MANUFACTURING AND CLEANING GUIDELINES FOR UHV DEVICES

SPECIFICATIONS OF SOLARIS VACUUM CHAMBERS, INCLUDING TENDER DOCUMENTS FOR MANUFACTURING AND QUALITY ASSURANCE.

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1 INTRODUCTION

Solaris is an international Research Center that will allow understanding the properties of matter and the phenomena, observed in atomic and molecular scale.
The Synchrotron Radiation facility will investigate many fields of science such as physics, chemistry, materials science, biochemistry, pharmacology, biology medicine and will have a deep impact and several benefits in technological developments.
The chambers for the ultra-high vacuum (UHV) are critical components to the system and to the production of the synchrotron light. The synchrotron facility will operate at pressures between 10^{-9} and 10^{-10} mbar. Great care must be taken in the fabrication phase to prepare the chambers so that unwanted gases are not reabsorbed and the requested high level of vacuum can be reached.

2 SCOPE OF WORK

This document specifies the requirements and procedures that must be used to produce components and vacuum chambers that will operate at UHV for the Solaris facility.
This document applies to the vacuum components fabricated by forming, machining and welding operations and covers the requirements for design, welding, cleaning, coating, inspection, testing, documentation, packaging and transportation.
The manufacturer shall secure complete compliance with these specifications. However, in case deviations from these specifications were necessary, a written communication shall be submitted for review to Solaris, who must approve in writing prior to proceeding any further.
This document is exclusive property of Solaris and it shall neither be shown to Third Parties nor used for purposes other than those for which it has been delivered.

3 CODES AND REGULATIONS

Under normal industrial practices the contractor shall comply with the guidelines of the following international organizations:

- International Standards Organization (ISO)
- American National Standards Institute (ANSI)
- American Society for Testing and Material (ASTM)
- American Welding Society (AWS)

The following documents are to be used, or their equivalent at fabricator discretion, for the various construction phases.

- Material certification according to ASTM or ISO 404
- Welding
  - ISO 15614-1, ISO 15614-11, test and inspection.
  - ISO 13919-1, ISO 5817, weld quality: level B, rigorous.
  - ISO 9606-1, welder qualification.
  - ISO 15609-3, ISO 15609-1, welding procedure specifications, WPS
  - AWS D1.6, Structural Welding Code – Stainless Steel
  - AWS D1.2, Structural Welding Code – Aluminum
  - ASME, BPVC, Section IX, welding processes and welder certification.
  - ASME, BPVC, Section V, non-destructive tests.
  - ASME, BPVC, Section II, part C, Specifications for Welding Rods Electrodes and Filler Metals.
- Manufacturing
  - ASME, BPVC, Section VIII, Division 2

4 MATERIAL SELECTION

All of the materials used shall be UHV compatible and must reach, with proper pumping systems, pressures less than or equal to 10^{-10} mbar.

4.1 Allowed materials

Table 1, though not exhaustive, lists some materials compatible with UHV applications. UHV parts must be made of the materials stated in their relative drawing title block. Deviations from the material indicated in the title block and the use within the UHV system of materials other than those listed in Table 1 require Solaris prior written consent.
If glues are used, the vendor shall submit a written declaration of UHV compatibility and proceed only upon Solaris written authorization.

Stainless Steels - AISI 304L, 304LN, 316L, 316LN, 321, 347
Aluminum and its alloys 5086, Alclad 6061, Alclad 6063, ISO AlMgSi6060,
Beryllium
Copper (OFC, OFHC, GlidCop AL-15 and Al-25 grade)
Glass
Sapphire
Gold
Silver
Mumetal, Monel metal
Titanium 50A
Inconel
PTFE
Mica
High density and high purity Alumina, Aluminum Nitride, Zirconia, Silicon Nitride, Silicon Carbide

Table 1 – Some UHV compatible materials

4.2 Not permitted materials

Generally, materials with a high vapor pressure are not acceptable for use. In particular: Zinc, Cadmium, Lead, Cesium, Mercury, Potassium, Magnesium, Sodium, Selenium, Strontium. This also precludes the use of any alloy containing the aforementioned materials since possible surface segregation may occur.

