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Appendix 6 Windows

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ITER Vacuum Handbook
Appendix 6

Guide to the Supply of Vacuum Windows for the ITER Project

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6 Requirements for the Supply of Vacuum Windows for the ITER project

6.1 Scope

This appendix is written as a guide for the manufacture and supply of vacuum window assemblies for use on the ITER project.

It is intended that the *suppliers* of vacuum bellows and flexibles should follow the guidance in this appendix to achieve the requirements of the ITER Vacuum Handbook.

The *supplier* is at liberty to utilise other techniques not described in this appendix provided that the components manufactured comply with the requirements of ITER Vacuum Handbook.

"Supply" includes the design, manufacture, testing and delivery of windows as described in the specifications, including the design, manufacture and testing of beryllium windows for use on ITER diagnostic systems.

6.2 Design

ITER IO is responsible for specifying the interface between ITER systems and the window assemblies.

The supplier is responsible for the detailed design of the window assemblies.

Flanges or end fittings will be specified by ITER in accordance with The ITER Vacuum Handbook Appendix 8 and the design of the window assembly must conform to the ITER remote handling requirements as detailed in the ITER Remote Handling Code of Practice.

Window assemblies for use on ITER vacuum vessels forming part of the vacuum containment boundary for VQC1A should be bakeable to 250 °C and, to conform to the ITER Vacuum Handbook Section 15, should be of a double window design (either pre-assembled or installed as separate elements) unless permanently installed behind an Ultra High Vacuum (UHV) isolating valve. The interspace between the two windows will be backfilled with a suitable gas (as *accepted* by the ITER Vacuum Responsible Officer) and connected to the Service Vacuum System.

Similarly, window assemblies for use on ITER vacuum vessels forming part of the vacuum containment boundary for VQC2A should be of double construction. However, there is no requirement to operate at elevated temperatures.

For windows transmitting high power (e.g. RF heating systems) the interspace pressure needs to be monitored continuously and suitably interlocked with the power system.

Window assembly interspace volumes are to be manufactured with suitable connections to the Service Vacuum System, as detailed in the ITER Vacuum Handbook Section 8.

Windows used in VQC, 3 & 4 may be of a single window construction.

All joining processes, bonding of the window to the ferrule and brazing or welding of the metallic components, have to be pre-qualified and production proof samples should be made during the manufacturing process (see Attachment 1).

6.3 Materials

All vacuum facing materials for use in the manufacture of window assemblies should comply with the ITER *accepted* materials list (Appendix 3).

6.3.1 Windows

CVD Diamond, natural crystal quartz, synthetic crystal quartz and sapphire are *accepted* for use in ITER window assemblies forming primary vacuum containment. Beryllium Oxide is *accepted* for use in vacuum windows that form part of the primary vacuum containment after qualification of the window in accordance Section 6.5 of this Appendix. Sodium chloride and other hygroscopic materials are not *accepted* for use in VQC1 & VQC2 systems.

6.3.2 Window (body) Assemblies

All tubes/pipes are to be of seamless construction and comply with the ITER Vacuum Handbook Appendix 11.

In accordance with the ITER Vacuum Handbook Appendix 8 flanges should be manufactured from forged material and supplied as follows:

1. Materials selection is to comply with Appendix 3
2. When there is a vacuum boundary across the grain of thickness <5 mm, the material must be Electro-Slag Remelted (ESR) or Vacuum Arc Remelted (VAR). The use of plate is prohibited. Alternative processes for achieving the required inclusion limits may be *accepted* if successfully validated.
3. The rate of inclusions in such steels should be checked in accordance with ASTM E-45 Method D (or equivalent) to be within the following inclusion limits:
    - Inclusion Type A ≤ 1.0
    - Inclusion Type B ≤ 1.0
    - Inclusion Type C ≤ 1.0
    - Inclusion Type D ≤ 1.5

6.4 Manufacture

Before assembly commences the supplier should submit to ITER for *acceptance* the documents listed in Section 6.10.

Tools used during the manufacture of the window assemblies must not contaminate the vacuum surfaces. Cutting fluids need be *accepted* before use and will be water based, oil free, non-halogenated, sulphur and phosphorus free. Those listed in Appendix 4 are *accepted* and, if chosen, should be specified in the quality plan and agreed in advance.

