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Technical Specifications (In-Cash Procurement)

Large Seal Test Rig Technical Specification

The ITER Organisation is planning to test the assembly and function of a suite of large metallic vacuum seals using a bespoke test rig. This Technical Specification defines the technical requirement for the design, manufacture, supply and delivery of a Large Seal Test Rig for that purpose.

Table of Contents

1 Purpose

The ITER Organization (hereinafter also called “IO”) is planning to test the assembly and function of a suite of large metallic vacuum seals using a bespoke test rig, the ITER Large Seal Test Rig, (hereinafter also called “the Test Rig”). The proposed test campaign is defined in [1]

This Technical Specifications shall define the technical functional requirement of the Test Rig for the Supplier to Design, Manufacture, Supply and Deliver the Rig to the IO for that purpose.

This supply shall include:

Phase 1. The detailed design of the Test Rig from the IO concept.
Phase 2. The manufacture and supply of the Test Rig and all ancillary items.
Phase 3. Delivery to IO of the Test Rig and all ancillary items.
Phase 4. Installation on site including any post-delivery assembly and staff training.
Phase 5. Commissioning and Handover of the Test Rig.

2 Introduction

ITER will be the largest and most complex vacuum system yet to be built. Situated in Southern France, adjacent to the French CEA Cadarache site, the ITER Organisation (IO) facility covers approximately 190 hectares and is designed to study the fusion reaction between the hydrogen isotopes of tritium and deuterium.

During machine operations, a plasma of tritium and deuterium is held in place by a magnetic field and superheated to 300,000,000 K. Under such conditions the ionised atoms of tritium and deuterium may fuse to create helium and a neutron. The released energy, in the form of kinetic energy, is carried by the fast neutron and helium atom.

The goal of ITER is to operate in conditions approaching steady state (i.e. continuous) with a Q=10 where Q is the ratio between the required power input to sustain the reaction and the fusion power output.

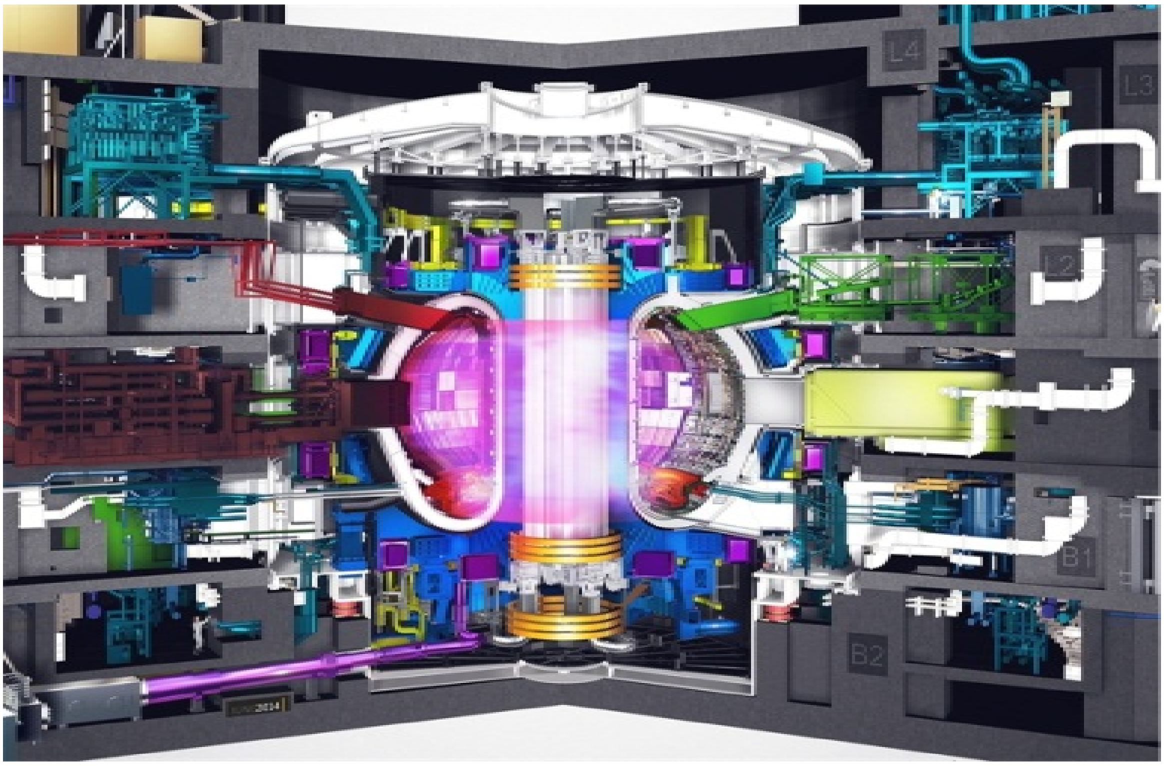


Figure 1 ITER Tokamak Facility

2.1 ITER Large Seal Test Rig

The ITER large seal Test Rig is a bespoke device to test and develop sealing for the port plug vacuum boundary seal. The aim of the Test Rig is to verify that the proposed seals can potentially meet the VQC1A leak rate [2] of better than $1x10^{-10}$ $Pa.m^3.s^{-1}$ and develop methods of handling such large seals.

The requirement is to provide a Test Rig that will allow sealing of several types of large metallic seal, in two sizes to suite the two flanges. The approximate flange dimensions are 2.7 m in height by 2.3 m in width for the larger outer flange and 2.2 m x 1.8 m for the smaller inner flange. The flanges share a common thickness of 150 mm and shall be made of Stainless Steel in grade 304. The Back Plate, simulating the mating flanges of the Vacuum Vessel Extension and the Port Plug, is of similar overall dimensions, approximately 3 m x 2.4 m and shall be made from the same material in a thickness of approximately 60 mm. IO requires an option to increase this thickness to 100 mm if required. The supplier shall include the option of this increased thickness in their offer.

A third flange simulates the Test Blanket Module (TBM) interface, this flange is part of this requirement and its interface to the Back Plate shall be provided. This flange shall be made from Stainless Steel in grade 304. Its approximate dimensions are 1.9 m x 0.75 m, 60 mm in thickness.