4.3 Magnetic permeability

Vacuum chambers and components in the vacuum chambers that stay within the apertures of the magnets are required to have a magnetic permeability of lower than $\mu_r \leq 1.01$, unless otherwise stated in the drawings or order documentation.

4.4 Material certification

All materials within the vacuum system are required to be approved and authorized in writing by Solaris before they shall be machined. The vendor shall provide, prior to the delivery, the certificate of conformance for the materials used stating the composition, the physical and chemical properties that attests their compatibility with UHV systems.
The supplier shall ensure the full traceability: during manufacture and at the end of the fabrication the material certificate shall be detectable for every piece.

5 MANUFACTURING

5.1 Machining

5.1.1 Introduction

The parts fabrication shall be achieved primarily by mechanical means. While the commonly used cutting tools are approved, the use of abrasives or polishing compounds shall be preferably avoided. In case the requested surface finish cannot be guaranteed solely by machining, then the surface may be polished with one of the approved abrasives (see §5.1.3). Any deviation from the abrasive listed in §5.1.3 is subject to Solaris approval. The fabricator shall determine the proper abrasive particle size and pressure to have a uniform distribution in order to avoid local surface overheating or particle inclusion into the surface.
Polishing by abrasive flow polish or slurry blasting is limited to glass or alumina abrasive particles.
Deburring shall be performed with a file or a knife or approved abrasive (§5.1.3).
Any evidence of contamination or inclusions shall be cause of rejection.

5.1.2 Flanges

The knife-edge surface of all UHV CF flanges shall be examined prior to any machining operation and the part must be discarded if any defect is observed. The flange sealing surface must be protected during any machining operation and machining methods compatible with such protection shall be preferred. Parts delivered to Solaris with damaged or defective sealing surface shall be rejected.

5.1.3 Abrasives

The approved abrasives are limited to:

Abrasive	Materials
3M Scotch Brite	Type A, aluminum oxide (purple) Type S, silicon carbide (gray)
3M Wetordry Fabricut	In aluminum oxide or silicon carbide

Table 2 – Approved abrasives

Other abrasives can be used only after receiving a Solaris written authorization.

5.1.4 Cutting Fluids

Cutting fluids and lubricants that may cause contamination of the parts to be used in UHV systems are not permitted. Hence, fluids either with high organic constituents of 50 ppm or more of sulfur or silicone are prohibited. Water-soluble cutting fluids are allowed.
A not exhaustive list of approved cutting fluids is shown in Table 3. For any other cutting lubricant, the manufacturer shall provide Solaris with the fluid composition and a written declaration of UHV compatibility. No further action shall be taken without prior Solaris written consent.

Isopropyl alcohol
Ethanol
Aqua Syn 55 (G-C Lubricants Co.)
Aqua Cool 21EP-5 (G-C Lubricants Co.)
Aqua Cool 4-EPX (G-C Lubricants Co.)
Cimcool 5 Star 40
Cimperial 1011
Cindol 3102
Cold Stream Coolant (Johnson Wax Co.)
Cutzol EDM 220-30
Diamond Way 2010 (Yamazen)
Dip Kool 862
Dip Kool 868
Dip Kut 819H
Haloform CW-40
Kool Mist 88
Micro-Drop “Advanced Synthetic Lubricant” (Trico)
“Pearl” Kerosene (Chevron)
Perkut 301GG (Perkins)
Rapid Tap
Relton A-9
Rust-Lick Vytron (ITW Fluid Prods.)
Rust-Lick G-25-J (ITW Fluid Prods.)
Rust-Lick WS11 (ITW Fluid Prods.)
Rust-Lick WS600A (ITW Fluid Prods.)
Rust-Lick Safetap Ultima (ITW Fluid Prods.)
Sunnen Man-852
Syntillo 9930 (Castrol)
Tap Magic
Tapmatic 1
Tapmatic 2
“Tool Saver” (Do All Corp.)
Trim 9106CS
Trim E206 (Master Chemical Corp.)
Trim Sol
Trim Tap

