COMPASS Upgrade
INSTITUTE OF PLASMA PHYSICS OF THE CAS

COMPASS-U Vacuum Requirements

CU_ORD_VacuumRequirements

Revision 1.8

Log of revisions

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Content

1 Scope of this document

This document summarizes general requirements and guidelines for all components/parts/assemblies that will be placed in a vacuum or interface with a vacuum in COMPASS-Upgrade.

Specific requirements for particular components on the vacuum (surface finish, cleaning, etc...) described in drawings or the technical specification document have priority over the general requirements written in this document.

2 Manufacturing requirements

All the processes used for cleaning or handling vacuum components (even when conforming with this document) shall be consulted and acknowledged by the IPP.

Several points in this guideline differ for different levels of the target vacuum. Vacuum levels are

- **High vacuum** - working pressure between 1 Pa and 10^{-5} Pa,
- **Ultra-high vacuum** - working pressure < 10^{-5} Pa.

The target vacuum level for specific parts/assemblies will be defined in its technical specification or drawing.

2.1 General materials requirements

All used materials should be high/ultra-high vacuum compatible according to their usage.

General requirements for materials used in vacuum are

- low intrinsic vapor pressure (compared with the desired vacuum level at working temperature),
- high gas tightness, and
- low foreign material contamination.

Specific requirements on vacuum properties of used material will be listed specifically.

2.2 Virtual leaks

All components must be designed and manufactured in such a way as to prevent the formation of trapped volumes causing virtual leaks - that is a trapped volume is an empty space connected to a vacuum through a very small hole (usually area < 1 mm^2), therefore having a low vacuum conductance.

2.3 Component joining

2.3.1 Welded joints

All weld seams on vacuum components must be free of pores and cracks (this may cause leakage or act as an outgassing source).

Welds shall be done preferably on the vacuum side of the components. If it is not possible, full penetration welds have to be done.

Welding under inert gas or vacuum is preferred to avoid introducing foreign material into the weld and consequently the production of cavities and cracks.

For welded joints, the parts have to be appropriately cleaned before welding to avoid the accumulation of contaminants and consequent hot cracks.

All the welds must be pickled and passivated, either by using a chemical agent (pickling gel/solution) or by using an electrochemical pickling machine. Any pickling solution used must be afterward neutralized and thoroughly cleaned.

If the selected welding procedure uses flux (shielded metal arc welding, flux cored arc welding, etc), all the flux residues must be completely removed.

Grinding down and polishing the welds is not required.

2.3.2 Soldered and brazed joints

All soldered and brazed joints have to be designed in such a way that they will avoid arising of closed volumes which can lead to creating virtual leaks.

All used solders and brazing alloy should be preferably vacuum-compatible. Standard solders/brazing alloys can be used depending on the level of an achieved vacuum level and only after approval of IPP.

If the flux is necessary during soldering or brazing, all the residues must be completely removed.

The usage of water-soluble flux is preferred.

2.4 Surface finish

2.4.1 High vacuum components (pressure > 10^{-5} Pa)

All the surfaces must be either machined, ground, glass-bead blasted, shot peened, or polished - without surface oxides. Recommended surface roughness is R_a 25 or better, however, the target is to minimize real surface area, not necessarily to improve roughness.

2.4.2 Ultra-high vacuum components (pressure < 10^{-5} Pa)

All the surfaces (even those not directly visible - for instance, between welded parts, etc) must be machined, ground, or polished. The mandatory resulting surface finish is R_a 3.2 or better.

2.5 Material contamination

2.5.1 Machining

Use only tools designed for specific machined material and not previously used for some other work. For example - when grinding stainless steel, use only stainless-steel compatible grinding discs that weren’t used on regular mild steel before.

Tools that do not leave residues into the surface layer or their residua are fully washable should be used only.

If possible, removing the last layer of material (final cut) should be performed without cutting fluid. This will eliminate possible contamination of the part surface with oily residues.

2.5.2 Handling

When lifting heavy pieces, pay attention to the material/coating of hooks/shackles or other lifting equipment.

For ultra-high vacuum parts (see def in General requirements), only synthetic or stainless steel lifting equipment must be used.

3 General procedures

3.1 Cleaning

Cleaning vacuum components is a multistep process that serves to remove the majority of contaminations (grease, oils, etc) that would compromise the vacuum performance of said components. The source of contamination is usually the material manufacturing process (scaling, fouling, …), machining (cutting fluids, …), and handling (hand grease, sweat, …).

Cleaning procedures must be adjusted according to contamination and the material of the part to be cleaned. If cutting fluid is used for machining, prior verification must be done that it is cleanable by the used procedure.

3.1.1 Cleaning of assemblies

Parts that will be assembled into units and which will be then delivered to the IPP must be cleaned before assembly. During assembly or any subsequent operation, precautions must be taken to avoid any contamination. Particular attention must be given to used tools and used fasteners.

If any contamination happens after assembly or any subsequent operation (testing, manipulation, ...), only light cleaning is allowed (dusting the parts with dry nitrogen, cleaning with isopropyl alcohol). If contamination is severe and “light” cleaning is not sufficient to reach the required cleanliness, parts must be disassembled and cleaned again separately.