The system is subjected to thermal cycling and vacuum loads only and is not considered a pressure system.

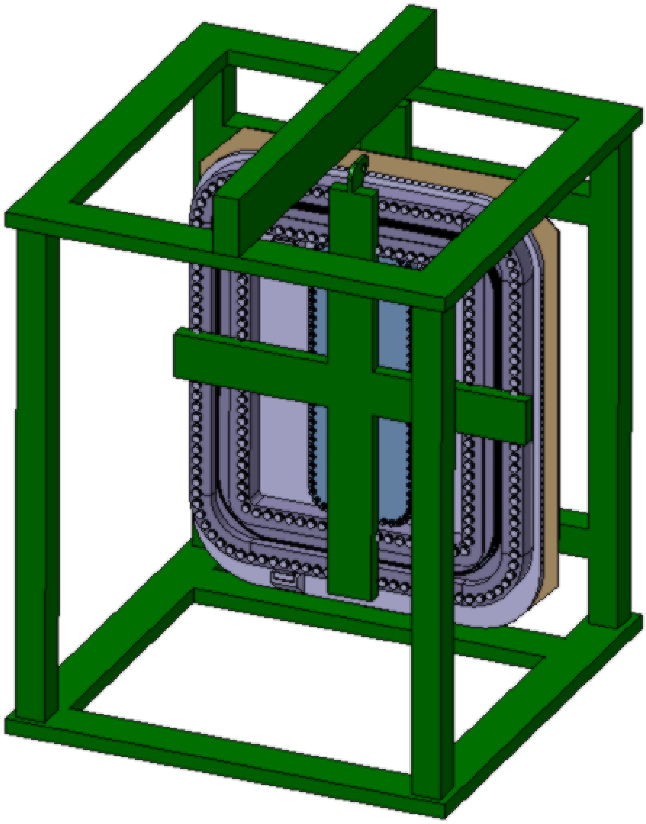


Figure 2 Test Rig Concept Model IO [7]

2.2 Regulatory Requirements

ITER is a licensed nuclear facility as defined in the Decree of Authorisation of Creation of ITER-INB-174 [3] and consequently IO, the Nuclear Operator, shall comply with the French Order of 7th February 2012 [4] establishing the general rules for licensed nuclear installations (INB-Order).

Certain components, structures and systems of ITER are classified as important for the interests of public safety as defined under Article L 593-1 of the French Environmental Code [5] and are further classified according to the area or service (i.e. their function). Specific quality assurance requirements must be applied which are proportional to the importance of what they protect.

The Test Rig specified in this functional technical specification will test the suitability and verify seals that are classified as Protection Important Components (PIC) since they are required as part of the primary confinement. Therefore under the scope of the INB-Order the testing of the seal becomes a Protection Important Activity.

The IO as Operator is responsible for ensuring that Protection Important Components are qualified, supplied, and applied to meet their safety functions in compliance with their associated safety requirements and under the requirements of the INB-Order [4]. For this Test Rig while the requirement does not include any nuclear confinement, the seal under test will provide that in its final installation. The design, manufacture, supply, installation and commissioning of the Test Rig shall therefore have an approved and traceable quality system and the seal tests shall be conducted under a specific QA system so that this PIA can be controlled.

The Supplier shall demonstrate compliance with the provisions for the implementation of the INB Order [4] including the defined requirements (articles 2.5.1 and 2.5.2) in their organisation and in the chain of subcontractors.

3 Scope

A conceptual design of the Test Rig has been made by IO and the test scope of the Test Rig has been detailed in Large Seal Test Campaign Specification [1].

The scope of the work by the Supplier shall be as follows:

<u>Phase 1.</u> The Detail Design of the Large Seal Test Rig from the IO Concept Design.

<u>Phase 2.</u> Manufacture and Supply of the Large Seal Test Rig and all ancillary items, namely:

a) The Testing Support Structure.
b) The Back Plate including all Stainless Steel Alloy S660 Inserts totalling 292, including 80 for TBM.
c) The Inner Front Flanges.
d) The Outer Front Flange.
e) The TBM Flange.
f) The M33 x 200 long Inconel Bolts totalling 212 in number.
g) The M27 x 135 long Inconel TBM Bolts totalling 80 in number.
h) The Load Washers and Load Measurement System.
i) The Heating System and its Control System.
j) The Specification of the Actuators, the design of their Control System and provision for their mounting to the Back Plate.
k) The Supply of the Actuators and their Control System.
l) The Assembly and Commissioning Elastomer Seals.

<u>Phase 3.</u> Delivery to IO of the Test Rig and all ancillary items.

<u>Phase 4.</u> Installation on site including any post-delivery assembly and training of IO staff.

<u>Phase 5.</u> Commissioning of the Test Rig and its systems and Handover of the Test Rig.

The following components are excluded from this Contract:

1) The metallic seals to be tested on this Test Rig.
2) The Multi-Ply Bellows that will connect the inner and outer flanges for future testing requirements.

4 Abbreviations & Acronyms

For a complete list of ITER abbreviations see ref [6]

Table 1 Definition of Abbreviations & Acronyms

Abbreviations or Acronym	Meaning
ASN	Autorité de Sûreté Nucléaire (French Nuclear Safety Authority)
BOM	Bill of Materials
CAD	Computer Aided Design
CoC	Certificate of Conformity
DRG	Drawing
FAT	Factory Acceptance Test
FEA	Finite Element Analysis
INB	Instillation Nucléaire de Base – Licensed Nuclear Installation
IO	ITER Organisation
IO RO	IO Responsible Office
KOM	Kick-off Meeting
MIP	Manufacturing and Inspection Plan
NC	Non-Conformity
NCR	Non-Conformity Report
PF	Port Plug Sealing Flange
PIA	Protection Important Activity
PIC	Protection Important Component
QAP	Quality Assurance Programme
QP	Quality Plan
RFID	Radio Frequency Identification
TBM	Test Blanket Module
The Test Rig	The ITER Large Seal Test Rig
STEP	Standard for the Exchange of Product model data i.e. ISO10303
UHV	Ultra High Vacuum
VF	Vacuum Vessel Port Extension Sealing Flange
VQC1	Vacuum Quality Class 1 [2]
VV	Vacuum Vessel

