Canadian Light Source Inc.

Vacuum Design Specification

CLSI Design Specification 8.4.33.1 Rev. 3

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Revision History

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TABLE OF CONTENTS

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1. INTRODUCTION

The Canadian Light Source is a national facility on the University of Saskatchewan campus in Saskatoon, Saskatchewan, which is operated by Canadian Light Source Inc. (CLSI). This facility is a 3rd generation synchrotron light source with electron beam energy of 2.9 GeV. That operates within high and ultra-high vacuum systems and produces a high intensity source of infrared, visible, ultraviolet and x-ray radiation.

This specification covers technical aspects of the design goal to which the vendor shall aspire and give some specific requirements to the CLSI vacuum components and vessels.

Complete compliance with requirements of this specification is expected. However, any desired deviations and proposals will be reviewed and must be approved by CLSI in writing prior to use.

2. PERFORMANCE GOAL

All components designed for use in the CLSI ultra-high vacuum (UHV) system have the goal to be capable of reaching the operating pressure of 1.33×10^{-8} Pa (10^{-10} Torr), unless otherwise specified in the contract specification.

All components designed for use in the CLSI high vacuum (HV) system have the goal to be capable of reaching the operating pressure of 1.33×10^{-5} Pa (10^{-7} Torr), unless otherwise specified in the contract specification.

3. DESIGN GOAL

3.1. The basic design goals for vacuum components and assemblies are minimizing **gas load** inside the vacuum volume and maximizing **pumping speed**.

3.2. **Minimizing gas load** is accomplished by proper surface treatment and by minimizing the surface area exposed to vacuum. In general, the less one does to a vacuum surface the better. Treatments such as acid etching or polishing result in an aesthetically pleasing surface that actually has much trapped gas. The best vacuum surfaces are those that are properly cleaned in the "as-received" condition. More specifically, hot rolled stainless steel sheet which has the oxide scale stripped with an air knife performs best. However, an electro-polished stainless steel surface that has been subsequently baked at a temperature of 450 ^{O}C can come close to the aforementioned stainless steel surface. (see CLSI Cleaning Technical Procedure 8.7.33.1)

3.3. The maximum **pumping speed** will be achieved when two main conditions are fulfilled. First, the interior of a vacuum chamber is open very wide to give molecules a better chance of migrating towards a vacuum pump. Second, the tube leading from HV / UHV chamber to a vacuum pump shall provide maximum **conductance.** Thereby the length shall be as short as possible and the aperture shall be as large as possible. For instance, improving of the conductance has greater benefits for the resulting pumping speed versus increasing of a capacity of the pump. An ideal configuration would be that the pump is a part of the chamber or directly connected.

3.4. For efficiency, it is frequently better to use distributed pumping versus spot pumping.

3.5. The elimination of **trapped volumes** is imperative for proper vacuum performance. A trapped volume is a volume that connects to the main vacuum chamber by a very small passage. It becomes increasingly difficult for molecules to make their way out through these small passages. As a result, trapped volumes increase pump-down times because they act as a **virtual leak** to the system. Trapped volumes must be identified and vented in all cases.

3.6. High heat load on the components in a vacuum is the cause of accelerated outgassing rates. The layout of the pumping system must have the capability to maintain vacuum despite any fluctuations of the gas loads (see material requirements in Section 5.2).

3.7. The design goal for the heated elements in the vacuum (absorbers, fix masks etc.) made from Oxygen-Free High Conductivity (OHFC) Copper or GlidCop® is to keep the power density on the surface below 15 W/mm^2.

3.8. In designs where vacuum surfaces are to be plated with another material, extreme care with selection of the plating material shall be taken to make sure that delamination or peeling of the plating does not occur.

4. DESIGN REQUIREMENTS

4.1. All components designed for the HV / UHV environment will **safely withstand the negative atmospheric pressure** that exists. Systems which employ bellows or geometries which might deform under differential pressure loading must include restraints that prevent these axial and lateral movements. CLSI reserves the right to require calculations implemented in ANSYS to prove the design concept.