Table 3 – Some of the permitted cutting fluids

5.2 Welding and Brazing

5.2.1 Introduction

The welding and brazing zones shall be free of scales, voids, micro cracks, pits, inclusions and any other type of defects. In order to guarantee that the welding zone is UHV tight, all parts shall be accurately cleaned and all cleaning processes shall be completed within 48 hours from the welding. Parts are to be protected from any contaminants – like oils, grease, fingerprints, etc. – before, during and after the weld operations and shall be handled only with UHV approved gloves. To protect the weld zone from oxidization, parts shall be flushed with inert gas until they have cooled down to a temperature of 60 ºC or below.
All of the welding of UHV parts shall be performed in compliance to one or more weld standards (see §3) using Gas Tungsten Arc Welding (GTAW), also known as TIG welding, or Electron Beam Welding (EBW); any other method must be specifically approved by Solaris.
All joints shall be internally welded i.e. from the UHV side of the part. Where this not possible, the welds shall have full penetration up to the surface facing vacuum and have a smooth surface free of defects (diameter of weld bead < 0.3 mm). It is not permitted to perform additional polishing of the weld bead surface. All longitudinal welds shall be continuous.
Where welding on both sides is required because the joint is subject to high forces, the side facing the vacuum shall to be continuous and the opposite side intermittent. No continuous welds on both sides of the joint are permitted.
The use of penetrant liquids is prohibited. Welding filler metals shall be used only upon written permission of Solaris.

5.2.2 Bimetallic Components

The use of bimetallic components obtained by welding or explosion bonding are required to be certified by passing an ultrasonic test showing that the interface between the two materials is complete.

5.2.3 Weld Burns Removal

As a general rule it is not advisable to remove burn marks with an acid paste other than to remove any welding scales. For extensive weld burns, the use of one of the abrasives listed in §5.1.3 is permitted.

5.2.4 WPS and PQR

The vendor shall qualify all welders to the relevant processes as listed in §3. Per Solaris's request the fabricator shall provide a list of all the welded assemblies and the relevant welding procedures used, Welding Procedure Specifications (WPS). Such WPS shall list all of the process parameters (welding velocity, type of inert gas, electrode diameter, etc.). Solaris reserves the right to request a sample of all weld configurations and the relevant documentation, Procedure Qualification Record (PQR), as a means to qualify the weld process proposed by the contractor. §3 lists the standards to follow in writing the WPSs and PQRs.

6 FABRICATION DRAWINGS

Based on the 2D drawings and 3D models provided by Solaris, the contractor shall produce his own fabrication drawings. The sole contractor is responsible for the preparation and content of this documentation. The contractor shall supply a complete set of fabrication drawings at least two weeks before production starts. Solaris will review the provided documentation for compatibility with the technical specifications and all requirements. Solaris will provide written authorization to proceed with production.

The drawings are original and confidential. The contractor must not:

- disclose, directly or indirectly, any part of the design to a third party for whatever reason may exist without prior written consent of Solaris;
- make a copy of the design in any form and for whatever use without prior written consent of Solaris;
- alter, modify, disassemble or decompile the design;
- patent or register under another name or contractor's name any components that might include this design.

7 ELECTROMECHANICAL DEVICES IN VACUUM

Electromechanical devices used in the vacuum system shall have a certificate of compliance with UHV systems. A statement of the minimum number of hours of operation within a UHV environment before maintenance or replacement is required.

8 BELLOWS

Great attention must be paid when cleaning the bellows, especially with thin wall or welded membranes. Given the risk of trapping solvent residues within the convolutions and consequent corrosion related leaks, while cleaning the bellows the use of solvent should be limited. The use of alkaline degreasers (see §9.3.1, Step 2) should also be minimized because they increase the precipitation of particles that, once trapped within the bellows membranes, might cause perforations or fatigue cracks.
If possible the bellows are to be in their fully extended length during all the cleaning phases (see §9), and, before proceeding with cleaning, all visible contaminants shall be removed by use of dry air or nitrogen.
The vacuum bake-out for cleaning the bellows shall be done at 250 ºC for a minimum of 36 hours. Under any circumstance the temperature shall not exceed the brazing temperature if this method has been used to join the parts. Heating and cooling shall be gradual in order to prevent any mechanical damage or leaks.

9 CLEANING

9.1 Introduction

Any deviation from the following cleaning procedures shall be communicated in writing to Solaris and without any Solaris prior written consent the manufacturer shall not proceed any further.