5 Definitions

Table 2 Definition of Terms

Term	Definition
Customer	ITER Organisation.
Certificate of Conformity	Certificate issued by the Supplier stating that the product concerned meets the requirements as given in this technical specification.
Deviations	A non-compliance with a defined requirement or non-compliance with a requirement set by the IO integrated management system that could affect the provisions of the Environment Code [5].
Non-conformance	Any condition that does not comply with a specified IO requirement.
Nuclear Operator	ITER Organisation
Protective Important Activity	An activity which can impact a Protection Important Component.
Protective Important Component	A component important for protecting the interests of public security as defined in the INB Order [4] and the Environmental Code [5].
Safety Important Class	Classification corresponding to the graduated approach of a PIC as defined in the Preliminary Safety Report.
Special Process	Any process which is not used in the manufacturer of a Supplier's proprietary items which must be developed and/or qualified to meet the requirements of this technical specification.
Subcontractor	Any entity that performs work for the Supplier.
Supplier	An entity that provides goods or services to the ITER Organisation under this Contract.

6 Specific Technical Requirements and Conditions

The Supplier shall perform the scope of the works indicated in Section 3, by fulfilling the following specific technical requirements:

6.1 IO Concept Design

A simple concept model of the Test Rig outlining its basic form, key interfaces and general concept has been produced by IO [7]. This shall form the basis of the machine design. IO shall make available all CAD information relating to this design to the tenderer on request. It should be noted that this is a concept design and only the bare requirements are indicated. Some general views of the model and drawings of the interfaces are presented in Appendix A.

The design of the seal Carrier-Spacer device and the assembly aids used to position the seal during installation are an integral part of the seal system. This is the subject of a separate IO procurement package [8]. The interfaces for this and the seal are defined in section 7.1. The tender shall review these interfaces and confirm that integration into their design is without any difficulty or open issues.

The overall objective of this work is to provide a testing system that shall allow the assessment of seals for the final end use: sealing the VF and the PF on the machine. The Test Rig Flanges provide a one-to-one replication of the VF to PF interface.

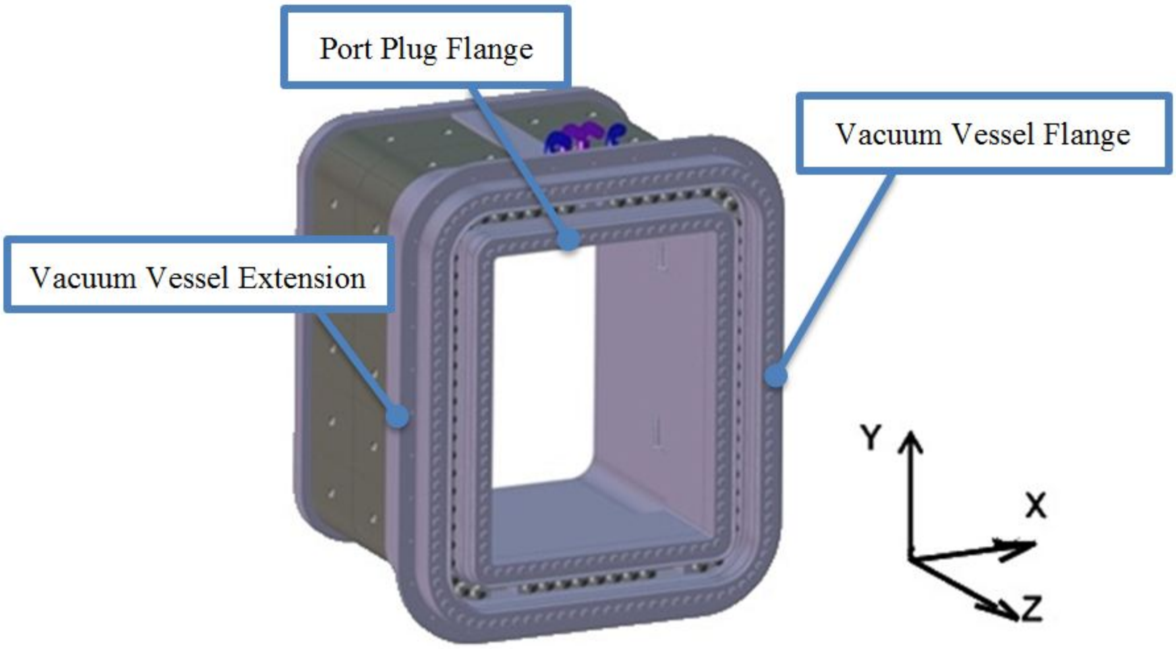


Figure 3 VV to PF Interface Coordinates – Port Plug Removed for Clarity

6.2 Safety

In the design phase the Test Rig shall be subject to a formal safety review using the IO methodology [9]. This shall include all aspects of the design including stability and hazards presented to personnel using the Rig [10]. In particular as the Test Rig shall be supplied for use in Europe then the requirements for CE marking shall be met along with the essential safety requirements for machinery and test equipment. This shall be completed prior to the initial design review and be presented as part of that review. The IO comments made shall be implemented in the final design and presented at that review.

6.3 Electrical Safety

All electrical equipment shall be fully compliant with Directive 2006/95/EC – Commonly known as the Low Voltage Directive [11]. In addition protection shall be to IEC 60529 IP2 or better. The CoC provided shall state this.

The design reviews and FAT shall be used to verify compliance with the above directive.

6.4 Mechanical Safety

The Test Rig shall comply with all requirements of the Machinery Directive [12]. Particular attention shall be paid to providing adequate guarding [13].

To comply with the requirements of Machinery Directive:

1) The Test Rig shall comply with the EHSRs (Essential Health and Safety Requirements) of the Directive.
2) The Test Rig shall have been assessed as complying with the EHSRs.

3) There shall be a Declaration of Conformity.
4) The supplier shall assemble a Technical File and submit this as part of 9.5.
5) The supplier shall provide the information necessary to operate the machinery safely, such as instructions and training in operation.
6) The supplier shall have followed one of the prescribed conformity assessment procedures.
7) The machine shall carry a CE mark.
8) The machine shall 'in fact' be safe.

