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ESS VACUUM HANDBOOK PART 3 - ESS VACUUM DESIGN & FABRICATION

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1. INTRODUCTION

The European Spallation Source (ESS) is an accelerator-driven neutron spallation source. The linear accelerator (Linac) of which is a critical component. The role of the accelerator is to create protons at the ion source, accelerates them to an appropriate energy, and steer them onto the target to create neutrons via the spallation process for use by a suite of research instruments.

2. SCOPE

The ESS Vacuum Handbook comprises four (4) parts:

ESS Vacuum Handbook Part 1 – General Requirements for the ESS Technical Vacuum Systems,

ESS Vacuum Handbook Part 2 – Vacuum Equipment Standardization Manual,

ESS Vacuum Handbook Part 3 – Vacuum Design & Fabrication Manual,

ESS Vacuum Handbook Part 4 – Vacuum Test Manual

Part 3 provides guidelines, and imposes requirements where necessary, for the design and fabrication processes associated with the vacuum systems of the Accelerator, Target and Neutron Instruments. It is applicable to all vacuum components and systems exposed to a technical vacuum environment.

This VH will be periodically updated throughout the life of the ESS project.

All queries or the request for additional information concerning the contents of this Handbook should be addressed to the ESS Vacuum Group Section Leader (VGL).

3. DESIGN

It is important to remember that a classical rule, valid for any type of equipment, is that more than 70% of the final cost is already defined at the end of the design phase. Investing more during this initial phase can always be of later benefit.

3.1. Design Considerations

3.1.1. Boundary conditions

Environmental conditions

The environment, in which the component, equipment or system is required to operate needs to be considered, e.g. will it be dry or humid, since it might effect the vacuum performance. Also if it will it be installed in a radiation area, which may effect the selection of materials and equipment used, e.g. the deterioration of elastomer seals, the potential for corrosion in an activated air environment due radiation leading to the formation of nitric acid.

Interfacing systems and equipment

Ensure that the interfaces with equipment and interfacing systems are know and well understood.

Space envelope

Consider the space envelope available for the component, equipment or system before the design starts since this could influence the approach to be taken. If for example space is limited to make a bolted flange connection, consider the possible use of a chain clamp. Insure that sufficient space is available for maintenance, e.g. replacement of equipment, etc.

Installation and Operations

- How will the equipment be installed, e.g. will it be a permanent or temporary installation, how will it be located and fixed.
- Are fiducials required for alignment and what alignment accuracy is required.
- Is access provided for leak testing at a suitable level of sensitivity.
- How will the equipment be operated, are interlocks required, what access is required for maintenance and exchange of equipment and components.

Pressure

Vacuum vessels and evacuated components can pose a potential hazard to other equipment and personnel resulting from collapse, rupture due to over pressurization when venting, or implosion due to failure of a vacuum boundary, e.g. a vacuum window failure. It is therefore essential to design and operate all vacuum systems and equipment in accordance with applicable and sound engineering principles.

The design shall ensure that allowable stresses are not exceeded and that the vessel is stable (resistant to buckling) under all operating and upset conditions. Full account must be taken of conditions that could effect allowable stresses, e.g. temperatures both cryogenic and above ambient, vibration, fatigue, earthquakes, etc.

One of the most critical failures that need to be considered in the design is the potential for over pressurization during venting. In general, it is desirable to vent vacuum vessels and components, especially those operating in the high vacuum and UHV regimes, to a dry atmosphere by a gas source, e.g. boil off from LN_2 Dewar is a common method (where an over pressure situation might occur if suitable precautions are not taken). To provide guidance for the design implementation of vacuum vessels, component and equipment, the following categories have been defined:

- Category I: Vacuum vessels in which the differential operating pressure across the vacuum boundary can never exceed 100 kPa (1 bar).
- Category II: Vacuum vessels that are protected from credible failures that could create pressurization exceeding 1 bar through the use of engineering controls such as pressure relief devices.
- Category III: Vacuum vessels that are not or cannot be protected from credible failures that could create pressurization exceeding 100 kPa (1 bar).

Under normal circumstances it is desirable to limit by design or engineering controls the vacuum vessel to vacuum service only. This avoids the complication involved in rating the vacuum vessel as a pressure vessel together with the additional costs involved. The guidelines for the rating of vacuum vessels will be determined by the categories describes below:

Category I and II Vacuum Systems

Vacuum vessels in these categories are not required to be classified as a pressure vessel but it is recommended to design of them be in accordance with applicable sections of the appropriate pressure vessel code as it applies to vacuum vessels.

Category III Vacuum Systems

All design requirements contained in the appropriate pressure vessel code apply to Category III vacuum systems. Vessels must be code stamped by the authority having jurisdiction.

Pressure Relief Devices

Pressure relief devices used for Category II or III vacuum systems must be code certified (e.g. ASME "UV" certification mark or equivalent). Calculations must be performed and documented to demonstrate adequate sizing of venting capacity for the pressure relief device(s).

Pressure Testing

For category I and II vacuum systems the test pressure should be the full atmospheric pressure differential. For vacuum vessels that will not be evacuated to full atmospheric pressure differential, the test pressure should be 110% of the maximum allowable external differential pressure, but not more than full atmospheric pressure.

