CLS Storage Ring Vacuum Chambers

Design Specification 5.4.33.1

2001-03-19

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1. INTRODUCTION

1.1 Purpose

The Canadian Light Source (CLS) requires vacuum chambers for the CLS storage ring. These chambers are divided into 8 different types. This document defines the requirements for the storage ring vacuum chambers and is to be used for the procurement of the chambers.

1.2 Scope

This document specifies the requirements for the Canadian Light Source (CLS) storage ring (SR1) vacuum chambers and details the requirements for the design, and fabrication of these chambers. This work includes, but is not limited to:

- All tooling including die sets
- Materials
- Equipment
- Commercial components
- Detailed drawings
- Fabrication
- Cleaning, and baking.
- Assembly
- Testing & Inspections
- QA/QC documentation
- Delivery to site

1.3 Background

The Canadian Light Source, CLS, is a national facility in the initial phase of 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 5 different types of ultra-high vacuum chambers to be designed and manufactured for installation into the CLS storage ring. The vacuum system process flow diagram, general arrangement, and chamber drawings are listed in Section 8. This storage ring will be capable of circulating electrons with energies of up to 2.9 GeV. These electrons will then be used as a source of synchrotron light.

The required vacuum chambers all consist of an electron beam chamber, neck, and antechamber. The conceptual design presented in this RFP utilizes a constant electron beam chamber profile with one side open to let the photons pass through to the antechamber where absorbers intercept the unwanted photons. The connection between the electron chamber and antechamber (neck) is designed to present minimum RF impedance to the electron beam while still providing enough area for the photons to pass through and the electron chamber to be pumped on. This design is very similar to that of the SLS[1]. The chambers consist of 2 curved chambers for the dipoles and 3 straight sections, which will be inserted into the quadrupoles, sextupoles, and insertion device straights.

2. REQUIREMENTS

2.1 Design

2.1.1 The required vacuum vessels shall be designed to form an ultra high vacuum system. The system is expected to reach a pressure of < 133 nPa.

2.1.2 CLS supplied drawings shall be used as a conceptual design basis. Proponents may make alternative proposals to CLS ***in addition*** to a proposal for the conceptual design laid out by CLS.

2.1.3 Tolerances should be as given in the drawings referenced in section 8. Tolerances where difficult to achieve or unspecified are subject to negotiation with CLS.

2.1.4 Proponents shall in addition follow Canadian Light Source High Vacuum Design Specification[2], CLS Design Specification 8.4.33.1.

2.1.5 Vacuum chamber vessels shall have a helium leak rate < 20×10^{-9} Pa l/s and a specific desorption rate < 100 pPa l/s/cm^2 after cool down from a 24 hour bake-out at 250°C.

2.1.6 Proponent shall be responsible for the design of all structural support members on the vacuum chamber vessels.

2.1.7 Proponent shall be responsible for the detailed structural analysis of all vacuum vessels. Results of this structural analysis shall be presented to CLS for review and acceptance. The expected maximum deflection in the antechamber shall be <1 mm. Calculations and any code modelling the chambers shall be submitted to the CLS.

2.1.8 Proponent shall maintain a 2.0 mm clearance of all magnet pole tips.

2.1.9 Proponent may use electron discharge machining to remove material at locations around the magnet pole tips.

2.1.10 Proponent shall work with CLS to develop a method of integrating/supporting photon absorbers within the chambers. Current designs of the absorbers are based on designs similar to those used at ANKA[3], and the SLS.

2.1.11 Bellows shall have radio frequency (RF) shields incorporated into the design.

2.1.12 Proponent shall develop a support system for the vacuum chamber in conjunction with CLS. The support system should be based on using pumps and/or levelling pads directly connected to the vacuum chamber. This support system shall be designed prior to start of chamber fabrication.

2.1.13 Proponent shall provide sufficiently designed beam position monitor (BPM) blocks, such that when mounted on a rigid support no damage will occur to the remainder of the chamber. It is expected that the BPM blocks shall be rigidly supported while the remaining portion of the chamber is allowed to freely move on the levelling pads.

