

**Guideline (not under Configuration Control)**

**Appendix 15 Vacuum Baking**

| <i>Approval Process</i>  |  |                             |                              |
|--|--|-----------------------------|------------------------------|
|  | <i>Name</i>  | <i>Action</i>               | <i>Affiliation</i>           |
| <i>Author</i>  | <b>Worth L.</b>  | <b>02 Sep 2009:signed</b>   | <b>IO/DG/COO/PED/FCED/VS</b> |
| <i>Co-Authors</i>  |  |                             |                              |
| <i>Reviewers</i>   |  |                             |                              |
| <i>Approver</i>  | <b>Pearce R.</b>   | <b>09 Sep 2009:approved</b> | <b>IO/DG/COO/PED/FCED/VS</b> |
| <i>Document Security: Internal Use</i><br><i>RO: Chiocchio Stefano</i> |  |                             |                              |
| <i>Read Access</i>   | <b>GG: MAC Members and Experts, GG: STAC Members &amp; Experts, AD: ITER, AD: External Collaborators, AD: IO_Director-General, AD: EMAB, AD: Auditors, AD: ITER Management Assessor, project administrator, RO, LG: [CCS] CCS-All for Ext AM, LG: [CCS] CCS-Section Leaders, LG: [CCS] JACOBS, LG: [CCS] CCS-Doc Co...</b> |                             |                              |

| <i>Change Log</i>                         |                             |                          |  |
|---|-----------------------------|--------------------------|--|
| <b>Appendix 15 Vacuum Baking (2DU65F)</b> |                             |                          |  |
| <i><b>Version</b></i>                     | <i><b>Latest Status</b></i> | <i><b>Issue Date</b></i> | <i><b>Description of Change</b></i>                        |
| v1.0                                      | In Work                     | 27 Aug 2008              |  |
| v1.1                                      | In Work                     | 12 Jan 2009              |  |
| v1.2                                      | In Work                     | 12 Jan 2009              |  |
| v1.3                                      | Approved                    | 02 Sep 2009              | Minor textual changes for consistency with Vacuum Handbook |

**ITER Vacuum Handbook: Appendix 15**

Revision: 1.3

Date: July 28<sup>th</sup>, 2009

Page 1 of 8

**ITER Vacuum Handbook  
Appendix 15****Guide to the Vacuum Baking of Components for the ITER Project**

|                            | Name          | Affiliation        |
|----------------------------|---------------|--------------------|
| Author/Editor              | Liam Worth    | Vacuum Group - CEP |
| Vacuum Responsible Officer | Robert Pearce | Vacuum Group - CEP |

|  |                                    |             |
|--|------------------------------------|-------------|
| <b>ITER Vacuum Handbook: Appendix 15</b> |                                    |             |
| Revision: 1.3                            | Date: July 28 <sup>th</sup> , 2009 | Page 2 of 8 |

|        |   |   |
|--------|---|---|
| 15     | Guide for Vacuum Baking .....                       | 3 |
| 15.1   | Scope .....   | 3 |
| 15.2   | General Comments .....                              | 3 |
| 15.3   | General Procedures for Baking of Vacuum Items ..... | 4 |
| 15.3.1 | Preliminary .....                                   | 4 |
| 15.3.2 | Vacuum Pumps and Gauges .....                       | 4 |
| 15.3.3 | Temperature Monitoring and Control .....            | 5 |
| 15.3.4 | Completing the Bake Process .....                   | 5 |
| 15.4   | Control of the Bake Process.....                    | 5 |
| 15.5   | Types of Bake Procedure .....                       | 6 |
| 15.5.1 | Total Immersion Bake .....                          | 6 |
| 15.5.2 | Oven Bake .....                                     | 6 |
| 15.5.3 | “Tape” Bake .....                                   | 7 |
| 15.5.4 | Air Bake .....                                      | 7 |
| 15.6   | Documentation to be Supplied. ....                  | 8 |

| ITER Vacuum Handbook: Appendix 15 |                                    |             |
|-----------------------------------|------------------------------------|-------------|
| Revision: 1.3                     | Date: July 28 <sup>th</sup> , 2009 | Page 3 of 8 |

## 15 Guide for Vacuum Baking

### 15.1 Scope

This Appendix specifies typical procedures and processes which may be used when vacuum components and materials used for vacuum components for the ITER project are required to be baked.