Cleaning operations need to be performed to an *accepted* procedure in accordance with the ITER Vacuum Handbook Appendix 13. The use of chlorine and other halogen containing fluids (e.g. trichloroethylene) is strictly forbidden.

All assemblies must be individually identified, packaged and shipped to the ITER site in accordance with Section 22 of the ITER Vacuum Handbook .

6.4.1 Welding of Window Assemblies

Prior to manufacture the supplier should submit a weld plan in accordance with the ITER Vacuum Handbook Attachment 1. The weld plan is a drawing which cross references each welded joint to a supporting Weld Procedure Specification (WPS).

Welding procedures and the Procedure Qualification Records should be qualified in accordance with Attachment 1

Where practical, all welds shall be full penetration butt welds unless otherwise *accepted*.

100 % visual examination of welds should be carried out in accordance with the ITER Vacuum Handbook Attachment 1

Butt welds are to be 100 % radiographed in accordance with the ITER Vacuum Handbook Attachment 1

Where radiography is not feasible, production proof samples must be performed in accordance with the ITER Vacuum Handbook Attachment 1

Dye-Penetrant examination of production welds is only permitted in accordance with the ITER Vacuum Handbook..

6.4.2 Bonding of Windows

All windows should be bonded into metal ferrules.

6.4.2.1 VQC 1

Windows should be bonded into the window assemblies by aluminium bonding. Other bonding methods may be used with the advance agreement of the ITER Responsible Officer after *acceptance* of the method.

6.4.2.2 VQC 2

In addition to aluminium bonding, Sliver-Lead-Tin Eutectic may be used for windows for use on the outer cryostat boundary.

6.5 Qualification of Windows (type testing)

Prior to the manufacture of window assemblies the *supplier* must qualify the window design. The *supplier* should submit for *acceptance* a qualification plan (as part of the quality plan) detailing the tests to be performed on window assemblies. After the completion of all manufacturing processes the window assemblies should undergo the following qualification tests.

1. Pressure test[1]
2. Mechanical shock testing
3. Thermal shock test
4. Helium leak test
5. High power RF transmission (where applicable)
6. Voltage stand-off (including Paschen breakdown where applicable)

[1] The pressure test should include a rapid vent "type test" in which the window is mounted in a small evacuated vessel which is then vented rapidly (simulating survival of a Vacuum Vessel loss of vacuum event).

In each case the method of testing should be *accepted* before manufacture shall commence.

6.5.1 Pressure testing

Prior to leak testing it must be demonstrated that the window assemblies can withstand, and remain unaltered by, a 0.2 MPa pressure differential in either direction. Proof tests to 0.3 MPa are required to qualify the window assemblies.

6.5.2 Mechanical shock

Type testing of the window bonded elements must show no failure at 15 g acceleration for 1000 cycles.

6.5.3 Thermal Shock

Type testing of the window bonded elements must exhibit no change in helium leak rate when sprayed with water at 100^{o} C while at the window normal operating temperature

6.5.4 Leak Testing

The supplier should perform leak testing of the window assemblies in accordance with the ITER Vacuum Handbook Appendix 12

Window assemblies for use on VQC1 systems should be baked and hot leak tested at 250 °C as follows:

1. Global leak test of the window assembly
2. Leak test of the water cooling circuits (if applicable)
3. Leak test of the window interspace (both to vacuum and to atmosphere)

The leak test procedure should include three operating cycles of the window assembly at each test temperature before leak testing.

The procedure for baking windows should be in accordance with the ITER Vacuum Handbook Appendix 15 and should be submitted for *acceptance* before baking operations start.

Immediately after bake-out, these tests should be repeated at room temperature.

In both cases the acceptance leak rate shall be met with the background reading on the leak detector being at least one order of magnitude below the acceptance leak rate without electronic correction. Leak rates for window assemblies for VQC1 (including the window interspace) should not exceed 1 x 10^{-10} Pam^3s^{-1} at 250 °C

Window assemblies for use on VQC 2 systems should be subject to the same tests as VQC 1 but with the requirement for temperature cycling waived. Leak rates for window assemblies for VQC2 should not exceed 1 x 10^{-10} Pam^3s^{-1} at ambient temperature.

Acceptance criteria for window assemblies is summarised in Table 6-1.