The design reviews and FAT shall be used to verify compliance with the above directive.

6.5 Manufacturing

The manufacturing of this Test Rig shall be performed in accordance with the Manufacturing and Inspection Plan to be proposed by the Supplier and accepted by the IO TRO in advance.

Welding of the Outer Flange, Inner Flange or Back Plate from smaller component pieces is permitted. This is planned for the mating flange of the Vacuum Vessel Port Extension where this component will be manufactured from eight forgings welded to form a rectangular ring from which the final flange is machined, (Out of the Scope of this supply). No welding is permitted for the TBM Flange, this shall be made from a single plate.

If any welding is proposed to be used in construction of a component having a sealing surface such as the Outer Flange, Inner Flange and Back Plate, and that the weld crosses or impinges on the said sealing surface then the weld shall conform to the welding requirements of the ITER Vacuum Handbook [2] Attachment 1. The testing of such a weld shall be considered a hold point in manufacture.

IO shall reserve the right to reject the weld if it does not comply with the requirements of the vacuum handbook [2] and when finally machined to the finished dimensions it shall meet the surface finish requirement for the seal defined in 6.8 below.

Structural Steel Welds for the Support Frame and other non-vacuum components shall be made using best practise welds to EN 1993 Eurocode 3 Design of Steel Structures or other recognised structural steel design code.

6.6 Documentation for Welding

If for the flange seal surface any welding is planned then this would be a hold point and shall comply with the requirement of the ITER Vacuum Handbook [2] attachment 1 [14]. The weld or welds shall be properly documented and this documentation supplied to IO.

6.7 Construction Materials

The construction materials for the Flanges and Back Plate shall be Stainless Steel grade 304L [15]. The normal requirement in the ITER Vacuum Handbook for cross forged flange material is waived. The material of the Flanges and Back Plate may be made from plate only if the major rolling direction is parallel to the seal surface, see Figure 4. This requirement is due to the possibility of inclusion stratification causing long leak paths.

The M33 x 3.5 Pitch bolts used to clamp the flanges shall be of the material grade INCONEL Alloy 718 in the solution annealed and aged condition [16]. They shall conform to the dimensions in drg 036981 Sheet 03[17].

The M52 x 5 Pitch bushings used to house these M33 bolts shall be of the material SS660 [18]. They shall conform to the dimensions in drg 036981 Sheet 03[17].

The TBM Bolts, 80 off M27 x 3 Pitch drg 036981 Sheet 05 [17] shall be of INCONEL Alloy 718 in the solution annealed and aged condition [16]. These bolts use a smaller M45 x 4.5 Pitch S660 Bush that shall conform to the dimension in drg 036981 Sheet 05[17].

6.7.1 *Alternative Materials*

The Rig will be testing alternative materials for the bolts and bushes. For the early stages of the test program there is a requirement to substitute materials. For the bolts in Inconel alloy 718 an alternative material shall also be offered in Stainless Steel Grade A2-80. For the Bushes in Stainless Steel Alloy S660 an alternative material shall also be offered in S304.

For other materials used in construction there are no restrictions. The Supplier is free to use any appropriate materials they see fit for the construction. In the design these materials and their finishes shall be specified at the initial design review stage.

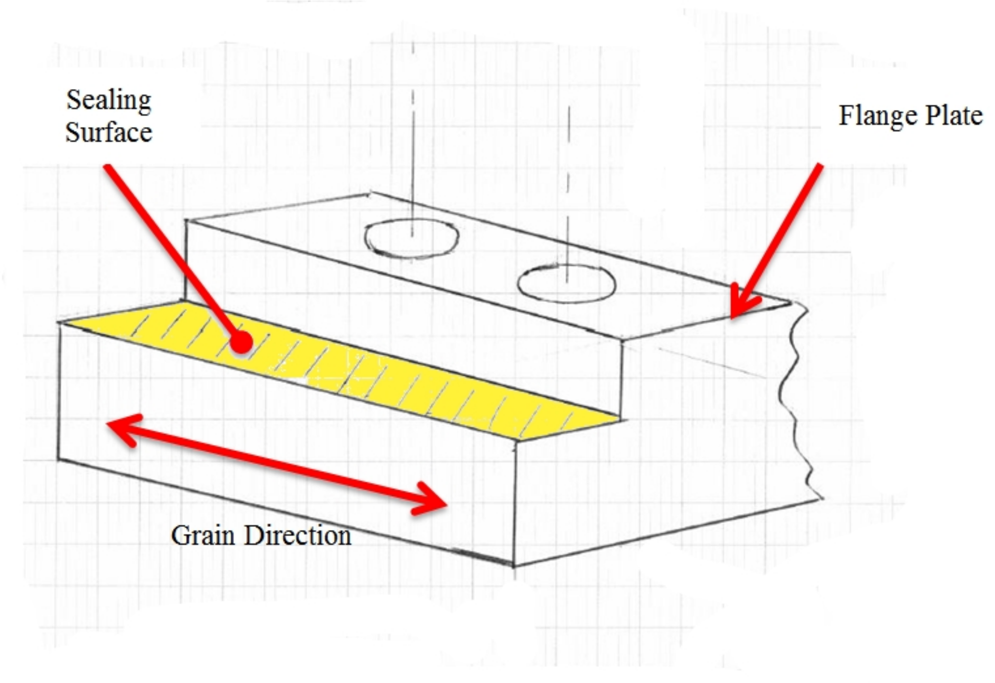


Figure 4 Material Grain Orientation Defintion

6.8 Specific Requirements for the Seal Interface Surface

The interface of the seal with the Test Rig is important to the functioning of the seal test. The Back Plate and the mating flanges of the Test Rig are a one-to-one replication of the functional surfaces on the machine. The surface finish requirements are as follows:

Table 3 Surface Finish Requirements for Seal Mating Surfaces

Surface (see Figure 5 and detail 6 drg 039681)	Surface Roughness Max. / Min. ISO 4287 [µm Ra]	Machining Lay	Flatness Requirement	
			Along Seal Major Axis	Normal to Seal Major Axis
Front Flange Outer Surface A	1.0 / 0.4 Target 0.8 Minimum roughness shall be exceeded.	Parallel to Seal direction axis[//] over the whole seal area including an extra margin of 5 mm on each side. No cross scratching permitted.	0.4/1000	0.5/100
Front Flange Inner Surface A				
TBM Flange Surface A				
Backing Plate Surfaces B		No Specific Requirement.		
General Finish all other surfaces	12.7 / 6.4	No restrictions	2/1000	2/1000