It is intended that the *suppliers* using such processes 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 supplied comply with the requirements of the ITER Vacuum Handbook.

### 15.2 General Comments

Vacuum components for the various classifications may require to be baked to ensure satisfactory vacuum performance. Baking can be included as in the component leak testing procedure (Appendix 12) and/or the component cleaning procedure (Appendix 13). A bake temperature and duration will normally be specified in the specification documents and/or drawings for individual components or assemblies. If this is not the case, then the standard temperatures and durations listed in Table 15-1 should be used.

Vacuum baking has three functions, *viz.*, (a) the removal of contaminants which can break down to volatile components under the application of temperature (b) reducing the outgassing rate of the surface by accelerating the thermal desorption of molecular species (most often water) and (c) opening up incipient leaks, particularly porosity, where the leak path has been blocked by, for example, a carbon inclusion.

In order that the objectives of this Appendix are achieved, the times and temperatures specified for vacuum bakes have been based on considerable experience of using the processes.

In the following sections, the term “vacuum item” shall be taken to refer to an individual vacuum component, a sub-assembly or complete assembly as appropriate. It may also refer to material, e.g. steel sheet, being processed prior to manufacture.

Where the temperature is too high for a composite assembly the component part requiring higher temperature baking should be baked at that temperature prior to assembly and then the complete assembly baked at the lowest listed temperature of the component parts. Temperature requirements for baking materials not listed should be *accepted* in advance of baking operations.

Where the manufacturer is unable to carry out a bake procedure, either to the standard conditions in Table 15-1 or as otherwise specified, then any variation shall be *accepted* by ITER before proceeding.

## ITER Vacuum Handbook: Appendix 15

Revision: 1.3

Date: July 28<sup>th</sup>, 2009

Page 4 of 8

**Table 15-1 Standard Temperatures and Durations for Vacuum Baking**

| Vacuum Classification | Temperature (°C) | Time (hr) | Comment                              |
|-----------------------|------------------|-----------|--------------------------------------|
| VQC 1                 | 240              | 24        |                                      |
| VQC 1*                | 350              | 24        | Stainless steel and beryllium        |
|                       | 450 - 2000       | 24        | Carbon composites (see Appendix 16)  |
|                       | 250              | 24        | Precipitation-hardened copper alloys |
|                       | 350              | 24        | Tungsten                             |

\* For vacuum items in line vicinity of plasma

### 15.3 General Procedures for Baking of Vacuum Items

#### 15.3.1 Preliminary

Prior to baking, the vacuum item will have been thoroughly cleaned in accordance with the procedure of Appendix 13 of the ITER Vacuum Handbook.

If the vacuum item is not capable of being vacuum sealed and pumped down (e.g. it may be a batch of material or a part-finished vessel), then the vacuum item should be subjected to a total immersion bake (see 15.5.1 below)

All vacuum flanges should be sealed with a blank flange of material and thickness similar to that on the main vacuum item, using gaskets of the type to be used when the vacuum item is in service and fasteners of the appropriate strength.

Where a copper gasket is to be used and the bake temperature is greater than 100°C, then the gasket should be silver plated to avoid the formation of a loose oxide on the atmospheric side of the joint.

The vacuum item should be placed in or on a suitable bakeout stand which can safely support the vacuum item at the maximum temperature of the bake procedure. Any fixings should take into account the thermal expansion of the vacuum item and stand.

The vacuum item should be pumped down to an appropriate vacuum level and thoroughly leak tested to the appropriate specification in accordance with Appendix 12 of the ITER Vacuum Handbook prior to starting any baking process.

#### 15.3.2 Vacuum Pumps and Gauges

Vacuum Pumps of the appropriate pumping speed and base pressure specification should be used in these processes.

