GSI FAIR	Technical Guideline	Number	7.28e
B-MT	Vacuum Testing of Complete Cryogenic Modules	Status	2011-04-04

Contents

1. Scope

1) This document defines requirements and procedures to be executed for vacuum testing of complete cryogenic modules like
   - cryo-magnetic modules
   - cryogenic supply systems
   - cryogenic transport systems
   - cryogenic current lead boxes
   - auxiliary cryogenic systems

   within FAIR accelerators.
2) The described testing procedure shall NOT be applied to empty cryostat vacuum shells or single cryogenic tubing.
3) The described testing procedure does NOT represent the full acceptance test of cryogenic modules.
4) This document is NOT related to any other purpose as aforementioned.

2. Definitions

1) *A complete cryogenic module* in terms of this document is assembly like cryogenic equipment being fit for installation on site of operation.

3. Codes and Standards

1) The European pressure equipment directive 97/23/EC [1] defines the legal standards for components and assemblies being recognised as pressure equipment.
2) The AD 2000 Code [2] defines the engineering and documentation standards in terms of pressure equipment.

4. Basic Requirements

4.1. Requirements on Equipment to be Tested

1) In case of the equipment to be tested is identified as pressure equipment in terms of [1], all properties as defined by [2] must be proven and all documentation as defined in [1] and [2] must be available on site.
2) The equipment to be tested must be featured for being operated under insulation vacuum at warm conditions without being installed in operation site.
3) The equipment to be tested must be featured for being pressurised to the corresponding maximum operation pressure in all internal vessels and tubing at warm conditions.
4) In case serviceability for testing purposes in a warm standalone mode (as defined in 4.1.1) and 4.1.3)) is in doubt, a different procedure for approval must be agreed with the contracting entity in writing.
5) All additional equipment, associated to the cryogenic module and being in direct contact to the insulation vacuum must be installed for being tested.

4.2. Surrounding conditions

1) The tests shall be performed in a clean, low dust and dry surrounding.
2) No contamination e.g. with dust, grease or oil shall be accepted due to testing.

4.3. Required Documentation

1) All documentation listed below must be available on site at the date of testing.
2) A copy of the calibration certificate of the He – leak tester in use for the tests is required and shall be added to the documentation. At the date of testing the certificate must show a date of calibration not older then one year.

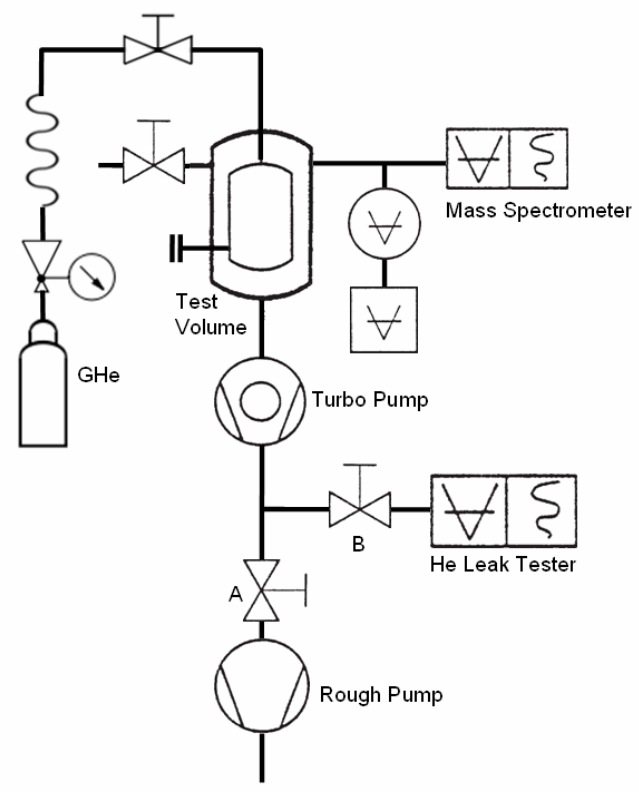

Figure 1: Testing scheme

3) The certificate for a passed acceptance test for the cryostat vacuum vessel as defined in [3] must be available.
4) The certificate for a passed acceptance test for the thermal shield as defined in [4] must be available.
5) Certification; as defined in [5]; for He leak tightness of the interior installed inside the device being tested must be available.
6) In case of pressure equipment the documentation certifying the pressure safety of the complete device as well as the operation manual as defined in [1] must be available.
7) A template of a testing protocol showing the structure as defined in 7.1 shall be prepared prior to the test procedure being executed.