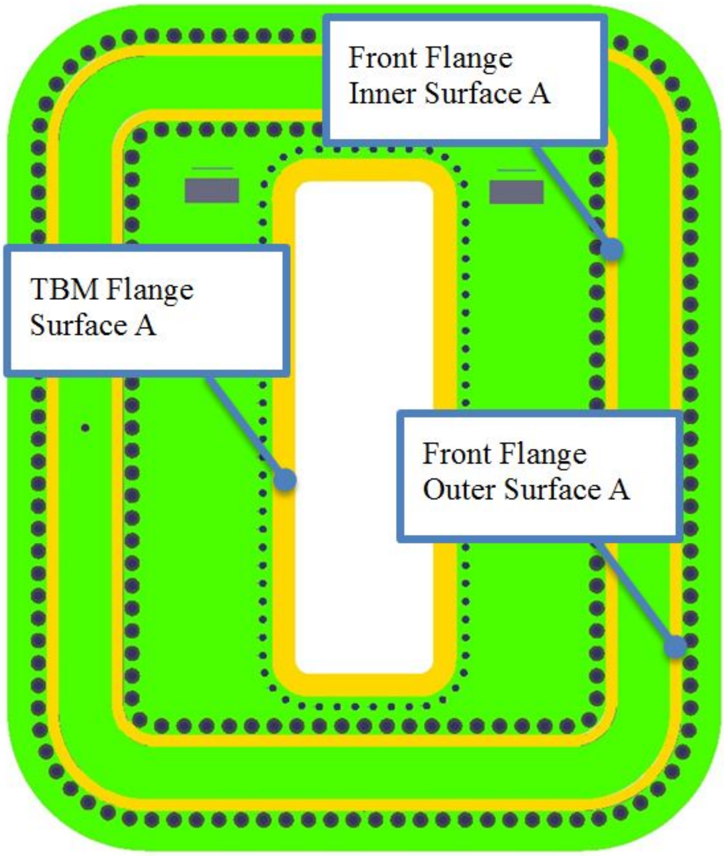


Figure 5 Back Plate Critical Vacuum Seal Surfaces A – Marked in Yellow on Front View of Back Plate. Green =Surface B

6.9 Test Assembly and Commissioning Seal

The Supplier shall use a suitable elastomer seal when testing the Test Rig. IO can provide details of such a seal [19].

6.10 Vacuum Pumping of the Test Rig

The estimated value of the evacuated volume between each of the seals under test is approximately 4000 cm^3 and an ultimate pressure of <0.1 Pa is required. This small volume may be pumped directly with a leak detector. This is the IO preferred method and in the MIP the supplier shall state the method, expected sensitivity, model and type of leak detector to be used for the FAT.

6.11 Leak Testing

As the Test Rig's function is to test the suitability of the seal system then its own leak tightness is of paramount importance. The assembly shall be leak tight to better than $1x10^{-10}$ $Pa.m^3.s^{-1}$ to ensure that the leak rate of the seal can be established. To this end, the leak tightness of the Test Rig shall be tested to the VQC1A leak rate requirement [2].

A number of Ø10 leak testing holes are provided in the flanges. Each of these shall be furnished with a welded tube terminated in a Swagelok male VCR fitting [20] Figure 6.

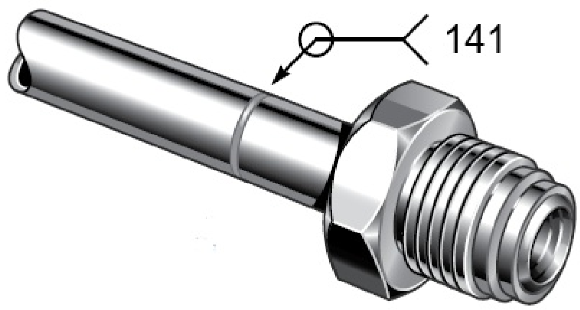


Figure 6 Swagelok Male ¼" VCR

6.12 Heating System

Initial calculation on the mass of the concept designed flanges shows the approximate need of 17 kW heating load. The power density calculation shows that this is less than 2 W.cm^{-3} so this could be achieved by a number of radiative heaters, mounted facing the flanges and backing plate within an insulated enclosure. See section 14 for the calculations using masses from the concept design. The Supplier shall provide a detailed calculation sheet of the masses and allowances for losses in their design proposal at the initial design review.

The chosen set temperature shall be adjustable between 50 ºC and 240 ºC. When at the chosen set temperature the variation of temperature from top to bottom of the test rig shall be maintained to be better than ± 10 ºC of the chosen set temperature. During heat up to the chosen set temperature the ramp rate shall be adjustable in the range of 5 ºC/hr to 30 ºC/hr and controlled to better than ± 1 ºC/hr.

Over temperature protection shall be incorporated into the control system to protect the test rig and its environment. It shall be fail-safe in design.

The outside temperature of the insulated covers shall be less than 60 ºC otherwise guarding shall be put in place to prevent operators being exposed to direct contract with the covers or other hot components of the rig.

6.13 Lifting and Guidance of the Flanges

The lifting system shall have the capability and capacity to lift from a horizontal orientation either the TBM flange or both Inner and Outer Flanges at the same time if coupled with a bellows to the vertical orientation required by the sealing flange alignment.

The design shall incorporate features that allow the good guidance of the flange to the back plate. The metallic seal is sensitive to transverse shear and shall be assembled parallel to the mating flanges. In this sense, the final approach of the flange to the back plate over the last 20 mm of travel shall be parallel within 0.5 mm and controlled to a rate of between 10 mm and 30 mm per minute. This may be achieved by either electro-mechanical means or by a hand feed system. There shall be a kinematic guide built in to both the outer and inner flange to allow either system. The concept of using a cylinder-in-vee combination with a flat-on-flat is shown in detail 2 and 3 on drg 036981 Sheet 03[17]. It is important at that the guidance system allows this parallelism to be maintained and no binding or crabbing during closure or opening shall be accepted.