Vacuum pumps used for these processes should be inherently clean (e.g. turbomolecular pumps with magnetic or greased bearings, dry backing/roughing pumps, cryosorption pumps or sputter ion pumps). Otherwise, the supplier needs to satisfy ITER that a suitable failsafe trapping system has been implemented to protect against back-streaming and/or pump failure.

| ITER Vacuum Handbook: Appendix 15 |                                    |             |
|-----------------------------------|------------------------------------|-------------|
| Revision: 1.3                     | Date: July 28 <sup>th</sup> , 2009 | Page 5 of 8 |

Vacuum gauges (total and partial) with suitable measurement ranges and with appropriate calibration certificates should be fitted as required to monitor satisfactorily the progress of the bakeout process.

The manufacturer should provide ITER with complete details of all such equipment (including manufacturer, age, calibration certificates and history).

No bake procedure should be started before ITER has *accepted* the use of this equipment.

ITER will have the right to request documentary proof of the performance of the pumping equipment in the form of blank pump down characteristics and/or residual gas scans of the pumping equipment.

### 15.3.3 Temperature Monitoring and Control

The manufacturer should implement a suitable system to monitor, control and record the temperature of the baked vacuum item throughout the procedure.

It is important that the rate of rise and fall of temperature is controlled to within the *accepted* specification as detailed in the *accepted* baking procedure.

Full details of this system should be supplied to ITER.

No bake procedure may be started before ITER has *accepted* the use of this equipment.

### 15.3.4 Completing the Bake Process

When the temperature of the vacuum item has fallen to room temperature, the vacuum item should be leak tested thoroughly to the appropriate specification in accordance with Appendix 12 of the ITER Vacuum Handbook.

The vacuum item should be vented to dry nitrogen (dew point  $-50\text{ }^{\circ}\text{C}$ ), removed from the bakeout stand and suitably packed and protected for transport or storage.

## 15.4 Control of the Bake Process

To avoid undue stress on the vacuum item being baked, the temperature should be controlled such that it is uniform to within  $\pm 20\text{ }^{\circ}\text{C}$  at all points on the surface of the vacuum item, unless otherwise *accepted* by ITER.

The temperature differential across a metal sealed vacuum flange pair of greater than 200 mm diameter should be less than  $10\text{ }^{\circ}\text{C}$  at all times.

The rate of rise and fall of the temperature of the vacuum item should be held within specified limits and, unless otherwise *accepted* by ITER, should be no greater than  $10\text{ }^{\circ}\text{C}$  per hour.

When the temperature is falling, it is normally permissible to switch off the temperature control when the temperature falls below  $50\text{ }^{\circ}\text{C}$  and let the vacuum item cool naturally to room temperature.

Thus for a  $200\text{ }^{\circ}\text{C}$  bake, the rise time will normally be 18 hours, the dwell time 24 hours and the fall time 15 hours plus the natural final cooling time.

| ITER Vacuum Handbook: Appendix 15 |                                    |             |
|-----------------------------------|------------------------------------|-------------|
| Revision: 1.3                     | Date: July 28 <sup>th</sup> , 2009 | Page 6 of 8 |

At no time during the bake process should the pressure within the vacuum item being baked exceed  $10^{-3}$  Pa. If it should approach this level, the temperature must be held until the pressure falls again as the outgassing rate decreases.

The use of a residual gas analyser to monitor the bake process is strongly advised. This can indicate possible leaks opening up during the process. It can also be used for “end point” detection – e.g. when the water peak falls to below a specified partial pressure.

## 15.5 Types of Bake Procedure

### 15.5.1 Total Immersion Bake

In this procedure, the vacuum item is totally immersed in the vacuum environment of a vacuum furnace which is capable of reaching the required temperature and maintaining a pressure less than  $10^{-3}$  Pa at the maximum temperature used.

The manufacturer should, before the start of any baking process, demonstrate to ITER, by the provision of residual gas analysis spectra of the furnace during a blank run at the temperature to be used for the bake procedure, that the vacuum level and the cleanliness of the furnace at the temperature at which the bake is to be performed is satisfactory for the purpose. This requirement may be waived by agreement with ITER where the furnace has not been used for any other purpose between two successive bake processes for the ITER organisation.

Any vacuum joints on the vacuum item to be baked shall be left open.

The vacuum item is placed in the furnace, which is sealed and pumped down to the starting pressure with equipment conforming to the requirements of Section 15.3.2 above.

The furnace is checked for leaks.