9.2 Cleaning Conditions

Proper cleaning conditions must be established during the whole manufacturing and assembly process of UHV components.
Construction, cleaning and assembly shall be carried out in an area adequately clean and efficiently separated and isolated from the machine shop. Some of the parameters that require careful control are: ambient temperature, the way the air is circulated, proper work areas and clean working surfaces.

For this purpose it is prescribed that, in the work area:

- It is strictly forbidden to smoke, prepare or consume food or beverages;
- It is prohibited to use fluids or materials that contain sulfur which can corrode the vacuum parts;
- laboratory smocks, head covers, gloves and shoe covers are required;

- adequate number of hand tools and fixtures, cleaned and degreased, must be permanently kept within the clean area and be promptly available.
- all fixtures and tools that come in contact with the vacuum components shall be in stainless steel or aluminum (do not use carbon steel, brass, copper, etc.);
- lift systems shall have adequate protection in order to prevent any oil or contaminant drips from getting onto the parts being machined.

The manufacturer shall indicate what the work area cleanliness standards are. If this is not possible then the company shall state how they intend to achieve and maintain the required cleanliness standards. An inspector from Solaris could verify the adequacy of the work area.

9.3 Cleaning Procedures for the Surfaces Exposed to Vacuum

The finish and cleanliness of the surfaces exposed to vacuum is paramount to achieve the required vacuum level.
The cleaning materials and the subsequent storing must not leave residues.
Sandblasting or shot peening of the surfaces exposed to vacuum is not allowed. Lapping or other polishing method are not allowed, except for what specified in §5.1.1.
At the end of the machining, the vacuum surfaces shall have a surface finish Ra < 0.8, without oxides or other impurities, unless otherwise specified in the mechanical drawing provided by Solaris or in the purchase order documentation.

A complete surface cleaning procedure shall include the following steps:

1. Degreasing
2. Chemical etching to remove oxides
3. Buffer chemical polishing (optional)
4. High pressure rinsing
5. Drying and storage.

Surface treatments shall be carried out before welding and repeated before proceeding with the final vacuum checks.
Detergents, solvents, chemical baths and operating procedures shall be submitted to Solaris for approval.

9.3.1 Degreasing

Degreasing, necessary to remove oils and grease, must be performed in two steps so that both organics and inorganic oils are eliminated.

STEP 1. Degreasing by Organic Solvents
The following organic solvents can be used: acetone, benzole, not-denatured ethylic alcohol, Detersol, Citranox. Components contaminated during machining with oils or grease shall be degreased with perchloroethylene vapor at 120 ºC or, alternatively, will be high pressure rinsed with alkaline detergent approved by Solaris inspectors.

STEP 2. Degreasing by Alkaline Phosphates-free Detergent
Such rinsing shall be conducted at about 60 ºC, with alkaline phosphates-free detergent in an ultrasound bath. Special care shall be taken in case the ultrasounds might damage the part material (i.e. aluminum).

9.3.2 Rinse

All parts after degreasing shall be washed in 30-40 ºC water. A pre-rinse can be carried out using tap water, but the final rinse shall be done with purified running water.

9.3.3 Oxides Removal

Removal of oxides formed during machining or welding shall be achieved via chemical etching or buffer chemical polishing (BCP) or electropolishing (EP). Do not clean ceramic feedthroughs with chemical means.

9.3.4 Mirror Finish (optional)

A mirror finish to be achieved via BCP or EP may be requested.

9.3.5 Neutralization

Before the final rinsing, after the chemical baths, a neutralization bath is necessary to eliminate any acid traces.

9.3.6 Surface Protection

Surfaces that require a high surface finish, like seal landing zones, shall be protected by chemical agents with a coating or other equivalent mean.

9.3.7 Bathing Methods

Mechanical bathing methods (bath agitation, part motion, etc.) shall be chosen according to the piece geometry in order to guarantee throughout the part that the rinsing/chemical etching is homogeneously done.
Cleaning tools (bathtubs and brushes) shall be in stainless steel, nylon or polyethylene.

9.3.8 Drying and Storage

After cleaning and the final vacuum check, parts shall be dried off with inert gas (i.e. nitrogen, argon) and subsequently stored as indicated in §14.