For category III vacuum systems the test pressure should be the full atmospheric pressure differential. For vacuum vessels that will not be evacuated to full atmospheric pressure differential, the test pressure should be 110% of the maximum allowable external differential pressure, but not more than full atmospheric pressure. In addition, the system is to be tested at the 110% of the maximum design internal pressure.

For a vacuum vessel within a pressure vessel, the test differential pressure should be 110% of the maximum allowed working pressure differential. Thin windows and other delicate equipment may be removed while testing the vacuum vessel.

Temperature

The vacuum system shall be designed to accommodate the full operating range anticipated in service, which may include upset conditions. The operating temperature may impact material selection, e.g. performance of elastomer at high and low temperatures, and the use of bellows to compensate expansion and contraction, heating due to beam losses, etc.

Vibration

If vibration is an issue, isolation bellows might be required to decouple rotating equipment, e.g. pumps, from vacuum equipment. This applies also for resonant frequencies, e.g. equipment supports, bellows connections, etc.

Corrosion and Erosion

Corrosion issues might be a concern due to the environment, e.g. humidity, air activation due to radiation leading to the formation of nitric acid, etc.

The potential risk of an in-break of cooling water into the vacuum cavity due to erosion in water-cooling circuits, resulting from to high velocities and other factors, shall be considered.

The potential for galvanic corrosion as a result of the use of dissimilar metals shall be considered.

Contamination and Particulate Control

The operating environment is critical in achieving the performance for which the vacuum system is designed. This requires the use of only approved fabrication, cleaning and handling procedures.

Some vacuum systems are extreme sensitive to particulates and must be designed as such to ensure that they can be cleaned effectively. This is especially important for equipment that will be installed in close proximity to the superconducting section of the accelerator where special procedures for manufacture, cleaning, handling and installation are required.

Procedures

In some cases, as part of the design process , it will be necessary to have specific manufacturing, QA, installation and test plans for the equipment being designed. In other cases the engineering design will be adequate. This determination needs to be made as part of the design process.

3.1.2. Material Selection

Material shall be selected in accordance with the ESS Vacuum Handbook Part 1 – General Requirements for the ESS Technical Vacuum Systems.

3.1.3. Selection of Vacuum Equipment and Hardware

Standardized vacuum equipment and hardware shall be selected where possible in accordance with the ESS Vacuum Handbook Part 2 – Vacuum Equipment Standardization.

3.1.4. Selection of Raw Materials

The procurement of all raw materials should be accompanied with material certification certificates.

Sheet and Plate

All sheet and plate shall have a #4 finish on the vacuum side and shall be protected with a surface protection material (SPV) coating.

Tube

In general, tubing as opposed to pipe will be used for vacuum applications. This tubing should be cold drawn and seamless where possible. The inside bore is required to be polished or bright annealed. If the outside of the tube will be exposed to vacuum then this should also be polished.

Standard Vacuum Weld Fittings

These components should be purchased from vacuum manufacturers or suppliers common to the food process industry to ensure a good surface finish. As for tubing this should be polished on the inside or bright annealed. In general, the wall thicknesses of these fittings will be similar to that of tubes and allow uniform heating during the welding process.

3.1.5. Analysis to Support the Design

A stress and thermal analysis, if needed, shall be completed to support the vacuum design.

3.2. Areas Requiring Special Attention in the Design

3.2.1. "Virtual" Leaks

A virtual leak is a trapped volume of gas connected to the vacuum side of a chamber that cannot be pumped out easily due to the restriction in the path connecting the trapped volume to the chamber volume. As the chamber pump down cycle crosses over from viscous to molecular flow, the gas molecules within the trapped volume can only be pumped out at a rate proportional to the conductance of the path between the trapped volume and the chamber volume. This rate is called "virtual leak".

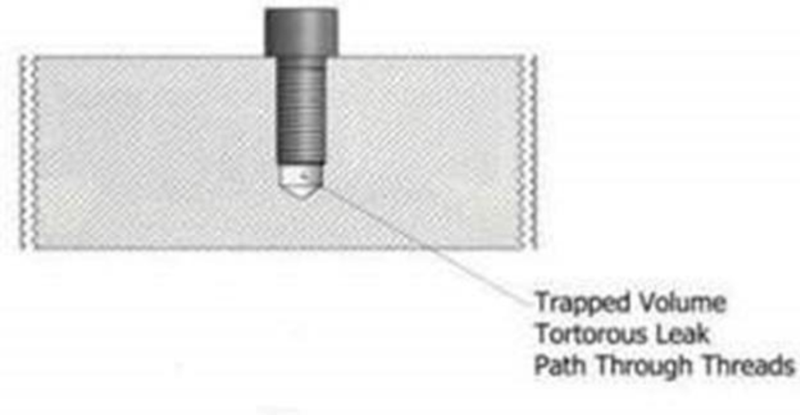
A virtual leak will not be detected in a normal helium leak testing cycle. The presence of a virtual leak will become apparent during the system pump down cycle if the vacuum pumps cannot keep up with the gas load coming from the virtual leak and ultimate pressures can not be reached or only within an excessive time.

Poor design techniques or workmanship issues are the major cause of virtual leaks. They can also be caused by laminations in raw materials, but these are much rare occurrences.