4.4. Required Equipment and Media

1) Following equipment and media are required for He pressurisation:
   - compressed He gas cylinder with pressure regulator providing the appropriate pressure range,
   - a port flange with calibrated pressure gauge showing an adequate pressure range and accuracy,
   - He tight valve,
   - flexible or rigid tube and fittings.
2) All equipment used for pressurising must be suitable for the applied testing pressure, e.g. in terms of pressure range and safety.
3) All equipment must be suitable for generating oil free vacuum.
4) Following equipment and media are required for the vacuum test
   - calibrated He leak tester with a most sensible range of at least $1*10^{-8}$ mbar*L/s,
   - quadrupole mass spectrometer with
     - faraday cup detector
     - minimum detectable partial pressure of $5*10^{-12}$ mbar
     - atomic mass number range of 1 - 100
   - turbo molecular pump,
   - rough pump,
   - tubing, T – fittings and valves,
   - a set of blank flanges and seals for all flanges not in use during testing.
5) A plastic balloon covering the complete device for performing an integral leak test must be available for the integral He leak test of the insulation vacuum vessel.

5. Test Preparation

1) For safety reasons in case of pressure equipment to be tested is not certified properly as defined by [1] and [2], the equipment must NOT be pressurised under any circumstance.

2) Equipment to be tested shall be rejected directly in case it shows obvious contamination with e.g. dust, grease, oil or any other solids or liquids.
3) All openings and flanges not in use, must be properly closed with adequate flanges. In case of pressure equipment all requirements as defined by [1] and [2] must be fulfilled also for all closures.
4) A testing scheme as described in Figure 1 shall be set up.
5) The testing scheme must be prepared for an oil free insulation vacuum.
6) Before performing the testing procedure it shall be assured that the setup is leak tight already without test volume.
7) For safety reasons, the relevant terms for operation safety as defined in the correlating operation manual for the device being tested must be fulfilled prior to pressurising any volume.
8) The device must be prepared for safe vacuum pumping of insulation vacuum and must be pumped down.

6. Checks and Tests

1) The checks and tests as defined in 6.1 to 6.6 must be performed following the listed sequence.

6.1. Document and Certification Check

1) All documentation listed in 4.3 must be checked for completeness.
2) In case of incomplete documentation, the test must be declared as failed.

6.2. Residual Gas Test

1) For this test valve A shall be opened and valve B shall be closed.
2) Before measuring the first residual gas spectrum the insulation vacuum must be pumped down to the start pressure of the mass spectrometer (mostly $\leq 1*10^{-4}$ mbar).
3) The vacuum pressure must be logged continuously during the full testing period. For evaluation the vacuum pressure via time graph shall be drawn in double logarithmic scales.
4) The residual gas spectra shall be measured and logged
   - when reaching the start pressure of the mass spectrometer (pumping time must be noted)
   - after 12 h, 24 h, 36 h and 48 h
5) During the full pumping time of 48 h all residual gas components shall degrease significantly. In case any residual gas component shows no significant reduction, the test shall be declared as failed.

6.3. Single He Leak Test of Insulation Vacuum Vessel

1) For single He leak testing valve B shall be opened and valve A shall be closed.

2) All flanges and existing feed-throughs shall be tested for leaks separately by applying He gas to all vacuum gaskets and feed-throughs.
3) One single detected He-leak must not exceed $1*10^{-9}$ mbar*L/s.
4) All existing leaks must be marked and documented.
5) In case of one single leak rate exceeds the defined maximum value, the test shall be declared as failed.