Table 6-1 Window assembly Leak Rates

	VQC 1[1]	VQC 2[2]
Max global leak rate	1 x 10^{-10} Pam^3s^{-1}	1 x 10^{-10} Pam^3s^{-1}
Max leak rate from / to window interspace	1 x 10^{-10} Pam^3s^{-1}	1 x 10^{-10} Pam^3s^{-1} (if applicable)
Max cooling channel leak rate	1 x 10^{-10} Pam^3s^{-1}	1 x 10^{-10} Pam^3s^{-1}(if applicable)

1. Acceptance criteria at 250 ^oC
2. Acceptance criteria at ambient

6.5.5 High Power RF Transmission

On windows designed for the transmission of high power RF it must be demonstrated that the vacuum properties of the window remain unaltered when high power RF is applied. The *supplier* shall submit for *acceptance* a test plan detailing the method and type of transmission tests to be performed in the qualification of the windows assemblies.

6.5.6 Voltage Stand-off

The supplier must demonstrate that windows required to stand off high voltage can do so with no degradation of the vacuum performance of the windows. It must also be demonstrated that the window assemblies are suitable protected from Paschen discharges (if applicable). The *supplier* shall submit for *acceptance* a test plan detailing the method and type of tests to be performed in the qualification of the window assemblies.

6.6 Testing and Inspection of Window Assemblies

Prior to the manufacture of window assemblies the *supplier* should provide for *acceptance* a test plan and test procedures detailing the tests to be performed on window assemblies before delivery to the ITER site. After the completion of all manufacturing processes the window assemblies should undergo a vacuum baking cycle to the operating temperature and a helium leak test according to 6.6.1 below.

6.6.1 Leak Testing

Prior to delivery to the ITER site, windows should be subject to helium leak testing in accordance with Section 6.5.4. Windows will be subject to acceptance helium leak testing on delivery to the ITER site.

6.7 Marking

Each window assembly should be individually marked with a unique identification which is traceable to the window assembly document package. The use of dyes, paints, pens and other such markers that transfer marking material into any window assembly surface should not be used for the marking of window assemblies. Scribing with a clean sharp

point and vibro-etching are acceptable marking processes. Chemical etching is also acceptable, but not for use on for VQC1 vacuum facing surfaces.

6.8 Packaging & Delivery

The packaging and delivery of window assemblies to the ITER site should be in accordance with the ITER Vacuum Handbook.

Where practical, window assemblies should be entirely enclosed in heat sealed polyethylene and backfilled with a suitable dry gas. Nitrogen is preferred but other gasses may be permitted with prior *acceptance*. All window assemblies shall be shipped dry internally and externally irrespective of final acceptance testing at the manufacturer's site.

The use of adhesive tape for the protection and packaging of components must be limited to prevent the risk of contamination from the tape. In particular tape used on austenitic stainless steel should meet leachable chloride and fluoride limits of 15 ppm and 10 ppm, respectively. Where used, tape must be fully removable without residue, using isopropyl alcohol or acetone as the solvent if necessary.

All window assemblies should be transported in rigid packing cases or containers which are lined with waterproof material. Components must be packed with adequate protection from thermal and mechanical stresses (particularly shock loads resulting from dropping and mal-handling) which may adversely affect the operation of the window. All packing case joints should be sealed and cases marked with individual window specific identification. Handling instructions should also be clearly marked on the outer packaging. Chemical or radiological hazards, etc., should be identified on the packaging. All packaging markings will be in English and French and include the Vacuum Classification of the component(s).

6.9 Incoming inspection at the ITER Site

In addition to the inspection detailed in this Appendix, window assemblies will be subject to an incoming inspection on delivery to the ITER site. This will include, as a minimum, dimensional inspection for compliance with the technical specification and helium leak testing in accordance with the ITER Vacuum Handbook Appendix 12.

6.10 Documentation

The following documents shall be *accepted* before pre-manufacture activities commence:

- Weld Plan
- Quality Plan (including test plan /schedule)
- Welding Procedures and Welder Qualifications
- Dimensional Drawings
- Qualification test plan

The following documents shall be *accepted* before manufacture commences:

- Type testing report

On completion of manufacturing, two sets of the following documents should be supplied as data books:

- Signed-off Quality Plan
- Welding Procedures and Welder Qualifications
- Radiographic Reports (if applicable)
- Production Proof Sample Reports (if applicable)
- Material Certificates, traceable to assemblies, in accordance with EN 10204 2.2 ,3.1 or 3.2
- Dimensional drawings identifying welds
- Type testing report (s)
- Dimensional Inspection Report