9.4 Bake-out

Bake-out shall be carried out heating parts in a vacuum oven, pumped down by a suitable number of roughing and turbomolecular oil-free pumps.
Parts cannot be assembled together but can be baked together during the same session. Proper temperature control, ±5 ºC, shall be achieved. The maximum bake-out temperature shall be compatible with the material physical and chemical properties. In general, it is advisable not to exceed 250 ºC for stainless steel and copper and 180 ºC for aluminum. In some cases – i.e. bellows, optical viewports, feedthroughs, etc. – the maximum local temperature must be accurately controlled to avoid damaging the part or the vacuum tightness. Critical components must be certified to withstand at least 120 ºC for 24 h. The manufacturer must preventively indicate in writing the maximum bake-out temperature, which must be approved by Solaris.
Bake-out will not start above 10^{-5} mbar. The oven pumping system must be capable of reaching 10^{-8} mbar or lower at the end of the process. The heating and cooling temperature ramps must be linear and span over 24 h. In case of critical components like bellows, optical viewports and feedthroughs, heating and cooling speeds shall be careful chosen to prevent mechanical damage or leaks.
The part must withstand the maximum bake-out temperature for 48 h or longer. The bake-out is considered accomplished when, during cool down, the part temperature is close to room temperature and pressure in the oven is ≤ $1x10^{-8}$ mbar.
The vacuum system shall be gradually filled with dry nitrogen and the part protected and stored as described in §14.

The manufacturer shall prepare a report describing
- the vacuum system
- the bake-out diagram
- starting and final conditions (temperature and pressure).

The bake-out data shall be also provided in electronic format (i.e. ASCII, etc.).
The vendor shall inform Solaris in advance of the upcoming bake-out and allow a Solaris inspector to attend the operation.

9.5 Residual Gas Analyzer (RGA) Test

The vacuum test with quadrupole residual gas analyzer (RGA) allows knowing the composition of the residual gas present in the vacuum chamber. The mass spectrum sensitivity must cover the 1-200 atomic mass units (a.m.u.) range and the instrument must be capable of detecting partial pressures lower than $5x10^{-12}$ mbar. The test shall be performed when the pressure is < $5x10^{-9}$ mbar.
A sole Faraday cup detector is not allowed; detections will be achieved by means of a secondary electron multiplier (SEM) with conversion dynode or equivalent. The instrument shall be calibrated on nitrogen (28 a.m.u.) and the calibration factor shall be stated on the attached documentation together with:

1. RGA model
2. detector type and operating voltage.
3. ion source type
4. filament current
5. electron energy
6. any other parameter determining univocally the measurement conditions.

The test is performed at the end of the bake-out. The instrument filament must be outgassed beforehand during the bake-out cool-down starting at 80 ºC. The vacuum system must be isolated from the turbomolecular pumping system with all metal gate valves. Adequate sputtering ion pumps shall maintain the UHV condition.

The test report shall also include:

1. description of the vacuum system
2. test phases
3. initial and final pressure
4. initial and final temperature
5. the analog diagram with logarithmic scale of the peak intensity versus the a.m.u.

Raw data, comprising pressure and temperature versus time, shall be saved in electronic format and delivered together with the paper documentation.
The test has positive outcome if the sum of the peak intensities for a.m.u>44 is three orders of magnitude smaller than the total sum of the peak intensities in the 1-200 a.m.u. range. Solaris reserves the right to have its designated representative(s) witness the test.

10 ACCEPTANCE TEST

Great care shall be taken carrying out the vacuum inspections and the vendor shall provide the entire test setup. This chapter establishes the procedures that need to be followed, the instrumentation requirements, the personnel training and qualification prerequisites and acceptance criteria. Besides the present Scope of Work, the guidelines expressed in the ASME *Boiler and Pressure Vessel, Section V, Article 10, Leak Testing* shall be followed.

10.1 Acceptance Requirements

Components intended for UHV use at Solaris facility shall meet the acceptance class (b) (see Table 4).