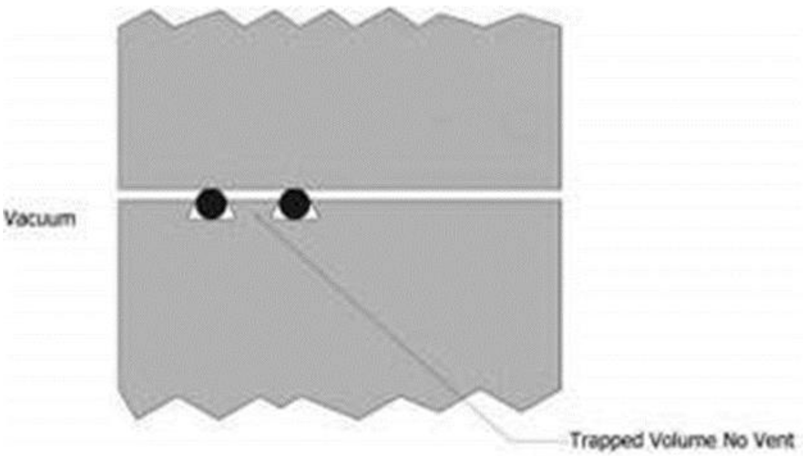
Virtual leaks are easily avoided if good vacuum practice is followed in the design and fabrication of the chamber.

Below are some typical examples showing trapped volumes:

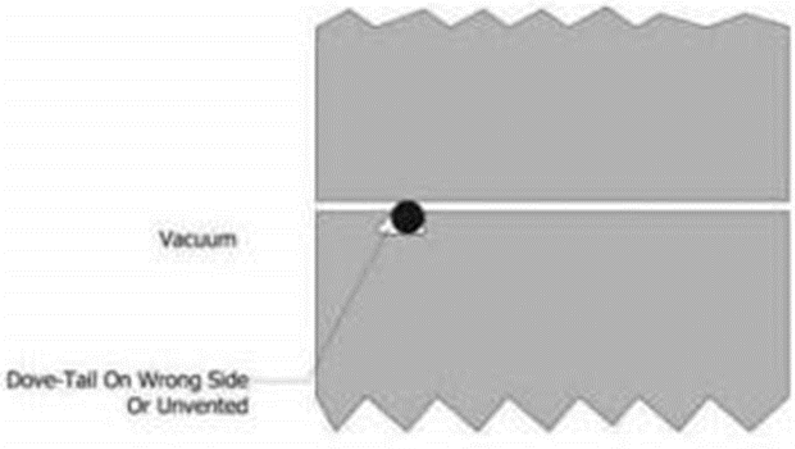
- Trapped volumes caused by un-vented or poorly vented blind tapped holes within the vacuum volume.



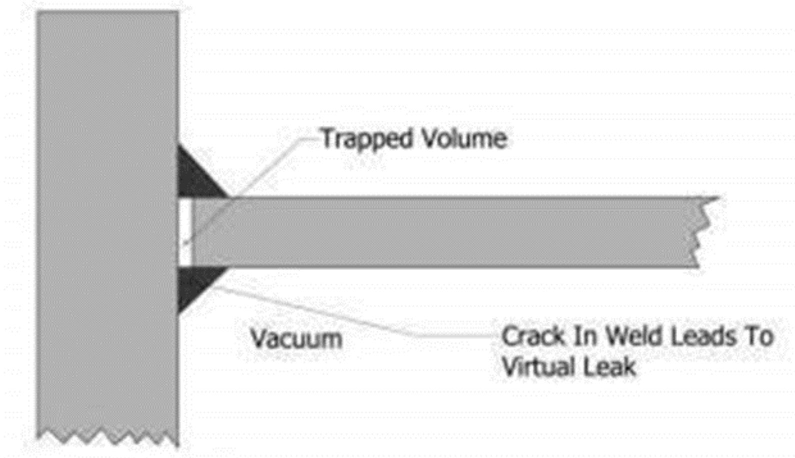
- Trapped volumes caused by unvented double o-ring seal designs.



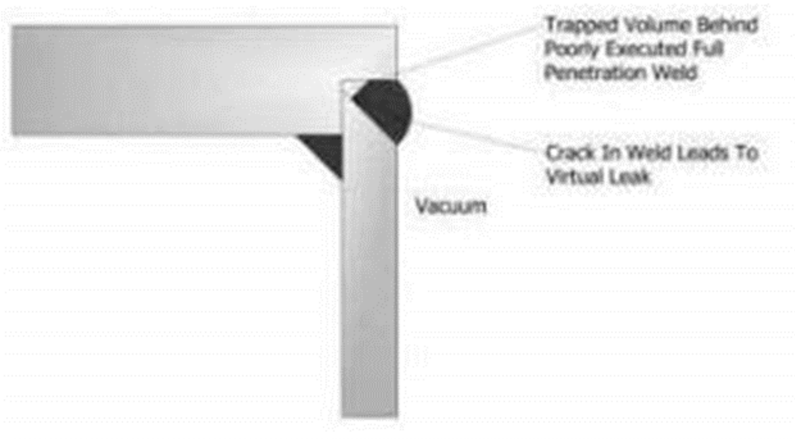
- Trapped volumes caused by unvented single or double dovetail o-ring groove designs.

