Canadian Light Source Inc.

Vacuum Component Fabrication

Technical Specification

CLSI Document 8.8.33.4 Rev. 1

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1. INTRODUCTION

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

This document specifies requirements for the fabrication of components and vessels used in the CLSI high and ultra-high vacuum systems. This specification covers the technical aspects for machining operations, welding of stainless steel, brazing, inspection, testing, handling, packing and shipment/delivery.

Complete compliance with this specification is expected. However, any desired deviations from this specification must submitted to CLSI for review and must be approved by CLSI in writing prior to use.

2. PERFORMANCE REQUIREMENTS

All **ultra-high vacuum** (UHV) systems fabricated for use in CLSI must be capable of reaching at any point inside an operating pressure of 1.0×10^{-7} Pa (~7.5×10^{-10} Torr) or lower, unless otherwise specified in the contract specification.

All **high vacuum** (HV) systems fabricated for use in CLSI must be capable of reaching at any point inside an operating pressure of 1.0×10^{-5} Pa (~7.5×10^{-8} Torr) or lower, unless otherwise specified in the contract specification.

NOTE: Typically, in the contract specification, the vacuum requirement to the pressure inside of the particular component is 20 … 30% lower of the required performance herein, please see the contract.

Rationale: This 20 … 30% reserve may be based on consideration that the particular component is a part of the HV/UHV system and a neighbor components may not have a pumping at all. Due to a limited conductance in vacuum the pressure will rise beyond of the particular component, but shall comply with the performance requirements above.

3. FABRICATION REQUIREMENTS

3.1 Components shall be manufactured exactly to the fabrication drawings and/or specifications received by the vendor from CLSI. Any deviations from original drawings and/or specifications must be reviewed and approved by CLSI in writing prior to fabrication.

3.2 Materials for fabrication shall be as specified in the fabrication drawings and comply with Section 5 -"Material Requirements" of the CLSI Vacuum Design Specification 8.4.33.1.

3.3 Prior to fabrication all surfaces of the material must be thoroughly examined for damage and free of pitting, cracks, scale and indentations.

3.4 Machining shall not cause contaminants to be embedded into the surface of the component. Therefore, the use of abrasive resin/rubber bonded wheels, abrasive cloths of any kind is prohibited.

3.5 Ceramic bonded abrasives, tungsten carbide or diamond wheels/tools may be used. These tools shall be new or have been previously used on 300 series stainless steel only.

3.6 Heavy organic lubricants or coolants with sulfur or silicone based cutting fluids shall not be used since these can be retained to some extent by the component surface.

3.7 Only water soluble cutting fluids shall be used. These may include: 5% solution TRIMSOL, 20% solution CIMCOOL, or Hangsterfers S-500. The vendor must submit to CLSI a specification of any other lubricant to be used and will not proceed until written permission has been obtained from CLSI.

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

Rationale: A higher quality surface finish gives great benefits in the subsequent cleaning procedures, reducing efforts to achieve the necessary outgassing rate, see Section 2 of the CLSI Cleaning Technical Procedure 8.7.33.1.

3.9 Burnishing, honing and cutting with dull tools shall not be used.

Rationale: A microscopic pleating effect on the working surfaces can become a serious source of outgassing.

3.10 For improving and cleaning of the vacuum surface appearance the use of harsh abrasives or files, and bead, sand or shot blasting is prohibited.

3.11 Techniques permitted for improving of the vacuum exposed surface are slurry blasting with alumina or glass beads, grinding wheels 60 grit or finer (see requirements in 3.5 above), 300 series stainless steel brushes and hand finishing with ScothBrite™ (Grade A). The tools shall be new or have been previously used on 300 series stainless steel only. Polishing with diamond powder wetted with alcohol and applied on a lint-free pad is also acceptable. These techniques should be kept to minimum and preferably avoided, see Section 3.2 of CLSI Vacuum Design Specification and Note in Section 3.18 below.

3.12 Any type of acid treatment is prohibited unless prior written consent is given by the CLSI. If in exceptional circumstances acids are permitted by the CLSI in writing (as a part of the cleaning procedure, for example), then exposure of the component must be kept to a minimum and must be followed by copious washing in hot demineralised water.

Rationale: Most acid treatments are for cosmetic purposes only and may result in reduced vacuum performance.