2.1.14 Proponent shall be responsible for the detailed specification of the welding procedures and shall make such test pieces and trials as are necessary and record the details in the welding procedure specification.

2.1.15 Proponent shall propose a method to actively cool the neck of the dipole chambers.

2.1.16 Chambers shall contain branches for vacuum pumps and vacuum diagnostics as well as beam position monitors (BPMs)

2.1.17 BPM heads shall be flanged mounted on the vacuum vessel. The feedthroughs will be supplied by the CLS for the Proponent to mount (weld) into the flange. BPM radio frequency (RF) feedthroughs will be 50 Ohm coaxial feedthrough SMA type.

2.1.18 Chamber to chamber vacuum tight connections should be completed using Conflat® flanges. These flanged connections shall be RF shielded using a spring insert.

2.1.19 Chamber connections to other auxiliary equipment shall be by Conflat® flange.

2.1.20 All chambers and their flanged connections shall allow for bake-out to 250°C. It is foreseen to perform the baking of a fully mounted vacuum sector including the all-metal valves on each end and all pumps in a baking bed on the technical gallery.

2.2 Material

2.2.1 Chambers shall be fabricated from stainless steel grade 316LN. All forgings for flanges, BPM blocks, and milled pieces shall be stainless steel of grade 316LN.

2.2.2 The standard for production and remelting of the 316 LN steel material shall be submitted to CLS for review and acceptance.

2.2.3 All forgings shall be forged in all axes in order to arrive at grain size <3.5 according to ASTM E 112-88. After forging the forgings are to be quenched in water. The material shall have a maximum of 1 inclusion of type A, B, or C and a maximum of 1.5 inclusions of type D according to ASTM E 45-87. The entire volume of every tenth forging shall be tested by ultra-sound, according to ASME V23, SA 745. The acceptance criteria QL1 and QA1 shall be used.

2.2.4 Flanges, BPM blocks, and other milled pieces shall be fabricated from forgings. The structure of these forgings shall be homogenous, free from porosity and fully austenitic with less than 1% ferrite. The presence of sigma phase of precipitated carbide is not permitted.

2.2.5 Forgings shall have a Brinell hardness of 170 to 300 in the area of the sealing edge of the Conflat® flanges.

2.2.6 Flanges, BPM-blocks and the other pieces to be milled shall undergo a degassing process at 900°C at a pressure of less than 1 mPa for two hours before being welded to the chambers. The temperature area between 900 and 600° C shall be passed fast during the cool down step in order to avoid precipitation of carbide.

2.2.7 Chambers shall have a low magnetic permeability (μ_{rel}<1.01) everywhere inside the magnets.

2.2.8 Material shall only be ordered when the Proponent has submitted and obtained CLS's approval in writing of the procurement documents pertaining to the order.

2.3 Fabrication

2.3.1 Fabrication of chambers and tooling shall commence only after the Proponent has submitted and obtained CLS's written approval of the following documents:

2.3.1.1 Detailed time schedule showing the duration of all major activities.

2.3.1.2 Overall quality schedule listing quality control procedures at all stages of procurement, fabrication, assembly and testing.

2.3.1.3 Detailed fabrication drawings for the component parts of the chambers,

2.3.1.4 Detail and assembly drawings for tooling.

2.3.1.5 Welding plan and procedures for the vessel.

2.3.2 Proponent should allow sufficient time in their schedule for review of documents. CLS will make all reasonable effort to give acceptance or otherwise comment on documents submitted for acceptance within two weeks of receipt

2.3.3 All parts to be welded shall be cleaned prior to welding.

2.3.4 All welds shall be backed by an inert gas purge, to prevent undue oxidation of vacuum surfaces.

2.3.5 Vacuum sealing welds made externally shall have full penetration leaving a smooth surface on the vacuum side of the weld. Any later brushing or other finishing work on the welds is prohibited.

2.3.6 All longitudinal welds shall be made by electron beam welding without interruptions. All other welds may be completed using TIG.

2.3.7 If, at any stage of fabrication, a weld is shown to be defective, no rectification shall be done without the prior written approval of CLS.