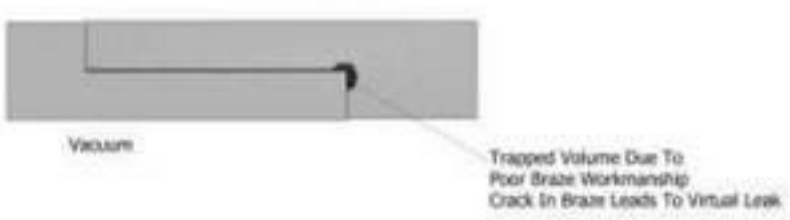


- Trapped volume caused by incorrect weld design

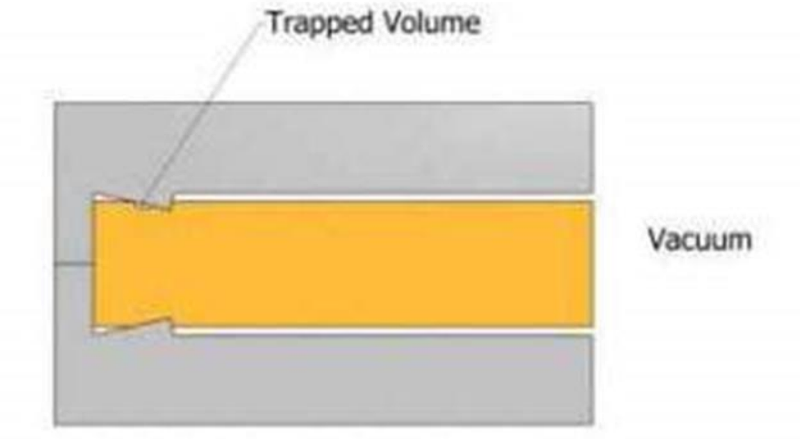


- Trapped volumes caused by uneven up of full penetration welds and lack of interior welds or braze joints.





- Trapped volumes caused by cracks in Conflat knife



All diagrams courtesy of: Meyer Tool & Mfg., Inc.

3.2.2. Welding Methods

It is essential that

- The base metal is thoroughly cleaned before welding.
- A continuous gas purge is provided during pipe welding to prevent the formation of an oxide layers which will be detrimental to vacuum performance.

The preferred welding processes for vacuum applications are as follows:

Gas Tungsten Arc Welding

Gas tungsten arc welding (GTAW), also known as tungsten inert gas (TIG) is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area is protected from atmospheric contamination by an inert shielding gas (argon or helium) and a filler metal is normally used, although some welds, known as autogenous welds, do not require it. This is the most common welding technique for vacuum work.

Gas Metal Arc Welding

Gas Metal Arc Welding (GMAW) sometimes referred to by its subtypes Metal Inert Gas (MIG) welding or Metal Active Gas (MAG) welding, is a welding process in which an electric arc forms between a consumable wire electrode and the work piece metal(s), which heats the work piece metal(s), causing them to melt and join. Along with the wire electrode, a shielding gas feeds through the welding gun, which shields the process from contaminants in the air. The process can be semi-automatic or automatic. A constant voltage, direct current power source is most commonly used with GMAW, but constant current systems, as well as alternating current can be used. It is used on heavier structures with a root pass using TIG to provide a better interface with vacuum. Preferable the root pass should be leak tested before the MIG passes are made.

Electron beam welding

Electron beam welding (EBW) is a fusion welding process in which a beam of high-velocity electrons is applied to two materials to be joined together. The work pieces melt and flow together as the kinetic energy of the electrons is transformed into heat upon impact. EBW is often performed under vacuum conditions to prevent dissipation of the electron beam. EBW is becoming the standard method for the production of superconducting cavities.

Laser Beam Welding

Laser beam welding (LBW) is a welding technique used to join multiple pieces of metal through the use of a laser. The beam provides a concentrated heat source, allowing for narrow, deep welds.

Orbital welding

Orbital welding is a specialized area of welding whereby the arc is rotated mechanically through 360° (180° in double up welding) around a static work piece, an object such as a pipe, in a continuous process.

Ideal for the welding of small-bore pipes but more suited to larger quantities due to set up time.

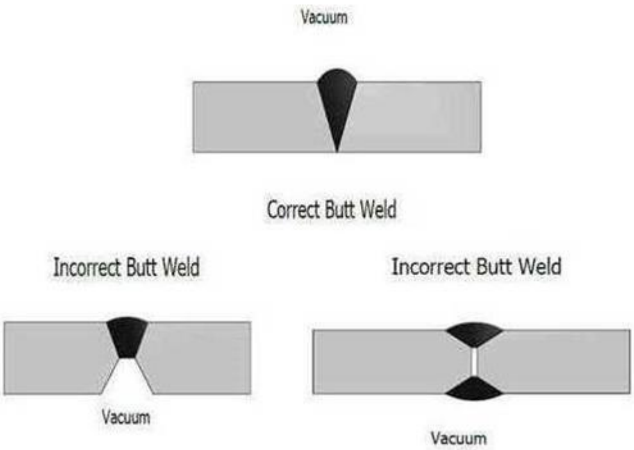
3.2.3. Weld Joint Design

When designing or constructing a vacuum system, the following points need to be observed:

- Full penetration welds wherever possible to avoid pockets where volumes of gas or contaminants can be trapped.
- Single pass welds wherever possible to avoid trapped volumes that could be generated with multi-pass welds.
- Welds shall always be made on the vacuum side of the joint.
- If for structural reasons double welds are required, an easy path to flow gas from the joint shall be available. This could be in the form of a machined hole between the two welds or a discontinuous weld on the non-vacuum side.