There shall be adequate space between the back plate and the flange to allow seal installation, at a minimum this shall be 1.5 m. This shall allow installation of the Outer Flange, Inner Flange or both Inner and Outer flanges if connected by a bellows assembly. To allow easier integration and mounting of the seal, the facility to rotate a flange in 90 degree increments about the vertical axis shall be provided. During the time the machine is open there shall be a method of locking the machine to prevent inadvertent closure or movement of the flanges.

The supply of the TMB flanges is within the scope of this technical specification and provision shall be made to use the same system in a position suitable for the TBM flange in the same manner as the device used to guide the inner flange.

6.14 Flange Weld Leg

For the both Inner Flange and Outer Flange a Weld Leg shall be provide 20 mm in length to allow future machining of the weld preparation for the metal bellows assembly. This weld leg is shown in the drg 036981 Sheet 05 Section Cut A-A [17]. Any required bevel or weld prep will be advised at a suitable point in the contract.

6.15 Inner Flange Actuations System

In the future configuration of the system when a bellows is used to connect the Inner and Outer Flanges, the Inner Flange shall be able to be moved relative to the Back Plate. This is to allow a test of the Metallic Multi–Ply Bellow’s ability to accommodate movement in a future test campaign.

The specification of the actuators, their design and provision for their mounting to the back plate shall be made. The actuators shall utilise at least four of the M52 bush locations for the Inner Flange. Provision for at least this number of actuators shall be made in the corner areas.

The anticipated spring rate for the bellows is 3 000 N/mm. The actuator design should allow for up to 20 mm of travel in the Z direction, see Figure 3. The mounting design shall provide a bearing element such as a spherical bearing to allow the small angular displacement during the actuation of the flange of the range of its movement.

The actuator control system shall allow:

1. Independent controlled movement of all four actuators.
2. Simultaneous motion of the any of the actuators.
3. Repeated cycling of the pre-programmed motion shall be possible between set limits up to the range of motion.
4. Provide adequate power to overcome the spring of the bellows.
5. Provide adequate support of the inner flange over the range of motion.
6. Provide feedback on the number of cycles and amount of travel made by each actuator.

6.16 Bolt Loading Measurement

A number of devices shall be provided to measure the bolt load on the flanges. These shall cover both the M27 and M33 bolt systems. The method shall be to use a loading washer such as [21]. IO would consider alternative manufactures of loading washers if suggested. The capability of eight simultaneous independent bolt load measurements in any location is required. The provision to record the bolt loads shall be provided.

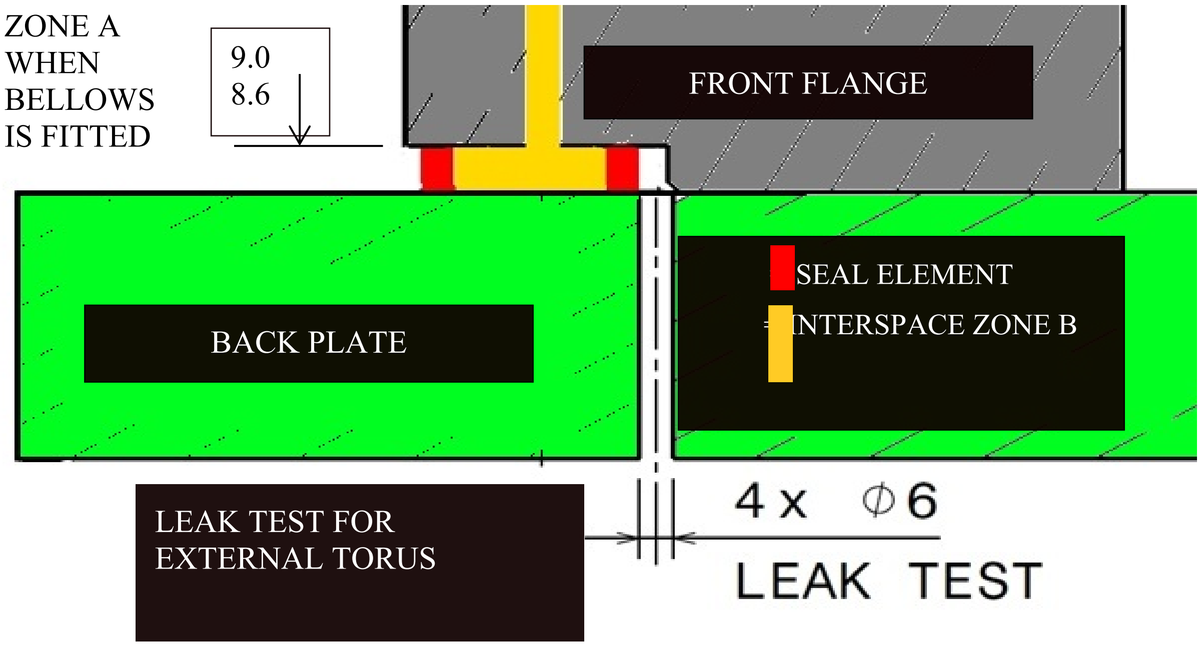


Figure 7 Seal Element Location & Interspace Region

Mode	Temperature	Pressure Deferential Zone A to Zone B. [kPa]	Frequency	Expected Duration during testing.
Storage, Installation, Assembly, initial testing.	Ambient (12 °C to 35 °C)	Nil	Open	Open
Operational Simulation.	80 °C – 100 °C	100	500	8 – 168 hrs
Bake-out Simulation.	240 °C Max	100	100	8 – 168 hrs

Table 4 Test Rig Operational Temperatures and Pressures

6.17 Seal Assembly Aids

An assembly aid for each seal will exist. IO shall provide a dimensioned drawing of the seal assembly aid at a suitable point in the contract. This aid shall hold the seal in a vertical orientation to allow mounting to the face flange. The overall dimensions for the seal are shown in Figure 8 and Table 5 below.