4.2. The finish of any **surface** exposed to vacuum shall be **0.8 µm** (32 micro inches) or better.

4.3. Any screws or bolts in the vacuum environment will trap gas at the bottom of a blind hole. A trapped volume can be between the head and the fixture, and between the fixture and the bushing. **Vent holes** shall be drilled to accommodate the release of this trapped gas. For example, a vent hole may be drilled through the centerline of the screw or a slot along the length.

4.4. Blind holes of diameter less than 3.175 mm or through holes less than 1.5 mm are not permitted in the HV / UHV parts.

Rationale: During the cleaning procedure chemical solutions may be trapped in these small holes and cause an increase in vacuum pressure.

4.5. All HV and UHV vacuum sealing welds should be **internal welds**. If an interior weld is not possible, full penetration external welds may be used.

Rationale: External seal welds trap gas, oil and dirt between the weld and the interior mating surfaces of the joint.

4.6. The best weld practice is to have the same thickness of the welded elements. If this is impossible, **thermal compensators** shall be used or special development of edges to decrease a local stress inside the material.

Rationale: The best results, according to the leak tests, are obtained when the width of weld seam within the range 1.0 … 2.5 mm.

4.7. If more strength is required than an interior seal weld can provide, then an additional **external skip weld** with a reasonable gap shall be used on the outer surface of the joint.

Rationale: This will allow the joint to be leak tested.

4.8. In general, vacuum seal welds or braze joints shall be correctly designed in such a way that a seam could be implemented smooth with no cracks or crevices remaining on the inside vacuum surface.

4.9. Mechanically assembled UHV elements shall utilize **Conflat**® flanges listed in Table 1 with annealed Oxygen-Free High Conductivity Copper gaskets (see material requirements in Sections 5.2, 5.6 and 5.8). The Nominal Sizes of the Conflat® flanges different from those listed in Table 1 or any other type of flanges must be approved by CLSI in writing.

Table 1

Conflat® flange Nominal Size (inch)	1.33	2.75	4.5	6	8	10	12
International Designation	NW16CF	NW35CF	NW63CF	NW100CF	NW150CF	NW200CF	NW250CF

4.10. Mechanically assembled HV elements shall utilize **Conflat®** flanges listed in Table 1 or **ISO-KF** quick connect vacuum fittings / flanges listed in Table 2 for applications where the temperature will not exceed 150^{o}C. For **ISO-KF** quick connect vacuum fittings / flanges the gaskets made from Viton® may be used only. The Nominal Sizes of the flanges / fittings different from those listed in Table1 and Table 2 or any other type of flanges must be approved by CLSI in writing.

Table 2

ISO-KF flange Nominal Tube Size (inch)	0.5	1.0	1.5	2.0
International Designation	NW16	NW25	NW40	NW50

4.11. If mechanically assembled HV / UHV joints will reach temperatures of 140^{o}C or higher, the stainless steel fasteners used for those assemblies shall be **silver plated**. For example, the typical application for the through hole is a couple: silver plated nut and not silver plated bolt. Only silver plated bolts / studs can be used for the threaded holes (see also 5.9 below).

Rationale: A diffusion weld can occur between fasteners of similar materials.

4.12. Assemblies must be designed so that they can be stripped down far enough to clean all areas properly.

4.13. Any surface that will absorb radiation from the electron and/or photon beam, or heat from Radio Frequency (RF) power, or other heat sources will be designed to **withstand the temperature increases**, **local stresses and fatigue** which result from thermal loading. Cooling shall be used in instances of high heat load. CLSI reserves the right to require calculations implemented in ANSYS to prove the design concept.

Rationale: The cooling capabilities are a determining factor as to how well the component diffuses the heat load and depend upon the material, the component size, thermal conductivity and more important the presence of conduction paths away from the heated surface to evacuate heat. The particular case mentioned in Section 3.7 above can serve as a guideline for design.

4.14. For the CLSI applications where the water cooling is supposed to be used the design criteria shall be as follows:

- Coolant passage for the water flow and pressure shall be designed to sufficiently cool the component while keeping the water safely in its **liquid phase.** The maximum temperature rise in the water-cooling circuits should be kept below 10 degrees Celsius.