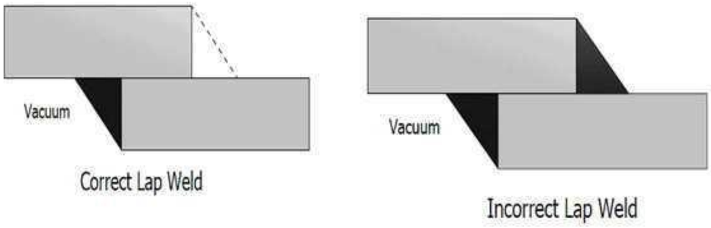
The following pictures (Courtesy of: Meyer Tool & Mfg., Inc.) represent both correct and incorrect practices for various styles of weld joints commonly used in vacuum chamber construction:

Butt Welds



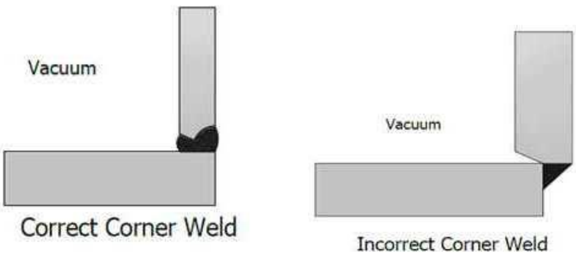
The correct style butt weld uses full penetration welds while incorrect style butt welds leave a pocket for contamination or a trapped volume between the two welds.

Lap Welds



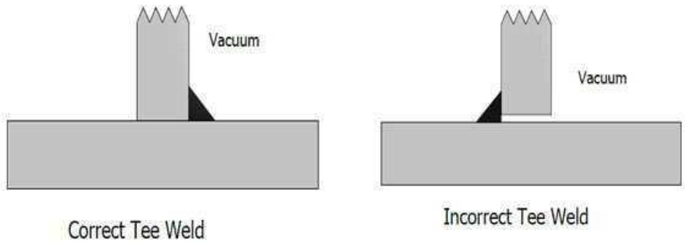
The correct style lap weld uses a full continuous weld at the vacuum side. If more structural strength is required, a skip weld can be added to the non-vacuum side. The incorrect style lap weld uses two continuous welds on both the vacuum and non-vacuum side or a single weld on the non-vacuum side leaving a trapped volume for gas and contaminants.

Corner Welds



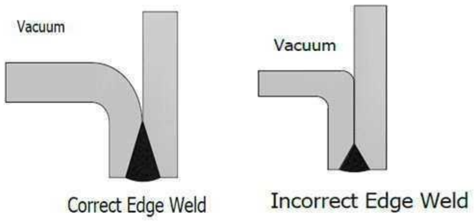
The correct style corner weld has the two sides that meet to form the corner flush with each other, and uses a full penetration weld. The incorrect style corner weld has one side overhanging the other at the weld joint, leaving a trapped volume for gas and contaminants.

Tee Welds



The correct style tee weld uses a full continuous weld at the vacuum side. If more structural strength is required, a skip weld can be added to the non-vacuum side. The incorrect style tee weld uses two continuous welds on both the vacuum and non-vacuum sides or a single weld on the non-vacuum side leaving a trapped volume for gas and contaminants.

Edge Welds



All diagrams courtesy of: Meyer Tool & Mfg., Inc.

The correct style edge weld uses a full penetration welds where the two sides meet. The incorrect style edge weld has an elongated section where the two sides meet without a full penetration weld. This leaves a pocket for contamination, or leaves a trapped volume between the two surfaces.

These are just a few examples of weld styles that you may encounter during the design of a vacuum system. This by no means covers all the possibilities, but by using the basic concepts described here you will increase your success for a properly operating vacuum system.

3.3. Vacuum Notes for Drawings

For simple components, especially when procured from outside vendors it may be preferable to impose the requirements to be met in the form of notes on the drawing (as opposed to imposing the entire VM). Contact the ESS VG for assistance in this regard and subject to their agreement to use the following notes:

3.3.1. Rough Vacuum Systems

All parts shall be fabricated in accordance with good vacuum practice, which shall include, as a minimum, the following:

- Removal of all contamination, e.g. scale, dirt, grease and oil prior to fabrication.
- Use only water soluble, non-sulphurous bearing, cutting oils for machining.
- Wash all parts with detergent to remove cutting oils prior to final washing and rinsing with de-ionized water.

- All fabricated parts shall be helium leak tested and show no detectable leak >10^{-8} Pa m^3 s^{-1} (>10^{-7} mbar l s^{-1}) when tested using a Mass Spectrometer Leak Detector (MSLD) to a sensitivity >10^{-11} Pa m^3 s^{-1} (<10^{-10} mbar l s^{-1}) c.f. ESS Vacuum Test Manual.
- Fabricated components shall be packaged to protect all sealing surfaces and to stop contamination from entering the vacuum volume. The usage of aluminium foil over flanges and the sealing of small items in polyethylene bags is preferred.