3.13 The use of dye penetrant is strictly forbidden.

3.14 All vacuum tight (seal) **welding** shall be performed according to the CSA W47.1-03 standard with adopted AWS D 1.6 using the inert shielded Gas Tungsten Arc Welding (GTAW) process, known as TIG welding according to BS 7475, or electron beam processes unless otherwise authorized in writing by CLSI prior to welding.

3.15 Welding filler rod must be in compliance with CSA W48-01. Any other rod must be accepted in writing by CLSI prior to welding. Filler metal shall be stored so that it is protected from oil, dirt and other contaminants.

3.16 Prior to welding or brazing, cleaned surfaces must not contact anything unclean, including bare hands. Components must be welded or brazed within **48 hours** of being chemically cleaned.

3.17 Vacuum side welds shall be implemented smooth with no cracks, scale, voids, blow holes or crevices remaining on the surface. And there shall be no visible evidence of inclusions.

3.18 Full penetration external welds shall use inert gas shielding on both/all sides during welding to prevent oxidation. If it is happened, descaling of welds or removal of oxidation shall be done using techniques in Section 3.11 above.

NOTE: In general, weld burns do not affect vacuum performance and are best left alone.

3.19 **Brazing** shall be done in a vacuum of 0.1 Pa (~10^{-3} Torr) or dry hydrogen atmosphere. Brazes must have sufficient filler metal and proper placement so that the vacuum side of the joint is filled uniformly and completely. There shall be no crevices or discontinuities of any sort that will be difficult to clean. No filler material shall be allowed to migrate external to the joint.

3.20 The filler metal alloy for the vacuum brazing according to the CLSI Vacuum Design Specification 8.4.33.1 in Section 5.3 shall be: BAg-8 (Ag72%/Cu28%) or Au50%/Cu50%. All other alloys shall be submitted to CLSI for review and acceptance prior to brazing.

3.21 The **assembly** of vacuum components must take place in a designated "clean" area. In this area the air shall be of Class 10000 purity or better, low humidity (<60%), free from oils, gases or any contaminants exhausted by machine tools, pumps, engines or any other mechanical or chemical device or process. Personnel shall be dressed so as to prevent dust or hair shedding and air contamination of any sort. Also, see Handling Requirements in Section 9 below.

3.22 Frequent cleaning of items during manufacturing processes is required to avoid cross contamination of clean and dirty components. Any surrounding equipment such as a jig shall be thoroughly cleaned (degreased) before using.

3.23 In the mechanically assembled HV/UHV flanges all bolts or studs shall be tightened carefully step-by-step in proper cross sequence to ensure an even pressure on flanges.

3.24 A final cleaning will take place just prior to final packing, storing and/or shipping and shall remove all contaminations including visible evidence of any particles, stains and discoloration of the surfaces. Compliance with CLSI Cleaning Technical Procedure 8.7.33.1 is required.

3.25 Any deviations from requirements in this section shall be submitted to CLSI for acceptance prior to proceeding.

4. INSPECTION, TESTING AND COMMISSIONING

The vendor shall perform technical inspections on all vacuum components and leak tests of all vacuum volumes at the vendor's facility to ensure compliance with this specification, procedures referenced herein and all other requirements of the contract agreement. This shall include but not limit the following:

4.1 All vacuum surfaces shall be free of cracks, scale, pilling or delamination, indentations or defects of any kind. Extreme care shall be taken to the knife sealing edges and sealing surfaces. Any evidences of scratches, pits, crosses rolling, inclusions or other defects are not acceptable.

4.2 Weld and braze regions on the finished components or chambers shall be free from visible sign of inclusions, scale, crevices, voids, holes of any kind and any defect that may cause a leak.

4.3 If vacuum surfaces are plated with another material, any evidence of peeling or bubbling is not acceptable

Rationale: If electroplating or any other process involving acids are used, it is a good practice to vacuum bake the plating at the 450°C to remove acid residuals. An electroless process such as the "Dalic" process, or vacuum evaporation, sputter coating or similar is recommended wherever practical.

4.4 All chambers or vessels shall then be successfully leak tested in accordance with CLSI Leak Test Technical Procedure 8.7.33.2.

4.5 Before the final leak test each component or chamber shall be cleaned in accordance with CLSI Cleaning Technical Procedure 8.7.33.1.