6.4. Integral He Leak Test of Insulation Vacuum Vessel

1) For the integral He leak test the vessel shall be covered completely by a plastic balloon permanently filled with gaseous He.
2) For integral He leak testing valve B shall be opened and valve A shall be closed.
3) The He partial pressure of the residual gas shall be recorded during a testing time of $\geq$ 60 min.
4) The integral He leak rate of the vacuum vessel must not exceed $1*10^{-7}$ mbar*L/s.
5) In case of an integral He leak rate exceeds the defined value, the test shall be declared as failed.

6.5. Integral He Leak Test of Interior Components

1) For integral He leak testing of interior valve B must be opened and valve A must be closed.
2) The integral He leak rate shall be measured with respect to the existing He background prior to pressurising.
3) All volumes and tubing related to the He processing system must be pressurised to their nominal operation pressures.
4) The He partial pressure of the residual gas in the insulation vacuum vessel shall be recorded during a testing time of $\geq$ 60 min.
5) The integral He leak rate of the inner He process tubing and volumes must not exceed $5*10^{-8}$ mbar*L/s.
6) In case of the integral He leak rate of the interior exceeds the defined value, the test shall be declared as failed.

6.6. Gasload Test

1) After performing the leak tests as defined in 6.3, 6.4 and 6.5 the integral gasload shall be calculated from the measured values of
   - effective pumping speed,
   - vacuum pressure when reaching start pressure of the mass spectrometer and after 12h, 24h, 36h and 48h,
   - integral leak rate of the insulation vacuum vessel (see 6.4),
   - integral leak rate of the interior components (see 6.5).
2) The calculated results must be documented.

3) The vacuum pressure diagram (double logarithmic scales) shall show a straight degrease in the saturation phase of the pumping process. In case the pressure graph shows horizontal characteristics within the saturation phase, a significant gasload must be assumed and the test shall be declared as failed.

7. Documentation

1) Any measured or calculated values and testing results shall be documented in writing within a protocol as defined as follows.
2) Time dependent measurements shall be recorded in diagrams and put to the protocol.
3) All described checks and tests shall be documented in a testing form, agreed by the contracting entity.

7.1. Testing Protocol Requirements

1) The testing protocol shall show comprehensible structure and content documenting each single test executed.
2) The following information shall be at least documented within the cover sheet:
   - Test identification
   - Address of Company or Institute,
   - Identification of Department,
   - Names of testing personnel,
   - Name of quality testing leader,
   - Date and time,
   - Identification of tested object,
   - Serial number of tested object,
   - Test result,
   - Number of pages (including photo prints).
3) The measurement equipment in use shall be documented at least with
   - device identification,
   - serial number,
   - date of last calibration,
   - applied measuring range.
4) All tests, described in the chapter 6 shall be documented at least with
   - brief description of testing process,
   - test schemes if applicable (e.g. vacuum scheme),
   - relevant device settings,
   - registered non-conformities,
   - nominal values,
   - measured values,

- photos of non-conformities (if applicable),
- single ratings,
- full test rating

in clearly separated chapters.

5) All defined tests and procedures shall be signed by the executing personnel.
6) A conclusion page shall indicate the all over test result clearly. In case the full acceptance test failed a brief explanation shall be stated.
7) The protocol shall be crosschecked and signed by a person, responsible for the product quality of cryostat vacuum vessels.
8) The original testing protocol shall be handed out to the contracting entity.
9) A digital version shall be stored in EDMS following the relevant guidelines for EDMS access and usage. The EDMS storage shall be agreed with the contracting entity.

8. References

[1] Directive 97/23/EC, European parliament and the council of the European Union, http://eur-lex.europa.eu, 1997
[2] AD 2000-Code; Verband der TÜV e. V.; Beuth Verlag GmbH; Berlin; Germany; 2009
[3] Technical Guideline No. 7.16e: Acceptance Test for Cryostat Vacuum Vessels
[4] Technical Guideline No. 7.20e: Acceptance Test for Cryostat Thermal Shields
[5] Technical Guideline No. 7.24e: Pressurised Leak Testing of Cryogenic Tubing