2.4 Cleaning/Cleanliness

2.4.1 Proponents shall in addition follow Canadian Light Source Vacuum Component Cleaning Technical Procedure[4], CLS Technical Procedure 8.7.33.1. Proponent may recommend alternate cleaning procedures for CLS review and acceptance. Where procedures may be incompatible with ultra high vacuum systems, the Proponent shall identify the procedure and suggest alternate method.

2.4.2 Vacuum production, and handling procedures shall be compatible with ultra high vacuum requirements for the storage ring.

2.4.3 A high degree of cleanliness shall be observed during all stages of production to guarantee an acceptable low out-gassing rate and weld integrity.

2.4.4 Plate material shall be cleaned prior to any cutting or forming operation commences. It will be sufficient to swab with acetone or similar solvent. If a shear or press is to be used, the blades should also be cleaned with this solvent.

2.4.5 The vacuum surfaces of plate material or any other component forming part of or within the vacuum envelop has been cut, formed, finally machined and cleaned shall never be in contact with oily or greasy objects (including bare hands leaving finger prints), unless a thorough cleaning operation is scheduled to follow immediately afterward.

2.4.6 Components that will be immersed in vacuum shall be wrapped in aluminium foil and kept separately in polyethylene bags. The bags shall be suitably labelled when the components are too small to be inscribed with their drawing numbers, or other identification number.

2.4.7 A clean facility shall be provided with partition walls and a clean washable floor, for all welding assemblies. The clean facility shall be kept free from carbon steel contamination.

2.4.8 Final machining after welding of the vessel body shall be carried out in an area protected by, at a minimum, a plastic sheet enclosure.

2.4.9 Proponent shall propose a method to vacuum fire the vacuum chambers (excluding bellows assemblies) to 900°C.

3. SAFETY AND ENVIRONMENTAL

3.1 Tunnel Space

3.1.1 The vacuum chambers 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.

3.1.2 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.

3.1.3 All components shall be designed for operation in a radiation environment. The Proponent shall avoid all materials that are subject to damage by ionising radiation.

3.1.4 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.

3.2 Vibrations

3.2.1 The support girders will have a maximum vibrational movement of less than 0.4 microns at frequencies less than 100 Hz.

3.2.2 All equipment/structures shall conform to the BKL report "Vibration Isolation Mechanical Equipment"[4]

3.3 Water

3.3.1 Low conductivity cooling water (LCW) will be supplied by the CLS if active cooling of the chamber is developed. The supply water will have a conductivity of less than 6 μS/cm.

3.3.2 The Proponent shall specify the expected consumption of low conductivity water for the vacuum vessel cooling.

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

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

3.3.5 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.

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

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

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

4. APPLICABLE CODES, STANDARDS, AND PROCEDURES

The work shall meet the following standards. The issue of any standard shall be the issue in effect as of the date of request for tender. Any conflicts between this specification and the referenced documents shall be brought to the attention of CLS in writing for resolution before any related action is to be taken by the proponent.

American Welding Society (AWS)
American Society for Testing and Material (ASTM)
American Society of Mechanical Engineers, Boiler and Pressure Vessel Code (ASME-BPVC)
American National Standards Institute (ANSI)
International Standards Organization (ISO)
Canadian Light Source Vacuum Component Cleaning Technical Procedure[5]
Canadian Light Source Vacuum Component Leak Test Technical Procedure[6]

5. QUALITY ASSURANCE

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

6. INSPECTION, TESTING AND COMMISSIONING

6.1 General

6.1.1 The Proponent shall submit a detailed quality schedule specifying the intermediate tests and checks that will be made during the whole manufacturing, testing, and assembly procedure.

6.1.2 The Proponent shall inspect and vacuum test all the vacuum chamber vessels to ensure that they conform to this specification.

6.1.3 The Proponent shall provide all equipment, facilities, and personnel to carry out the quality schedule.

6.1.4 The Proponent shall submit all procedures used in the quality schedule to CLS prior to start of fabrication. These procedures shall be reviewed and accepted by the CLS prior to start of fabrication.

6.1.5 Acceptance of any component shall only be given when it has met the full requirements of this specification. In the event of a test failure, the Proponent shall document the failure and submit a proposal for correcting any fault or failures. Written approval from CLS shall be received before any corrective action is taken.