3.3.2. High Vacuum Systems

All parts shall be fabricated in accordance with good vacuum practice, which shall include, as a minimum, the following:

- Removal all contamination, e.g. scale, dirt, grease and oil prior to fabrication.
- Use only water soluble, non-sulphurous bearing, cutting oils for machining.
- Wash all parts with detergent to remove cutting oils prior to final washing and rinsing with de-ionized water.
- Metal seals should be used (when used on the component) for performing the final helium leak test.
- All fabricated parts shall be helium leak tested and show no detectable leak >10^{-9} Pa m^3 s^{-1} (>10^{-8} mbar l s^{-1}) when tested using a Mass Spectrometer Leak Detector (MSLD) to a sensitivity >10^{-11} Pa m^3 s^{-1} (<10^{-10} mbar l s^{-1}) c.f. ESS Vacuum Test Manual.
- Fabricated components shall be packaged to protect all sealing surfaces and to stop contamination from entering the vacuum volume. The usage of UHV aluminium foil over flanges and the sealing of items in polyethylene bags is preferred.

3.3.3. Ultra High Vacuum Systems

All parts shall be fabricated in accordance with good vacuum practice, which shall include, as a minimum, the following:

- Removal all contamination, e.g. scale, dirt, grease and oil prior to fabrication.
- Use only water soluble, non-sulphurous bearing, cutting oils for machining.
- Wash all parts with detergent to remove cutting oils prior to final washing and rinsing with de-ionized water.
- Metal seals shall be used when performing the final helium leak test.
- All fabricated parts shall be helium leak tested and show no detectable leak >10^{-10} Pa m^3 s^{-1} (>$1x10^{-9}$ mbar l s^{-1}) when tested using a Mass Spectrometer Leak Detector (MSLD) to a sensitivity >10^{-11} Pa m^3 s^{-1} (<10^{-10} mbar l s^{-1}) c.f. ESS Vacuum Test Manual.
- The total out-gassing rate of the vessel or assembly shall be measured after 10 hours of pumping from atmosphere. The outgassing rate must not exceed 10^{-11} Pa m^3 s^{-1} ($2x10^{-10}$ mbar l s^{-1} cm^{-2}) c.f. ESS Vacuum Test Manual.
- Fabricated components shall be packaged to protect all sealing surfaces and to stop contamination from entering the vacuum volume. The usage of UHV aluminium foil over flanges and the sealing of items in N2 filled polyethylene bags is recommended.

4. FABRICATION

4.1. Manufacturing

4.1.1. Machining

No lubricant shall be used which might result in material contamination that cannot be removed by the cleaning methods used by the process described here. The use of cutting fluids or lubricants, which contain sulfur or silicone compounds are prohibited. Only water-soluble oils shall be used for machining.

4.1.2. Welding

For *Welding Methods* and correct *Weld Joint Design* see sections 3.2.3 & 3.2.4 respectively of this handbook.

Any parts shall be cleaned prior to welding. If there is any doubt whether the parts have been contaminated prior to welding, those parts shall be cleaned again. All welding shall be performed in a clean area. The welder(s) shall handle equipment in accordance with their intended use in an ultra-high vacuum system. They shall be kept free of smudges and blotches, which might stem from handling and contact with dirt or oil. Therefore, clean gloves shall always be worn. All jigs, fixtures, and heat sinks shall be clean. Only clean 300 series stainless steel brushes are to be used on 300 series stainless steel to remove oxides from welds. Power driven brushes, abrasive papers, abrasive wheels, welding pickling gel or paste and passivation products shall not be used.

Dye penetrant techniques shall not be used for weld inspection.

Welds specified according to level B of standards ISO 15614-1 for arc welding, ISO 15614-11 for electron and laser beam welding, with reference to standard ISO 6520-1 and ISO 5817 or ISO 13919-1 for classification and quality levels for imperfections, are generally specified at ESS for vacuum applications.

4.1.3. Brazing

Brazing is a metal-joining process whereby a filler metal is heated above melting point and distributed between two or more close-fitting parts by capillary action. The filler metal is brought slightly above its melting (liquidus) temperature while protected by a suitable atmosphere, usually a flux. It then flows over the base metal (known as wetting) and is then cooled to join the work pieces together.

The design of the interfaces to be brazed should be done according to strict rules taking into account the expansion of the materials to allow the brazing to flow through the gap. The surfaces are etched before and a high-quality cleaning after brazing is important since a classical problem is the appearance of corrosion on stainless steel following a deficient cleaning of the chloride-based flux.

The selection of the correct brazing material is essential since some braze alloys are not suitable for vacuum applications. Attention needs to be paid especially to the selection of braze alloys for cryogenic applications.

Soft soldering (<400°C with Sn, Zn, alloys of Pb, Cd) shall not be permitted.

4.1.4. Finishing

Surfaces that are exposed to vacuum shall have a roughness of $R_a \leq 0.8$mm. Further only concentric turning shall be applied on any sealing surfaces.

4.2. Cleaning

The chemical cleaning procedures described below, have been determined to yield the best results for UHV materials. All parts made from approved materials which will interface with the vacuum system, shall be cleaned accordingly. A proposed step-by-step cleaning process shall be submitted for approval for other materials than those listed below. No blind holes of small diameter (less than3 mm) are permitted in parts to be chemically cleaned for UHV applications since chemical solutions may be trapped in these holes. Screw holes should be drilled through or vented to allow the trapped gas to be pumped.

Cleaning procedures for unusual or over dimensional parts should be reviewed by VGSL prior to part fabrication. Where possible, small components should be thoroughly degreased in a vapour degreaser or ultrasonic bath prior to detergent washing.

