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ESS VACUUM HANDBOOK PART 4 - HELIUM LEAK TEST

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TABLE OF CONTENT .... PAGE

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 4 provides guidelines, and imposes requirements where necessary, for the tests associated with the vacuum systems of the Accelerator, Target and Neutron Instruments. The VH 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 additional information concerning the contents of this handbook should be addressed to the ESS Vacuum Group Section Leader (VGL).

3. TEST PROCEDURES

3.1. Visual inspection

This is a general inspection to ensure that the quality of workmanship of the vessel or component etc., from a vacuum prospective, is sound and that it shows no deterioration or damage has occurred during fabrication, handling or transport etc. that will impact vacuum performance.

3.2. Leak testing

3.2.1. Preparation for testing

All equipment used to conduct vacuum leak testing is to be approved and inspected by ESS VG prior to use. The use hydrocarbon free dry pumping is preferred, alternatively equipment which is suitably trapped to avoid the potential for contamination, due to back streaming of oil maybe used.

The Mass Spectrometer Leak Detector (MSLD) used for leak testing shall be calibrated as per ISO 3530 (Mass-spectrometer-type leak detector calibration). If an internal calibrated leak is used then this must be traceable to an external calibrated leak calibrated against a traceable standard.

Vessels and assemblies must be cleaned and vacuum baked (if specified) as appropriate by methods approved by ESS VG prior to testing, refer to the relevant sections of the VH.

Leak testing is to be conducted in accordance with the requirements of SS-EN 1779.

3.2.2. Testing requirements

UHV Systems and Components

Where applicable all connections between the vessel under test and the vacuum pump must be made using metal seals. When connecting the vessel and carrying out these tests take care must be taken to ensure that the cleanliness of the vessel is maintained. This is of particular concern for vacuum assemblies and components installed adjacent to the superconducting cavities of the LINAC where particulate contamination is a major concern.

The acceptable leak rate for the vessel/part shall be $<10^{-10}$ Pa m^3 s^{-1} ($<10^{-9}$ mbar l s^{-1}) using an open probe (spray) method and $<10^{-8}$ Pa m^3 s^{-1} ($<10^{-7}$ mbar l s^{-1}) when the chamber is completely bagged and filled with helium (>95% concentration) for a period of >10 minutes and tested using a MSLD peak to a sensitivity $<10^{-12}$ Pa m^3 s^{-1} ($<10^{-11}$ mbar l s^{-1}), unless another value has been specified in the contract or other technical documentation or agreed in writing with ESS VGL (For example in the accelerator we have a leak rate requirement for the spray test of less than $2x10^{-10}$ mbar l s^{-1}.)

High Vacuum Systems and Components

Where applicable all connections between the vessel under test and the vacuum pump should be made using metal seals or the sealing type used on the component in its final configuration when performing the final helium leak test. When connecting the vessel and carrying out these tests take care must be taken to ensure that the cleanliness of the vessel is maintained.

The acceptable leak rate for the vessel/part shall be $<10^{-9}$ Pa m^3 s^{-1} ($<10^{-8}$ mbar l s^{-1}) using an open probe method (spray) and $<10^{-7}$ Pa m^3 s^{-1} ($<10^{-6}$ mbar l s^{-1}) when the chamber is completely bagged and filled with helium (>95% concentration) for a period of >10 minutes and tested using a MSLD peak to a sensitivity $<10^{-11}$ Pa m^3 s^{-1} ($<10^{-10}$ mbar l s^{-1}), unless another value has been specified in the contract or other technical documentation or agreed in writing with ESS VGL.

Rough Vacuum Systems and Components

Where applicable all connections between the vessel under test and the vacuum pump should be made using the sealing type used on the component in its final configuration when performing the final helium leak test. When connecting the vessel and carrying out these tests take care must be taken to ensure that the cleanliness of the vessel is maintained.

The acceptable leak rate for the vessel/part shall be $<10^{-8}$ Pa m^3 s^{-1} ($<10^{-7}$ mbar l s^{-1}) using an open probe (spray) method and $<10^{-6}$ Pa m^3 s^{-1} ($<10^{-5}$ mbar l s^{-1}) when the chamber is completely bagged and filled with helium (>95% concentration) for a period of >10 minutes and tested using a MSLD peak to a sensitivity $<10^{-10}$ Pa m^3 s^{-1} ($<10^{-9}$ mbar l s^{-1}), unless another value has been specified in the contract or other technical documentation or agreed in writing with ESS VGL.

3.2.3. Notification of Testing

Leak testing of large vessels or assemblies are to be witnessed by a member of ESS VG before acceptance for delivery to ESS unless otherwise agreed with the VG.

At least 3-week notice shall be given prior to the conducting of off-site testing.

3.2.4. Reporting of Leak Test Results

Proof of vacuum test results are required for all leak tests performed to demonstrate that the acceptance criteria have been met. A test report shall be submitted using the "Leak Test Report" form attached as Appendix A. together with other leak test documentation to the VG for review and approval prior to shipment for delivery to ESS.