- Coolant passage shall be designed to **withstand** the pressure up **to 20 atm** (equal ~300 PSI)

- The pressure drop to achieve the required flows in the cooling water circuits shall **not exceed 7.5 atm** (110 PSI).

- The velocity of the cooling water under normal operation shall be maintained in the transition zone between laminar and turbulent flow, and maintained below 3 m/s to minimize vibration.

- No direct water-to-vacuum joints as welded, brazed or mechanically assembled can be used. This means joints within a water line, or any other pressurized line, will be situated outside of the HV or UHV vacuum volume or vented to atmosphere or to a secondary vacuum volume called "airguard".

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

- The required water cooling parameters of the designed component shall not exceed the capabilities of the CLSI water cooling infrastructure and shall be coordinated with CLSI.

However, any alternative design or desired deviations will be reviewed and must be approved by CLSI in writing prior to use.

4.15. For the CLSI applications where pressurized air is supposed to be used the service line is available with the air pressure of 758 kPa (110 PSI or 7.5 atm).

4.16. If the design of HV / UHV components requires application of the purchase equipment such as Gages, Roughing ports, Pumps etc., the vendor shall follow the selection requirements specified in CLSI Vacuum Equipment Specification 8.8.33.1

4.17. Any components or assemblies heavier then 25 kg shall be designed and equipped for lifting/transporting. The CLSI site has various lifting equipment including overhead 10 ton crane. The free height under the crane hook is 3 meters.

5. MATERIAL REQUIREMENTS

5.1. Only metallic, ceramic or glass materials **compatible** with HV / UHV may be used. The material's compatibility within the vacuum depends on the material's vapor pressure at the operating temperature, permeability for gasses and porosity.

5.2. For the CLSI applications in HV / UHV environment all components shall be fabricated using the materials:

- austenitic stainless steel AISI grades **304, 304L, 304LN, 316L, 316LN**;

- aluminum **6061** or **6063**;

- ceramic Alumina (Al_2O_3);

- **Oxygen-Free High Conductivity** Copper UNS C10100 or C10200 class;
- low oxygen **GlidCop® AL-15** or **AL-25** and alloys in Section 5.3;
- a limited amount of **Viton®** as gaskets may be used for HV applications only;
- a limited amount of **Kapton**® as a wire isolation;

Any substitutions shall be submitted to CLSI for review and acceptance. Alloys with Zinc (Zn), Cadmium (Cd), Lead (Pb), and Bismuth (Bi) – shall not be proposed or used.

5.3. Filler metal alloy for the vacuum brazing shall be BAg-8 (Ag72%/Cu28%) as per ANSI/AWS A5.8 or Au50%/Cu50%. All other alloys shall be submitted to the CLSI for review and acceptance prior to brazing.

5.4. Standard **vacuum chambers** shall be manufactured from austenitic stainless steel ANSI grade 304, 304L, 304LN, 316L or 316LN (see recommendations in 3.2 with respect to 5.6 of this specification). Before using any other base metal the vendor shall provide written verification of the base metal chemistry for CLSI review and approval.

5.5. Vacuum chambers and components that exist within the aperture of a magnet shall have low relative magnetic permeability of the material in order < 1.005 in magnetic field of 12.6 A/m. Where the permeability is specified, the vendor shall supply a permeability test certificate for a sample taken from each batch of material used.

5.6. Knife edge vacuum flanges shall be manufactured from electro slag refined (ESR) hot forged austenitic stainless steel AISI grade 304L, 304LN, 316L or 316LN with Brinell hardness 170-210.

5.7. Elastomers or organic materials, except limited use of Viton® for HV application, are not permitted without CLSI written consent.

5.8. All HV / UHV vacuum joints where gaskets are required shall have **annealed** Oxygen-Free High Conductivity Copper, hardness < HV50 (by Vickers). If the joints will reach a temperature of 140^{o}C or higher, the Copper gaskets shall be Silver plated. The use of aluminum gaskets or other materials shall be submitted to CLSI for review and written approval.

5.9. The thermal expansion coefficient of the bolts / studs used in assembly must be very close, **within 5%** of the thermal coefficient of the assembled flanges / joints.