6.1.6 The Proponent shall supply CLS with a quality assurance document for each item delivered, certifying that it conforms to this specification and listing the results of all tests and inspections.

6.1.7 The final decision to accept or reject a vacuum chamber vessel shall be made by CLS after delivery. CLS may, at its discretion, repeat any of the tests and inspections detailed in this specification or those provided by the Proponent, prior to making the acceptance decision.

6.2 Material

6.2.1 Proponent shall supply CLS with material certificates for all material forming part of the vacuum vessel walls. These material certificates shall be in accordance to IOS 404 and confirm material specification, chemical analysis, and room temperature mechanical properties.

6.2.2 Where magnet permeability is specified on the drawings, the Proponent shall supply CLS with a test certificate giving the measured permeability for at least three samples widely spaced from each batch of material. The Proponent shall demonstrate that the magnetic permeability of the completed vessel is less than 1.01 in a magnetic field of 80 000 A/m.

6.2.3 No material shall be used for manufacture until the Proponent has submitted and received CLS's acceptance in writing of the test certificates pertaining to the material.

6.2.4 Acceptance of the test certificates by CLS shall not relieve the Proponent of their responsibilities under the contract for ensuring that all material meets the CLS specification.

6.3 RF Button

6.3.1 Button shall be visually inspected for concentricity.

6.3.2 SMA connector shall be visually inspected for concentricity.

6.3.3 Button shall be tested for shorts.

6.3.4 Button shall be tested for capacitance.

6.4 Assembly

6.4.1 The sequence of inspections and tests for the factory acceptance test on each completed and cleaned vacuum chamber vessel shall include but not limited to:

6.4.1.1 Visual internal and external inspection.

6.4.1.2 Vacuum leak test and desorption test after a bakeout of the vessel to 250°C. A helium leakage rate of < 20 nPa l/s and a specific desorption rate of < 100 pPa l/s/cm^2 is to be demonstrated.

6.4.1.3 Dimensional check.

6.4.1.4 Visual inspection of the sealing surfaces of flanges immediately prior to protective packing for dispatch.

6.4.2 Proponent shall visually inspect the vacuum chamber vessels internally and externally for any defects that may render them unfit for service. Attention shall be paid to the form and state of the vacuum surfaces, quality of weld joints, and sealing surfaces of the flanges.

6.4.3 Proponent shall demonstrate a helium leak rate < 20 nPa l/s and a specific desorption rate < 100 pPa l/s/cm^2 after cool down from a 24 hour bakeout at 250°C. The upper limit of the leak rate shall be documented for each vacuum chamber vessel in the quality assurance document.

6.4.4 Proponent shall demonstrate that all dimensions indicated on the corresponding drawings have been met. The quality assurance document shall document all dimensions against tolerances given on drawings.

7. RELIABILITY AND MAINTAINABILITY

All chambers and components shall be designed with a lifetime of 20+ years. The reliability and ease of maintenance of chambers and components shall be integral to any design.

8. LAYOUT

A preliminary design can be found in the following drawings:

