLS and the CLS will purchase these items.

3.8 Layout

3.9 Other Requirements and Constraints

4. REFERENCES

Diagrams:

1. Superconducting module components, SR1 RF Cavity Cryostat Assembly (Elevation View) SR1/PPL/RF/0034301 Rev. A
2. RF straight plan view, SR1 RF Straight Section General Plan View SR1/ME/RF/0037100 Rev. C.
3. RF straight, SR1 RF Cavity Arrangement Study SR1/PPL/RF/0034300 Rev. C.
4. Tunnel cross section, SR1 RF Cavity Tunnel Cross Section SR1/PPL/RF/0034304 Rev. A.
5. Global Plan view, 2D General Plan View Technical Details BLDG/ME/0035100 Rev. M.
6. Cavity dimensions, flutes etc., SR1 Niobium RF Cavity SR1/PPl/RF/0034302 Rev. A.
7. Vacuum chamber profile at RF straight,SR1 RF Cavity Transition Flanges SR1/PPL/RF/0034303 Rev. A.
8. Cryogenic Valve box schematic SR1/PPL/RF/0034305 Rev. A

Other specifications and Design Notes:

1. “CLS RF Design Note” (CLS 2.1.4 Rev 0)

2. “CLS Design Specification Control System Overview“ (CLS2.42.39.002 Rev. 0)
3. “CLS High Vacuum Specification” (CLS2.42.33.001 Rev.0).
4. "CLS documentation specification" (CLS2.42.01.001 Rev. 1)
5. “CLS Superconducting Cavi ty Niobium Specification” (CLS2.40.32.001 Rev. 1)
6. Materials list from Niobium order.
7. BKL report “Vibration Isolation Mechanical Equipment”.