Once fabricated, a trial assembly should be undertaken to ensure all components fit together correctly. Any machining, filing or welding operation should take place before cleaning. Only when UHV cleaning is completed, the final assembly should take place.

In the following sections standardized cleaning procedures are described for various materials:

4.2.1. Aluminium alloy

<u>METHODOLOGY:</u>

- Chemical degreasing with detergent and ultrasonic
  - Formulation and operating parameters:
    - Detergent NGL 17.40 spec. ALU III: 10 g/l.
    - Temperature: 50°C.
    - Time: 30 – 60 minutes.
  - Rinsing with water
- Stripping
  - Formulation and operating parameters:
    - Caustic soda: 42 g/l
    - Temperature: 60°C.
    - Time: 10 – 30 seconds.
  - Rinsing with water
- Neutralization with detergent and ultrasonic
  - Formulation and operating parameters:
    - Nitric acid: 400 ml/l.
    - Hydrofluoric acid: 8.5 ml/l
    - Temperature: 20°C.
    - Time: 1 – 5 minutes.
  - Rinsing with water.
- Rinsing with demineralised water
- Drying with clean compressed air and bake-out at 60°C

4.2.2. Stainless steel

<u>METHODOLOGY:</u>

- Chemical degreasing with detergent and ultrasonic
  - Formulation and operating parameters:
    - Detergent NGL 17.40 spec. ALU III: 10 g/l

        - Temperature: 50 – 60°C
        - Time: 30 – 60 minutes
    - Rinsing with water
- Pickling
    - Formulation and operating parameters:
        - Net inox (pure): HNO_3 (~ 50 %) + HF (~ 3 %)
        - Temperature: 20°C
        - Time: 30 – 90 minutes
    - Rinsing with water
- Neutralization with detergent and ultrasonic
    - Formulation and operating parameters:
        - Detergent NGL 17.40 spec. ALU III: 10 g/l.
        - Temperature: 50 – 60°C.
        - Time: 5 – 10 minutes.
    - Rinsing with water.
- Rinsing with demineralised water and alcohol
- Drying with clean compressed air and bake-out at 60°C

4.2.3. Copper (and bronze)

METHODOLOGY:

- Chemical degreasing with detergent and ultrasonic
    - Formulation and operating parameters:
        - Detergent NGL 17.40 spec. ALU III: 10 g/l.
        - Temperature: 50°C.
        - Time: 30 – 60 minutes.
    - Rinsing with water
- Stripping
    - Formulation and operating parameters:
        - hydrochloric acid: 50%
        - Temperature: 20°C (ambient)
        - Time: 30-60 seconds.
    - Rinsing with water
- Neutralization with detergent and ultrasonic
    - Formulation and operating parameters:
        - Chromic acid: 80g/l.
        - Concentrate sulphuric acid: 3 ml/l
        - Temperature: 20°C (ambient)
        - Time: 15 – 20 seconds.
    - Rinsing with water
- Rinsing with demineralised water
- Drying with clean compressed air and bake-out at 60°C

4.2.4. Ceramic-to-Metal Feedthroughs

Ceramic-to-metal feedthroughs present particular cleaning problems due to cracks and crevices inherent in their construction, which may trap acid cleaning solutions. Therefore, feedthroughs that have potential trapped areas shall NOT be acid cleaned. Feedthroughs shall be chemically cleaned according to the steps below.

METHODOLOGY:

- Chemical degreasing with detergent and ultrasonic
    - Formulation and operating parameters:
        - Detergent NGL 17.40 spec. ALU III: 10 g/l.
        - Temperature: 50°C.
        - Time: 30 – 60 minutes.
    - Rinsing with water
    - Rising with DI water
    - Dry with dry Nitrogen

4.2.5. Welded bellows

Welded bellows present cleaning problems since chemical solutions can be trapped in their convolutions. Therefore, all parts must be chemically cleaned prior to welding and subsequent handling must be accomplished in a manner, which does not contaminate the bellows. Ready to use items can be purchased from specialized suppliers.

4.3. Marking and labelling

Marking out or marking for identification should be carried out with clean dry scribers or vibrating engravers only, never by acid etching or marker pen. Vacuum surfaces should only essentially be marked, however never on sealing surfaces.

A UHV fabrication checklist will be provided by ESS for the purpose of signing off each stage of the manufacturing, cleaning and vacuum testing process. These should be tied to components or, in the case of small components, fixed to the packing bags. Self-adhesive labels, tapes, etc. should only essentially be used and may only be fixed to non-vacuum surfaces (the adhesives used shall be soluble in acetone).

4.4. Testing

Vacuum testing shall be conducted in accordance with the ESS Vacuum Handbook Part 4 – Vacuum Test Manual.

4.5. Handling & transport

Gloves shall always be used when handling clean components. New gloves shall be used for every new application. Gloves with talcum powder, chalk or other powders inside shall be avoided. A good solution is to use lint-free fabric gloves inside polyethylene gloves.

All non-sealed flanges and mechanically assembled joints must be protected with clean metal gaskets and shall be wrapped in new oil free aluminium foil. A plastic cover on top should prevent damage to the flange sealing faces during transport.

Special attention must be paid to assemblies or sub-assemblies with moving parts. They must be securely fastened for transport.

The transport boxes shall be clearly marked with the purchase numbers to allow for an easy identification.