Rationale: Joint can have leak during or after the bakeout process or in case of high heat load around the joint if an expansion of items will be not equal. It is preferably to use the bolts / studs and the joint elements made from the same material (see also 4.11 above).

6. DRAWINGS AND DOCUMENTATION REQUIREMENTS

6.1. All components used at the CLSI including “off the shelf” components will have drawings produced.

6.2. All **documents** shall conform to the CLSI Vendor Documentation Specification 0.4.1.1.

6.3. All **drawings** shall conform to the CSA standards:

CAN/CSA-B78.1-M83 Technical Drawings - General Principles

CAN/CSA-B78.2-M91 Dimensioning and Tolerancing of Technical Drawings.

6.4. If both, the design and manufacture of the components are specified in the contract, the vendor can produce **drawings** following to their own drawings' standards with respect to requirements in Section 2.2 of CLSI Vendor Documentation Specification 0.4.1.1.

6.5. A unique component drawing number shall be requested by the vendor from CLSI, if Section 6.4 above is not applicable.

6.6. All drawings for tooling, jigs and formers required to complete assembly of a chamber or component at the CLSI site shall be submitted to the CLSI for review and acceptance prior to manufacture. Such acceptance shall not relieve the vendor of his responsibilities under the contract.

7. SAFETY AND ENVIRONMENTAL

All chambers and components shall be designed pursuant to applicable codes and standards in Section 8 of this specification with paramount concern of safety, ease operating and handling.

8. APPLICABLE CODES, STANDARDS AND PROCEDURES

In design of components the vendor shall adhere to the best principals of relevant industrial standards follow from:

American National Standards Institute (ANSI)

International Standards Organization (ISO)

American Society for Testing and Material (ASTM)

The design of components shall meet the following codes, standards and procedures below. The issue of any document below 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 CLSI in writing for resolution before any related action is to be taken by the vendor.

CAN/CSA W47.1-03 Certification of Companies for Fusion Welding of Steel

AWS D1.6 American Welding Society, Structural Welding Code - Stainless Steel

CAN/CSA W48-01 Filler Metals and Allied Materials for Metal Arc Welding

CAN/CSA B51-97 Boiler, Pressure Vessel, and Pressure Piping Code

American Society of Mechanical Engineers, Boiler and Pressure Vessel Code

(ASME-BPVC)

CLSI Cleaning Technical Procedure 8.7.33.1: Canadian Light Source Inc. Vacuum

Component Cleaning Technical Procedure.

CLSI Leak Test Technical Procedure 8.7.33.2: Canadian Light Source Inc. Vacuum

Component Leak Test Technical Procedure.

CLSI Vacuum Equipment Specification 8.8.33.1: Canadian Light Source Inc. Vacuum Equipment Specification.

CLSI Vendor Documentation Specification 0.4.1.1.

CSA Standard: CAN/CSA-B78.1-M83 Technical Drawings - General Principles

CSA Standard: CAN/CSA-B78.2-M91 Dimensioning and Tolerancing of Technical Drawings.

9. REFERENCES

1. “DL/UHV/01/90: General Specification for the Design, Construction and handling of Ultra High Vacuum Vessels, Components and Assemblies”, Daresbury Laboratory high vacuum staff, (Central Laboratory of the Research Councils Synchrotron Radiation Source at Daresbury Laboratory, Warrington, Cheshire, U.K., 1995).
2. “Technical Specification for Vacuum Requirements of Ultra High Vacuum Devices for Beamlines”, Advanced Photon Source Staff, (Argonne National Laboratory, Argonne, Illinois, USA, 1994).
3. “Advanced Photon Source Accelerator Ultrahigh Vacuum Guide”, Chian Liu and John Noonan, (Argonne National Laboratory, Argonne, Illinois, USA, 1994).
4. “Technical Specification for Vacuum Systems”, J. Khaw, editor (Stanford Linear Accelerator Center, Stanford University, Stanford California, USA, 1987)
5. “An Introduction to the Fundamentals of Vacuum Technology”, H.G. Tompkins, (American Vacuum Society Monograph, American Institute of Physics, New York, 1984).
6. “A User’s Guide to Vacuum Technology”, John F. O’Hanlon, John Wiley & Sons, New York, (1989).