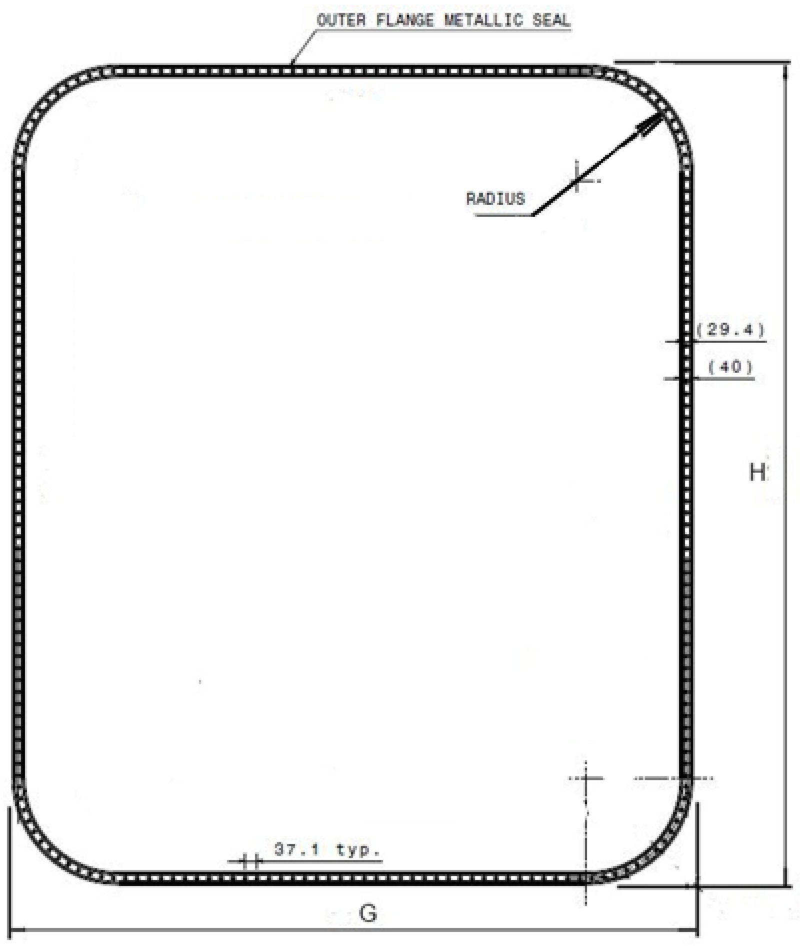


Figure 8 Seal Dimensions Sketch – Adapted from Drg 036981[17]

Name / Identification	Breadth ±2 [G]	Height ±2 [H]	Overall Width ±1	Inside Radius ±2
Inner Flange Seal	1684	2121	40	113
Outer Flange Seal	2112	2549	40	292
TBM Seal	617	1793	36	95

Table 5 General Seal Dimensions [mm] (For Information Only)

6.18 Cleaning of the Back Plate and Flanges to Vacuum Standards

The Inner Flange, Outer Flange and Back Plate Test Rig parts are UHV components. The cleaning process shall comply with the requirements of the ITER Vacuum Handbook [2] section 24. The condition of the mating surfaces are paramount to the successful operation of the Test Rig and shall conform to the parameters detailed in [2] after any cleaning operation. It is re-emphasised that any cross scratching of these seal surface shall not be permitted.

During cleaning, particular attention shall be given to the removal of any weld spatter, debris and other foreign matter. Final cleaning shall ensure effective cleaning without damage or change to the surface finish and material properties. The Supplier shall submit to the IO the proposed cleaning procedure for approval and acceptance as part of the quality plan.

6.19 FAT (Factory Acceptance Test)

Prior to shipment, the Supplier shall perform FAT (Factory Acceptance Test), which shall include the following tests**:**

1. Document Review – Documents shall be supplied to the IO RO three weeks prior to the FAT.
2. Compliance with the Machinery Directive check.
3. Compliance with Low Voltage Directive check.
4. Key Dimensions check.
5. Welding Reports and Radiography check.
6. Surface roughness reports and measurement check.
7. Visual Inspection of Seal Surface.
8. Visual Inspection of Test Seal.
9. Machine Guarding Inspection and Verification.
10. Kinematic Guide Inspection and Verifications of Movement.
11. Examination of the Lifting System and certification.
12. Examination of the Load Washer system and recording method.
13. Witness flange bolt up with Test Seal.
14. Compliance to Vacuum Handbook check.
15. Witness Pump down of TBM Flange, Inner Flange & Outer Flange.
16. Witness of Leak Tightness of the Rig to VQC1 Leak Rate.
17. Heating System check.
18. Operation Temperature Soak Test.
19. Bake out check.
20. Cool Down and disassembly of flange check.
21. Inspection of Packing and Transport Cases.

6.20 Equipment Marking

All components and the main subcomponents shall be clearly marked in a permanent way and in a visible place with the IO official numbering system according to the document "ITER Numbering System for Components and Parts" [22]. A detailed 'IO component identification standard' together with printed label templates and RFID tagging standards will be provided by IO.

6.21 Handling, Storage, Packing & Shipping

Following the Factory Acceptance Test, the UHV components shall be packed to the requirements of the vacuum hand book [2] section 24 to preserve their clean status.

The Supplier shall design and supply appropriate packaging, adequate to prevent damage during shipping, lifting and handling operations. The packaging shall be easily removable without causing damage or contamination to the component vacuum sealing surfaces. Where appropriate, accelerometers or other sensors shall be fitted to ensure that limits have not been exceeded. When accelerometers are used, they shall be fixed onto each box and shall be capable of recording the acceleration along three mutually perpendicular directions. Shock absorbing material shall be used.

For the vacuum facing elements of the system, handling, storage, packing and shipping is to conform to the ITER Vacuum Handbook [2] Section 24. Other Test Rig components can be shipped with normal engineering best practice in packaging to preserve their condition and prevent damage during shipping.

Subject to the prior acceptance by the IO, the Test Rig may be disassembled for transportation and shipping. If this is the case then the re-assembly and re-commissioning of the Rig shall be the responsibility of the Supplier.

The Supplier shall be responsible for the installation of the Test Rig on site ensuring that it meets the requirements of the FAT once shipped to and installed at IO. IO will recheck all elements of the FAT once the rig is installed at IO.