Any initial component failure and subsequent corrective action shall be documented as part of the Leak Test Report.

Any proposed deviation from this procedure, or alternative specifications, shall be submitted to ESS, in advance, for review and approval.

3.3. Outgassing Rate Test

3.3.1. Preparation for testing

The requirement to performance an "Outgassing Rate Test" will be specified prior to manufacture by the VG.

The total out-gassing rate of a vessel or assembly shall be measured after 10 hours of pumping from atmosphere. The measured outgassing rate shall be
$<10^{-11}$ Pa m^3 s^{-1}/cm^2 ($<10^{-10}$ mbar l/s cm^2).

A hydrocarbon free dry pumping unit and a Residual Gas Analyser (RGA) must be used for these tests. The RGA is to be calibrated against a special gas mixture containing 4 gases species e.g. He, N_2, Ar and Ne [ratio 5:60:20:15 respectively) using the ISO 20175.

3.3.2. Testing Requirements

The mass spectrum over the mass range of 1-100 u is to be recorded after 10 hours of pumping from atmosphere.

The "hydrocarbon" content, recorded by the RGA, must not exceed 10% of the maximum allowable outgassing rate. This can be calculated by summing all the hydrocarbon peak heights >40 u and expressing them as a fraction of the total peak height. From the total measured outgassing rate.

The outgassing rate due to hydrocarbon (HC) is to be calculated as follows:

Hydrocarbon outgassing (%) = Sum of HC peaks / sum of all peaks x measured outgassing rate

Peaks at 17, 18, 28 and 40 u are deemed to be non-hydrocarbon.

3.3.3. Notification of Outgassing Rate Tests

Outgassing tests on large vessels or assemblies are to be witnessed by a member of ESS VG before acceptance for delivery to ESS unless otherwise agreed with the VG.

At least 3 week notice shall be given prior to the conducting of off-site testing.

3.3.4. Reporting of RGA Test Results

A printout from the RGA is required to demonstrate that the acceptance criteria have been met. This printout shall be submitted with other leak test documentation to the VG for review and approval prior to shipment for delivery to ESS.

4. 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 VGL for resolution.

The following documents form a part of the ESS Vacuum Handbook Part 4 – Vacuum Test Manual.

Document	Description
ISO 3530	Vacuum technology – Mass-spectrometer-type leak detector calibration.
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.

5. APPENDIX

5.1. ESS Helium leak test report

Contractor:	HELIUM LEAK TEST REPORT	Contract number:

ESS technical specification.......: ______________________

ESS Part identifier .... : ______________________

Leak test procedure (Ref. N°, Revision) .... : ______________________

Volume to be tested .... : ______________________

Test equipment

Helium Mass Spectrometer type .... : ______________________

Pressure gauge type .... : ______________________

Turbo pump type .... : ______________________

Helium calibrated leak data

Calibrated leak N°.: __________ **Calibration** (Date,Temp.) : __________ °C

Test temperature : __________ °C **Nominal value.........:** __________ mbar l s-1

q_{FR} (Size of the calibrated leak after correction for ageing and temperature) ....: __________ mbar l s-1

System Calibration

R_{FR} (Residual signal prior S_{FR} measurement) ....: __________ mbar l s-1

S_{FR} (Signal given by the calibrated leak) ....: __________ mbar l s-1

S_m (Smallest readable signal deviation is equivalent to the amplitude of R_{FR} noise) ..: __________ mbar l s-1

q_{Gm} (Sensitivity of the leak test) $= S_m \dfrac{q_{FR}}{S_{FR} - R_{FR}}$ ....: __________ mbar l s-1

3t (Time to achieve stabilised leak signal) ....: __________ sec

Leak test conditions

p (System Pressure) ....: __________ mbar

C (Volumetric fraction of tracer gas in the injection envelope) ....: __________ %

R_F (Residual signal prior to S_F measurement) ....: __________ mbar l s-1

S_F (Signal given by the leak after: ______ minutes ≥ 3t) ....: __________ mbar l s-1

Leak tightness requirements

≤ __________ Pa m³ s-1

≤ __________ mbar l s-1

Leak evaluation

$$q_G = \frac{q_{FR}(S_F - R_F)}{S_{FR} - R_{FR}} \frac{1}{C} =$$ __________ mbar l s-1

Conformance.....: **YES / NO**

Remarks:

Operator	Checked by	Approved by
Date:	Date:	Date:
Name:	Name:	Name:

5.2. 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

5.3. 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

5.4. 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

6. 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

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1	First issue	Marcelo Juni Ferreira	2016-04-14
2	Updates	Marcelo Juni Ferreira	2018-04-13
3		Laurence Page	2019-01-11
4	Fix leak rate inconsistencies	Laurence Page	2020-08-05
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