5. APPLICABLE DOCUMENTS

In the case of conflict with the requirements stated in this VH, the VH shall take precedence. If the requirements of the VH are in conflict with Legislation and/or Regulations then these conflicts are to be brought to the attention of the VGSL for resolution.

6. APPENDIX

Document	Description
ISO 15614-1	Arc welding
ISO/TS 3669-2:2007	Bakable flanges Part 2: Dimensions of knife-edge flanges
ISO 9803-1	Mounting dimensions of pipeline fittings Part 1: Knife-edge flange type
ISO 9803-2	Mounting dimensions of pipeline fittings Part 2: Knife-edge flange type
ISO 2861	Dimensions of clamped-type quick-release couplings
ISO 20175	Vacuum technology - Characterization of quadrupole mass spectrometers for partial pressure measurement
SS-EN-1779	Non-destructive testing - Leak testing - Criteria for method and technique selection
DIN 1.4301/AISI 304	Standard Cr-Ni stainless Steel alloy
DIN 1.4306 (AISI 304L)	Standard Cr-Ni low carbon stainless Steel alloy
DIN 1.4401 (AISI 316),	Standard Cr-Ni-Mo stainless Steel alloy
DIN 1.4404 (AISI 316L)	Standard Cr-Ni-Mo low carbon stainless Steel alloy
DIN 1.4429-ESU (AISI 316LN)	Standard Cr-Ni-Mo-N low carbon stainless Steel alloy

Literature

Wutz M. (editor), Theory and Practice of Vacuum Technology, English Ed., Vieweg, 1989.

ISBN 3-528-08908-3

John F. O'Hanlon, A User's Guide to Vacuum Technology 3. Ed., Wiley, 2003.

ISBN-13: 978-0471270522

Karl Jousten (editor), Handbook of Vacuum Technology, Wiley-VCH, 2008.

ISBN 978-3-527-40723-1

6.1. Units

This document uses the SI system to express units, however other deviations are mentioned accordingly.

Symbol	Unit
m	metre
g	gram
s	second
A	ampere (electric current) [C s^{-1}]
K	kelvin (temperature)
mol	Mole
J	joule (energy) [N m]
W	watt (power) [J s^{-1}]
N	newton (force) [m g s^{-2}]
Pa	pascal (pressure) [N m^{-2}]
V	volt (electrical potential) [W A^{-1}]
°C	degree Celsius (temperature) [K] *no-SI unit
bar	bar (pressure) [Pa] *no-SI unit (defined by IUPAC)
l	litre (volume) [m^3] *no-SI unit
C	conductance [m^3 s^{-1}; l^3 s^{-1}]
u	unified atomic mass *no-SI unit

6.2. Abbreviations

ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AISI	American Iron and Steel Institute
AMU	Atomic Mass Unit
CCG	Cold Cathode Gauge
DC	Direct Current
DIN	Deutsches Institut für Normung
DN	Nominal Diameter
EBW	Electron Beam Welding
ESHR	Essential Health and Safety Requirements

ESR	Electro Slag Remelted
ESS	European Spallation Source
EU	European Union
GMAW	Gas Metal Arc Welding
GTAW	Gas Tungsten Arc Welding
HC	Hydrocarbon
ICS	Integrated Control System
IKC	In-Kind Contributor
IP	Ion Pump
IPC	Ion Pump Controller
ISO	International Organization for Standardization
LBW	Laser Beam Welding
LINAC	Linear Accelerator
MAG	Metal Active Gas
MIG	Metal Inert Gas
MPC	Mobile Pumping Cart
MSLD	Mass Spectrometer Leak Detector
NCR	Non-Conformity Report
NDT	Non-Destructive Testing
NE	Nitrogen Equivalent
NEG	Non-Evaporable Getter
QA	Quality Assurance
QC	Quality Control
RF	Radio-Frequency
RGA	Residual Gas Analyzer
SI	International System of Units
SOW	Statement Of Work
SRF	Superconducting Radio-Frequency
TCG	Thermal Conductivity Gauge
TIG	Tungsten Inert Gas
TMP	Turbo-Molecular Pump
US	Ultra-Sound
VESM	Vacuum Equipment Standardization Manual
VG	Vacuum Group
VGL	Vacuum Group Section Leader

VHB	Vacuum Handbook
VTM	Vacuum Test Manual

6.3. Nomenclatures

CF	Conflat ™ by Varian Corp.
EDPM	Ethylene Propylene Diene Monomer
FFKM	Perfluoroelastomer (Kalrez or Chemraz)
FKM	Fluoroelastomer (Viton)
HV	High Vacuum
LV	Low (rough) Vacuum)
MV	Medium Vacuum
OFHC	Oxygen-Free High Conductivity ™
UHV	Ultra-High Vacuum

7. GLOSSARY

Term	Definition
ESS	European Spallation Source
HV	High Vacuum
IKC	In Kind Contributor
LINAC	Linear Accelerator
RV	Rough Vacuum
NE	Nitrogen Equivalent
UHV	Ultra-High Vacuum
VG	Vacuum Group
VH	Vacuum Handbook
VGL	Vacuum Group Section Leader

DOCUMENT REVISION HISTORY

Revision	Reason for and description of change	Author	Date
1	First issue	Marcelo Juni Ferreira	2016-04-14
2	Review	Laurence Page	2019-01-11
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4	Transferred to template, no change of content	Laurence Page / Gunilla Jacobsson	2025-03-31