Class (a)
1) localized leaks: < 5 x 10^{-11} mbar l/s
2) overall leaks: < 1 x 10^{-10} mbar l/s per component
Class (b)
1) localized leaks: < 1 x 10^{-10} mbar l/s
2) overall leaks: < 2 x 10^{-10} mbar l/s per component
Class (c)
1) localized leaks: < 2x 10^{-10} mbar l/s
2) overall leaks: < 5 x 10^{-10} mbar l/s per component

Table 4 – Acceptance classes for vacuum leaks

The description of the required methods to perform and certify the tests are in the following chapters. Table 4 refers to Helium leaks. The air leaks can be easily calculated by:

$$P(air) = \frac{P(He)}{2.7}$$

10.2 Pumping Systems

Given the demanding cleaning requirements, the vendor shall use proper vacuum systems with the following minimum parameters:

- Oil-free roughing pump with 5-30 m^3/h pumping speed and 10^{-2} mbar ultimate pressure.
- Oil-free turbomolecular pump with 100-500 l/s pumping speed.

Adopting an oil-free pump prevents the vacuum parts from being contaminated.

10.3 Measuring Equipment

The test measuring equipment must be made of

- Pirani vacuum gauge for low-medium vacuum (1 bar – 10^{-3} mbar)
- Cathode ionization vacuum gauges for high and ultra high vacuum (10^{-3} – 10^{-11} mbar)

10.4 Inspection

10.4.1 Introduction

The required tests aim at discovering and eliminating vacuum leaks. If there are leaks and the atmosphere around the vacuum vessel is made of helium, the helium will enter into the chamber and the mass spectrometer will detect it.
The test setup flanges, piping, bellows and valves shall be in stainless steel. Accessories in other materials as copper, brass, aluminum, etc. are generally not permitted.
The connection pipes between the part being tested and the pumping system shall have adequate conductance. All gaskets and seals shall be in metal.
An inspector designated by Solaris will verify the qualification level of the personnel responsible for the vendor's vacuum tests.

10.4.2 Inspection Procedure

The test setup shall include the following devices

- Helium mass spectrometer with sensitivity 10^{-5} – 10^{-11} mbar l/s
- Calibrated leaks at 10^{-8} mbar l/s

Once the machining is complete, the parts shall be cleaned as indicated in §9 and welded. Afterwards the following checks shall be performed:

- Preliminary check to discover massive leaks and removal thereof.
- Local and integral leak check, leak detection and removal thereof.

During all tests, sealing shall be performed using metal gaskets. Viton® gaskets are not recommended since Viton® is permeable to helium and that alters time dependent measurements.

10.4.3 Leak Detector Calibration

In order to get accurate leakage rates, the leak detector shall be calibrated. This is done by means of a small helium filled vessel with a shut-off valve that releases a given amount of gas. The device should be calibrated before each use.

10.4.4 Background Noise Determination

The goal of this operation is to determine the background leak value from where the subsequent leak increments will be measured. Once the calibration is completed (see §10.4.3), the instrument background noise is recorded. The record is valid after 3 minutes of stabilized signal.

10.4.5 Characteristic Time Determination

The characteristic time is the time required until the instrument reading reaches back the background noise value as measured at §10.4.4, ±5%, after calibration with calibrated leak.

10.4.6 Room Temperature Vacuum Inspection

Prior to outgassing cycles, it is necessary to perform several inspections at room temperature, complete or partial as needed, on each component to guarantee that total and local leaks are within the requested specifications as in 10.1.

10.4.7 Localized Leaks

Once the leak detector is calibrated, a helium dynamic atmosphere around the part shall be realized in order to verify the presence of any possible leak. Subsequently, dosing the helium flow, an accurate scanning of the surface, with particular attention to the weld joints, shall be carried out.

10.4.8 Total leak

The following steps shall be taken:

1. Seal tightly the part in a polyethylene bag
2. Cover the leak detector with a polyethylene sheet so that it will be shielded from helium.
3. evacuate the component bag with a roughing pump
4. introduce helium in the component bag up to 1 bar pressure
5. record with the leak detector the measured leak for at least twice the characteristic time

Seals must be metallic.

10.4.9 Acceptance Requisites

The part must meet all of the requirements stated in §10.1. If the leaks are within the specified limits, the test is successful and the measured values are recorded in the Test Report (§ 10.4.10). If the part fails the test, then the vendor shall take proper corrective actions and the leak check shall be repeated.