The appropriate time/temperature bake cycle is carried out.

### 15.5.2 Oven Bake

The vacuum item, which will be a sealed vacuum vessel or assembly, is placed inside a suitable insulated enclosure and connected by a suitable pumping manifold to a vacuum pumping system conforming to the requirements of Section 15.3.2 above.

The arrangement shall be *accepted* by ITER before use.

Wherever possible, a suitable vacuum gauge or gauges capable of being operated at the maximum temperature of the bake cycle should be attached directly to the vessel or assembly being baked. Pressure readings on these gauges should be scaled to room temperature values by the appropriate temperature correction factor.

The insulated enclosure may be heated by convection heaters, radiant heaters or hot gas. It is recommended that some form of circulation of the air inside the enclosure be used to assist temperature uniformity.

A suitable number of temperature monitors should be fixed to the vacuum item so that the temperature distribution may be adequately monitored to ensure that the appropriate limits are not exceeded (15.4 above).



| ITER Vacuum Handbook: Appendix 15 |                                    |             |
|-----------------------------------|------------------------------------|-------------|
| Revision: 1.3                     | Date: July 28 <sup>th</sup> , 2009 | Page 7 of 8 |

If any glass or similar viewports or accessories are fitted, they should be covered in triple thickness aluminium foil for thermal protection and fitted with suitable mechanical protection against impact or implosion.

The assembly should be leak tested to the appropriate specification.

The appropriate time/temperature bake cycle is carried out

### 15.5.3 “Tape” Bake

In this procedure, the sealed vacuum item is wrapped with heater tapes. Rod heaters, heater plates or flange band heaters may also be used.

A suitable number of temperature monitors is fixed to the vacuum item so that the temperature distribution may be adequately monitored to ensure that the appropriate limits are not exceeded (15.4 above). In this case, it is very important to monitor the temperature on each side of every large (i.e. greater than 200mm diameter) flange pair. Temperature measurement sensors will normally be located close to the heating device (i.e. in the location of highest expected temperature)

Wherever possible a suitable vacuum gauge or gauges capable of being operated at the maximum temperature of the bake cycle are attached directly to the vessel or assembly being baked. Pressure readings on these gauges should be scaled to room temperature values by the appropriate temperature correction factor.

The vacuum item is connected by a suitable pumping manifold to a vacuum pumping system conforming to the requirements of Section 15.3.2 above.

The assembly shall be leak tested to the appropriate specification in accordance with Appendix 12 of the ITER Vacuum Handbook.

The vacuum item may then be wrapped in aluminium foil to assist in uniformity of the temperature distribution, taking care around electrical connections.

If there are glass or similar viewports or accessories fitted, they must be covered in triple thickness aluminium foil for thermal protection and fitted with suitable mechanical protection against impact or implosion.

The vacuum item is then covered with suitable thermal insulation, preferably a ceramic fibre filled flexible jacket or blanket.

The appropriate time/temperature bake cycle is carried out.

### 15.5.4 Air Bake

Where an air bake is specified for any item, the general procedures are as specified in this Appendix for the particular type of bake (Immersion, Oven or Tape) except that in this case all sections referring to pumping are ignored and all surfaces (interior and exterior) of the item shall be exposed to normal atmospheric air during the bake process.

Vacuum equipment conforming to the above requirements may still be required where a leak test and/or outgassing test has been specified as part of the bake process either before or after such a process.

| ITER Vacuum Handbook: Appendix 15 |                                    |             |
|-----------------------------------|------------------------------------|-------------|
| Revision: 1.3                     | Date: July 28 <sup>th</sup> , 2009 | Page 8 of 8 |

## 15.6 Documentation to be Supplied

For each vacuum item, the following certificates and records will normally be supplied:

- If requested by ITER a record of the performance of the pumping equipment
- A certificate of the initial leak rate
- A certificate of the final leak rate
- A record of the temperature distribution for the item and pressure within the vacuum item against time for the full duration of the bakeout process
- If agreed between the manufacturer and ITER, a full record of any residual gas scans taken with appropriate time markers which identify the scans to the position on the component bakeout cycle
- Full documentation regarding any leaks or other problems which occurred during the tests and any remedial action taken