4.6 If the chamber or component exceeds **10 liters** volume, an RGA spectrum shall be taken before baking, during baking and after cool down when the pressure has reached below 1.0×10^{-7} Pa (7.5×10^{-10} Torr) at the end of CLSI Cleaning Technical Procedure 8.7.33.1 in Section 4. Vacuum chambers and components shall be fitted with an RGA, thermocouples connected to the chamber and an ion gauge installed for pressure readout Pa or Torr. The data from thermocouples and ion gauge will have a record during the entire bake cycle. All of the aforementioned data shall be provided to CLSI, unless otherwise specified in the contract agreement.

4.7 For UHV applications the vessel under vacuum shall have the **total gas load** less than 4.0×10^{-7} Pa·l/s (~3.0×10^{-9} Torr·l/s) per 1000 cm^2 (0.1 m^2) of the volume surface (in average) measured 10 hrs after the end of the bake cycle in Section 4 of CLSI Cleaning Technical Procedure 8.7.33.1 or at such time the vessel temperature falls below 30°C.

NOTE: The total gas load includes outgassing from the volume surfaces (major factor), plus undetectable leaks and/or gas penetration.

Rationale: A typical vessel of 10 liters volume (e.g. spool with 20 cm /~8 inch diameter and 30 cm /~12 inch long) has ~2000 cm^2 of outgassing surfaces. After completion of the cleaning procedure for UHV environment the outgassing rate from the stainless steel surface shall be 3.0×10^{-12} Torr·l/s·cm^2 *or lower. Thereby the total gas load from all surfaces can be* 6.0×10^{-9} Torr·l/s. *Having a pump with the pumping speed 40 l/s shall allow of reaching a vacuum of* ~1.5×10^{-10} Torr (~2.0×10^{-8} Pa)*. That complies with performance requirements (with some reserve) in Section 2 above. The volume of 20 liters (with respect to the outgassing surface as a major factor!) may require the pumping speed 75 … 80 l/s to achieve the same operating pressure and so on.*

4.8 For HV applications the vessel under vacuum shall have the **total gas load** less than 4.0×10^{-5} Pa·l/s (~3.0×10^{-7} Torr·l/s) per 1000 cm^2 (0.1 m^2) of the volume surface (in average).

4.9 The vendor shall measure all dimensions critical for assembly and check the functionality and/or physics characteristics (include vacuum performance) of all completed components. A technical inspection report with the leak test certificate as per Section 4.4 above and RGA spectra, if applicable (see Section 4.6 above), shall be provided to CLSI upon delivery, unless otherwise specified in the contract agreement.

NOTE: The exact details of the contents of this report shall be discussed and agreed upon between the vendor and CLSI.

4.10 If any of requirements in Section 4 of this specification are not met, the chamber or component will not be acceptable. A report (with RGA spectra, if needed), shall be sent to CLSI for consideration. Any remedial action shall not be taken before contacting and receiving written approval from CLSI.

4.11 CLSI staff reserves the option to witness any tests at the vendor's site. As a result, if requested, the vendor shall provide written notice to CLSI 15 days prior to testing.

5. QUALITY ASSURANCE

5.1 The vendor shall provide all proposed quality assurance programs to CLSI for written acceptance prior to the commencement of work.

5.2 Upon receipt, CLSI will inspect all components visually and test using the appropriate equipment to ensure compliance with the contract specifications or other contract agreements and that no damage has occurred during shipping. Failure during any of

these inspections or tests will **require rectification** by the vendor as part of the contract conditions. Successful completion of these inspections and tests shall be the basis for final acceptance.

6. RELIABILITY AND MAINTAINABILITY

All chambers and components shall be fabricated to achieve a lifetime of 20+ years, unless otherwise specified in the contract agreement.

7. SAFETY AND ENVIRONMENTAL

All chambers and components shall be manufactured pursuant to applicable codes and standards in Section 11 of this specification with safety and ease of operation, handling and use as paramount concerns.

8. MARKING AND LABELING

8.1 All components shall be marked or labeled with two numbers: first, a fabrication drawing number (from the drawing's title block), second, a unique serial number six digits (For example – 000001, 000002 and so on), unless otherwise specified in the contract agreement. The numbers shall be visible together from the exterior. The number size shall be within 3.5 ... 14 mm. On the major assemblies the vendor's company name or/and his Trade-mark will be required.