3.1.2 Suggested cleaning procedure for stainless steel (and other nickel-based alloys):

- **Step 1 - Mechanical cleaning:** Remove big contamination by appropriate means - brush out the chips, and use compressed air or vacuum cleaner to clean out any remaining cutting fluid.
- **Step 2 - Cleaning:** Use appropriate detergent (Elma Clean 115c or Tickopur R33 or equivalent) with appropriate concentration (diluted in deionized water) and temperature. If the part is small or difficult to clean, an ultrasonic bath must be used for agitation. For large objects, a pressure washer may be used.
- **Step 3 - Rinsing:** Clean part with deionized water to remove all detergent and remaining contamination. For small or difficult-to-clean parts an ultrasonic bath must be used. For larger parts, a pressure washer may be used.
- **Step 4 - Drying:** Part must be dried in a low-dust and hydrocarbon-free atmosphere. Dry nitrogen or clean (filtered) airflow may be used.

If verification of cleanliness fails, the cleaning process should be restarted at step 2 or step 3.

3.1.3 Suggested cleaning procedure for epoxy resin composites:

All conductors, insulations, and VPI mold parts shall be degreased/cleaned using a solvent that can dissolve grease, tar, wax, adhesives, oils, and other soils, and is residue-free.

Recommended solvents are acetone and alcohol, however, only alcohol is permitted for use on the primed copper.

The cleaning procedure and solvent selected must be approved by IPP before use.

3.2 Verification of cleanliness

The cleanliness of finished and cleaned parts shall be verified by several means. Part technical specification or drawing should indicate whether tests are mandatory or only optional.

During the verification of cleanliness, effort must be made not to contaminate tested surfaces. The use of gloves (see Handling) is mandatory.

All the tests must be concluded with a written report, covering all the important details (including photographs in case of visual-based tests).

3.2.1 Tissue cleanliness test

This test is based on the fact that most of the contaminants in larger quantities are not transparent.

The test is performed so that the tested part surface is thoroughly and gently wiped with clean, lint-free, cotton or paper (generally non-synthetic) tissue. No visible contamination must be present on the tissue.

3.2.2 Water break test

This test is based on the fact that most of the severe vacuum contaminants have significantly higher surface tension than pure water. This means that if the tested surface is wetted by deionized water (either by immersion or spraying), a continuous layer must form without any imperfections or droplets for the surface to be considered as clean.

Tests must be performed according to the ASTM F21 or ASTM F22 technical standard.

3.2.3 UV light test

This test is based on the fact that several contaminants are visible after illumination of UV-A light.

To perform this test, the tested part must be situated in a dark area without any outer source of light present.

Part must be illuminated by sufficiently strong UV-A source(s) and all the surfaces must be carefully inspected. No visible contaminations (layers, splashes, droplets, spills, etc) must be present.

3.3 Leak testing

If leak testing is requested for the part (in its technical specification or drawing), it must be done according to this procedure. Any irregularities must be discussed with the IPP.

The leak testing procedure must be done in agreement with technical standards EN 1779, ISO 20484, ISO 20485, and ISO 20486.

The method used for testing must be selected according to EN 1779.

No humidity condensation or water is permissible on the tested piece during the leak test.

To consider the test passed required helium leak rate is 10^{-10} Pa.m^3/s. Technical specifications or part drawings however may specify different detection limits.

Protocol from each test will include (additional to requirements from the standard ISO 20485)

- reached vacuum level at the beginning of the test
- background level at the beginning of the test
- purity of used tracer gas
- pressure in the tracer gas supply bottle at the beginning of the test

3.4 Packing

All the sealing surfaces must be protected against accidental damage (scratches or dents from manipulation, etc). It is recommended to use polyethylene covers (for standardized flanges readily available) or to use blind flanges with appropriate seals.

All the cleaned components must be packed to avoid contamination during handling and transportation. Preferred materials used for packing are polyethylene, aluminum foil, and cellulose-based cloth/paper. All the used materials shall have low volatile compound content (colors, plastifiers, anti-corrosion products, hydrocarbons, etc…)

Three different packing schemes are recommended.

- For small parts (for example a handful of M10 bolts), use polyethylene bags sealed by a thermal bag welder.
- For bigger parts (for example a batch of M42x200 bolts), use a polyethylene-covered plastic box. Polyethylene foil should be arranged so that all surfaces of parts are covered.
- For large parts (for example a 2-ton part of support structure), use polyethylene foil to wrap the part, followed by stretch wrap or strings to hold polyethylene in place.

Packing must consider lifting and strap-down points, mainly regarding the large parts. The transport and packaging process must be designed so that packing will withstand all the required operations (for example lifting by crane, lifting by forklift, fixing to the truck trailer, …).

3.5 Handling

After cleaning, all the parts must be handled so that cleanliness is not compromised. This means strict usage of clean gloves (powder-free latex or nitrile gloves). Gloves must be changed regularly to keep cleanliness and avoid any cross-contamination.

Attention shall be paid to the cleanliness of any handling-assistant hardware used. If the crane lifts any manufactured components, clean lifting equipment must be used.

If parts are transported, attention must be paid to packing to maintain cleanliness.