SR1/PFD/VAC/0045315 Rev B – Vacuum System Process Flow Diagram Storage Ring (Cells 1-6)
SR1/PFD/VAC/0045316 Rev B – Vacuum System Process Flow Diagram Storage Ring (Cells 7-12)
SR1/ME/0034900 Rev A – Storage Ring 1 (SR1) General Plan View
SR1/ME/0035200 Rev I – Storage Ring 1 (SR1) Cell Typical Layout
SR1/ME/VAC/0053200 Rev A – Storage Ring 1 (SR1) Cell Vacuum Layout
SR1/ME/VAC/0046500 Rev A – SR1 Vacuum Bellows 8" OD Flange
SR1/ME/VAC/0046400 Rev A – SR1 Vacuum Bellows 6 3/4" OD Flange
SR1/ME/VAC/0036500 Rev B – SR1 Post-Insertion Device (ID) Vacuum Chamber
SR1/ME/VAC/0036600 Rev B – SR1 Dipole Vacuum Chamber 4° Beamline
SR1/ME/VAC/0036400 Rev C – SR1 Insertion Device (ID) Vacuum Chamber
SR1/ME/VAC/0036200 Rev C – SR1 Dipole Connection Vacuum Chamber
SR1/ME/VAC/0036100 Rev B – SR1 Dipole Vacuum Chamber 5° Beamline
SR1/ME/VAC/0037001 Rev C – SR1 Vacuum Chamber (0036400) Clearance to Quadrupole Magnet
SR1/ME/VAC/0037002 Rev B – SR1 Vacuum Chamber (0036500) Clearance to Corrector Magnet
SR1/ME/VAC/0037003 Rev C – SR1 Vacuum Chamber (0036500) Clearance to Quadrupole Magnet
SR1/ME/VAC/0037004 Rev B – SR1 Vacuum Chamber (0036100) Clearance to Dipole Magnet
SR1/ME/VAC/0037005 Rev C – SR1 Vacuum Chamber (0036200) Clearance to Sextupole Magnet
SR1/ME/VAC/0037006 Rev C – SR1 Vacuum Chamber (0036200) Clearance to Quadrupole Magnet
SR1/ME/VAC/0037007 Rev C – SR1 Vacuum Chamber (0036200) Clearance to Sextupole Magnet
SR1/ME/VAC/0037008 Rev C – SR1 Vacuum Chamber (0036400) Clearance to Quadrupole Magnet
SR1/ME/VAC/0037009 Rev C – SR1 Vacuum Chamber (0036400) Clearance to Sextupole Magnet
SR1/ME/VAC/0037010 Rev B – SR1 Vacuum Chamber (0036600) Clearance to Dipole Magnet
SR1/ME/VAC/0037011 Rev C – SR1 Vacuum Chamber (0036300) Clearance to Quadrupole Magnet
SR1/ME/VAC/0037012 Rev B – SR1 Vacuum Chamber (0036300) Clearance to Corrector Magnet
SR1/ME/VAC/0037013 Rev C – SR1 Vacuum Chamber (0036300) Clearance to Quadrupole Magnet
SR1/ME/VAC/0037014 Rev C – SR1 Vacuum Chamber Clearance Along Dipole Connector Straight

9. OTHER REQUIREMENTS AND CONSTRAINTS

9.1 Labelling

9.1.1 All vessels shall be given a serial number for reference. This serial number shall be inscribed at a straight part of the vessel such that it is readily visible when installed within the magnets.

9.2 Shipping

9.2.1 Components shall only be dispatched to CLS after the Proponent has been notified in writing that the factory acceptance tests of the vacuum chamber vessels have been accepted by CLS.

9.2.2 Vessels shall be shipped backed filled with clean, dry 99.99% pure nitrogen at slightly above atmospheric pressure (110 kPa).

9.2.3 Vessels shall be properly supported and contained to prevent damage and contamination during transport. Packing-cases shall be non-returnable and of a stout and robust nature suitable for lifting and transportation without damage using a forklift or crane.

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

-CLS contract number,
-shipping address as specified within contract,
-proponent's name,
-components contained within package,
-notes such as "top side up" or "fragile" if required.

10. REFERENCES

[1] L. Schulz, L.Rivkin, G. Mülhaupt, "Specification for the SLS Storage Ring Vacuum Chambers", SLS-TME-TA-1998-0103. July 1998.
[2] J. Fielden, "Canadian Light Source High Vacuum Design Specification", CLS Design Specification 8.4.33.1 Rev. 2. September 2000.
[3] S. Hermle, D. Einfeld, <u>E. Huttel</u>, "Layout of the Absorbers for the Synchrotron Light Source ANKA."
[4] BKL, "Vibration Isolation Mechanical Equipment." June 1999.
[5] J. Fielden, "Canadian Light Source Vacuum Component Cleaning Technical Procedure", CLS Technical Procedure 8.7.33.1 Rev.0. September 2000.
[6] J. Fielden, "Canadian Light Source Vacuum Component Leak Test Technical Procedure", CLS Technical Procedure 8.7.33.2 Rev 0. September 2000.