8.2 Vacuum surfaces may be marked if it is absolutely imperative to do so and shall be carried out only with clean, dry scribers or vibrating engravers. The use of acid etching and marker pen is strictly prohibited. It is good practice not to use these on external services as well because of possible cross contamination in subsequent cleaning processes.

8.3 In the case of small components, identification labels shall be fixed to packing bags.

8.4 If self-adhesive labels and tapes are essential, they will be fixed to non-vacuum surfaces only. In addition, the adhesive used must be soluble in acetone or alcohols.

9. HANDLING REQUIREMENTS

9.1 Extreme care is required at all times to avoid causing damage to vacuum surfaces, especially sealing surfaces and knife sealing edges.

9.2 Cleanliness is paramount at all times. Food, drink and smoking shall be prohibited in the clean areas and around clean items.

9.3 Cross contamination of clean and dirty components must be avoided. If the vacuum component or item is to touch a foreign surface, the foreign surface must be a clean surface or covered with new oil-free aluminum foil for vacuum purposes.

9.4 Gloves shall always be used when handling cleaned components. New gloves shall be used for every new application. A supply of new gloves should be on hand. In addition, gloved hands shall not touch unclean surfaces include bare skin. If unclean surfaces are touched, gloves must be replaced immediately.

9.5 Care shall be taken in selecting such gloves. Polyethylene or natural vinyl is preferred. Colored gloves shall be tested to ensure that the dyes do not leach out when exposed to the solvents used. Gloves with talcum powder, chalk or other powders inside shall be avoided since the powder can migrate into components. A good solution is to use **lint-free fabric** gloves inside polyethylene gloves. Hands must be washed before wearing clean gloves.

10. PACKING, STORING AND SHIPPING

10.1 After the component has been cleaned, baked and tested, it must be packed carefully in such way to ensure that it remains clean and free from damage during shipping or storage.

10.2 Assemblies must be secured for shipping so that they are not susceptible to contamination or weather and water damage. Special attention must be paid to assemblies or sub-assemblies with moving parts. They must be securely fastened, padded, crated and/or boxed for shipping so that they are not damaged due to vibration or unwanted motion.

10.3 For shipping and storing of clean vacuum chambers and components where RGA tests were taken as per Section 4.6 above, the chambers shall be sealed with blank flanges using metal gaskets and pressurized to 110 kPa with dry nitrogen (99.99% purity).

10.4 All non-sealed flanges and mechanically assembled joints must be protected with clean metal gaskets where possible and wrapped in new oil free aluminum foil and plastic covers for the purpose mentioned in Section 9.1 above.

10.5 All water passages shall be blown dry prior to shipment. Specific checks shall be performed to ensure no water is left in the cooling channels.

Rationale: Frozen water may damage passages during transportation to Saskatoon in the winter time.

10.6 Labels on the packing boxes/bags for identification purposes shall have the same numbers with labels or tags tied to the components (see Section 8 above).

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

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

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

10.9 The Vendor shall notify CLSI ten (10) days prior to the shipment date if any of one shipped piece is greater than 2m x 2m and/or heavier than 3,000 KG. The notice shall include a list of equipment, origin shipping date, routing of shipment and firm providing service, shipping weight, copies of customs documentation (if required) and anticipated date of arrival. CLSI reserves the right to approve shipping method and route.

10.10 Details of packing and shipping shall be discussed between CLSI and the vendor and included in the contract agreement.

11. APPLICABLE CODES, STANDARDS AND PROCEDURES

The vendor shall follow to the best industry practice taking into account from relevant industrial standards:

American National Standards Institute (ANSI)

International Standards Organization (ISO)

American Society for Testing and Material (ASTM)

The fabrication 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)

Canadian Light Source Inc. Vacuum Design Specification 8.4.33.1 Rev.3

Canadian Light Source Inc. Vacuum Component Cleaning Technical Procedure 8.7.33.1 Rev.2

Canadian Light Source Inc. Vacuum Component Leak Test Technical Procedure 8.7.33.2 Rev.2

12. 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).
7. "A survey of vacuum material cleaning procedures: A subcommittee report of the American Vacuum Society Recommended Practices Committee", Y. Tito Sasaki, (Quantum Mechanics Corp., 1990)