All the performed operations, including possible weld repairs, shall be included in the Test Report. Each component shall be certified and its Traveler (§12) will indicate all of the measured leaks.

10.4.10 Test Report

The vendor shall prepare a Test Report including the following:

- Test layout and system dimensioning
- Mass spectrometer type and model
- Instrument calibration and tune-up
- Calibrated leak certification
- Acceptance criteria
- Measured leaks and possible weld repairs, if the case.

11 MARKING

All chambers and vacuum parts shall be permanently and clearly marked (by vibro-pen, electro-erosion, laser, etc.) in areas easily accessible. The part shall be univocally identified with the relative drawing code and a serial number. Acids or felt markers are prohibited. Sticky labels are not allowed as well. The identification code shall be present on the protective packaging where adhesive labels are allowed.

12 FINAL REPORT AND TRAVELER

Prior to shipping, the Seller shall provide the Buyer with a copy of the accompanying documentation (Traveler) indicating test results, analyses and checks performed by the manufacturer, or appointed third party agency, to establish the part compliance to this Scope of Work. A template of such documentation together with the Quality Assurance Plan shall be submitted to Solaris for acceptance. This report must include the following:

- Name of the qualifying third party agency, if different from the vendor, and test or analysis date.
- Copy of all the fabrication drawings, both in electronic and paper form. Acceptable formats are IGES, STEP, DWG, DXF, Solidworks, AutoCad.
- Inspection results performed to determine compliance to Solaris design. Acceptable formats are PDF, Microsoft Word or Excel.
- Weld test results.
- Copy of encountered non-conformities, if the case, and corrective actions taken.

13 QUALITY ASSURANCE PLAN

At least two weeks before production starts, the vendor shall submit Solaris for approval a Quality Assurance Plan (QA). The ISO 9001:2000 code (or newer versions) provides preferred guidelines for the QA plan, which must guarantee that each fabricated part is compliant with the present Scope of Work. Solaris must accept the proposed plan and notify the vendor in writing prior to production. The QA plan must at least include:

- Inspection and part rework procedures
- Critical welds inspection procedure
- Post-weld dimensional tolerance validation
- Production traceability
- Traveler layout (see §12)
- Methods of inspection and dimensional control of parts or portions thereof including a description of the measuring machines, the control sequence and frequency, rejection criteria and possible corrective actions, data recording plan.

14 PACKAGING

Produced parts, once cleaned and ready for shipping, shall be placed in nylon or polyethylene bags filled with dry nitrogen and sealed. Silica gel may be used to keep the external packaging dry. Extra care shall be taken to protect the flange sealing surface using polyethylene caps or blank flanges with gasket.
The component shall be prepared for shipping according to good shipping standard practices and in agreement with the current norms and regulations relative to packaging and shipping of goods in order to prevent any damage to the parts. In particular, heavy boxes must allow for forklift and crane handling.

15 CORRECTIVE ACTIONS

In the event that any part or portion thereof is rejected by Solaris as a result of poor workmanship or nonconformance to this Scope of Work, the Seller shall take corrective action on the material or process, or both as necessary, on all items or portions thereof which were similarly manufactured which are subject to the same cause for rejection within ten working days. Acceptance shall be withheld until inspections and tests have shown that the corrective action was successfully implemented and the part or any portion thereof conforms to the requirements of this Scope of Work.

16 RIGHT TO INSPECTION

Solaris reserves the right to have its designated representative(s) witness, at the place of manufacture, processing/fabrication operations including metal forming, inspection of weld preparations, electron beam welding parameters, machining, etc. The Buyer reserves the right to have its designated representative witness, at the place of manufacture, the inspections, analyses, and tests established under the Seller's QA Program to demonstrate compliance with this Scope of Work. Solaris reserves the right as well to sample and inspect the production at the manufacturing place in order to verify compliance with the present document. The vendor commits himself to give advance notice to the person designated by Solaris of any critical upcoming operation.
The intent of the Buyer in witnessing inspections, tests, and/or processing/fabrication operations is to gain confidence that production operations will produce vacuum parts conforming to this Scope of Work.