The final on-site location of the Test Rig has yet to be defined. The Supplier shall consider the following as the tentative address of the location.

ITER Organization

Route de Vinon-sur-Verdon - CS 90 046

13067 St Paul Lez Durance Cedex

France

6.22 Access Arrangements and Resources for Re-Erection of the Test Rig

The general layout of the final location will be provided at an early stage in the Contract. It should be assumed that the location for the rig will have clear and level access. The dimensions of laboratory are approximately 12 m x 12 m with a 5 m ceiling height. The doorway is 4 m in width and 4.5 m in height. The laboratory has a crane capacity limit of 3 tonnes. Any items that need to be assembled shall be less than this weight including any lifting aids and rigging. The proposed assembly of the rig will be assessed during the initial design review.

7 Technical Interfaces

7.1 Interface with the Seal

The seal interfaces with the following component parts and surfaces:

1. The Back Plate – simulating the Vacuum Vessel port extension flange
2. The Front Flange - simulating either:
    a. The Vacuum Vessel Port Extension Outer Flange, (the Outer Flange).
    b. The Port Plug Inner Flange, (the Inner Flange).
    c. The TBM Flange.

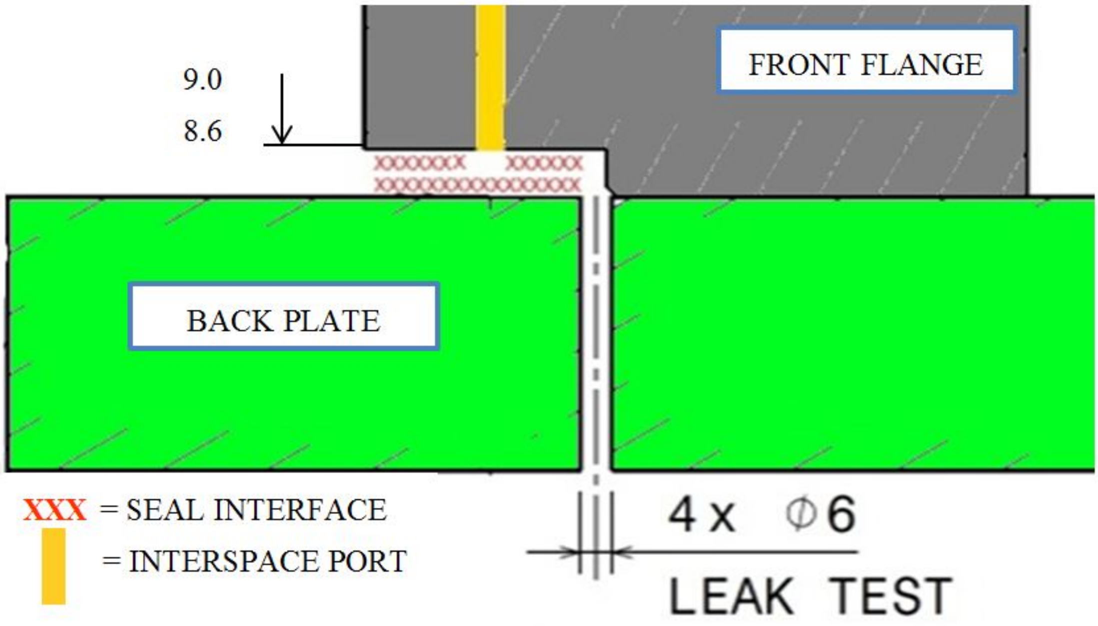


Figure 9 Seal Interface with mating flange

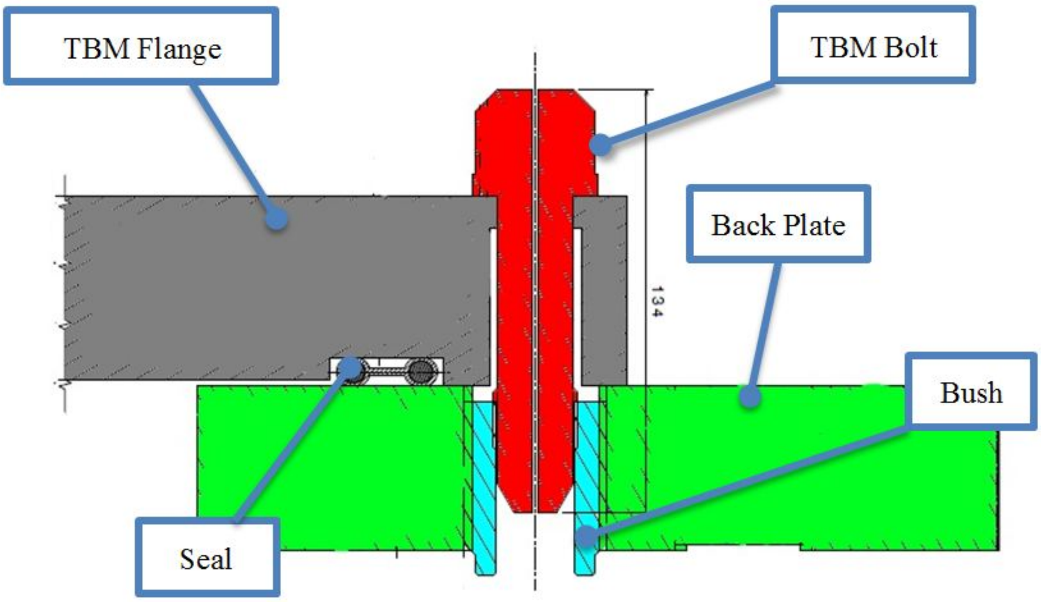


Figure 10 Seal Interface with TBM Flange

7.2 Interface with Seal Assembly Aid

The assembly aid interfaces with:

1. The seal, both sizes for Inner Seal and Outer Seal.
2. The Test Rig lifting device. The interface for this is defined in Table 6 Lifting Interfaces and Figure 11.

Total Assembly Mass including seal and assembly aid	Eye Bolt Threaded Connection EN ISO 3266 [23]	Number
Up to 200kg	M8	2
>200kg < 320kg	M10	2

Table 6 Lifting Interfaces

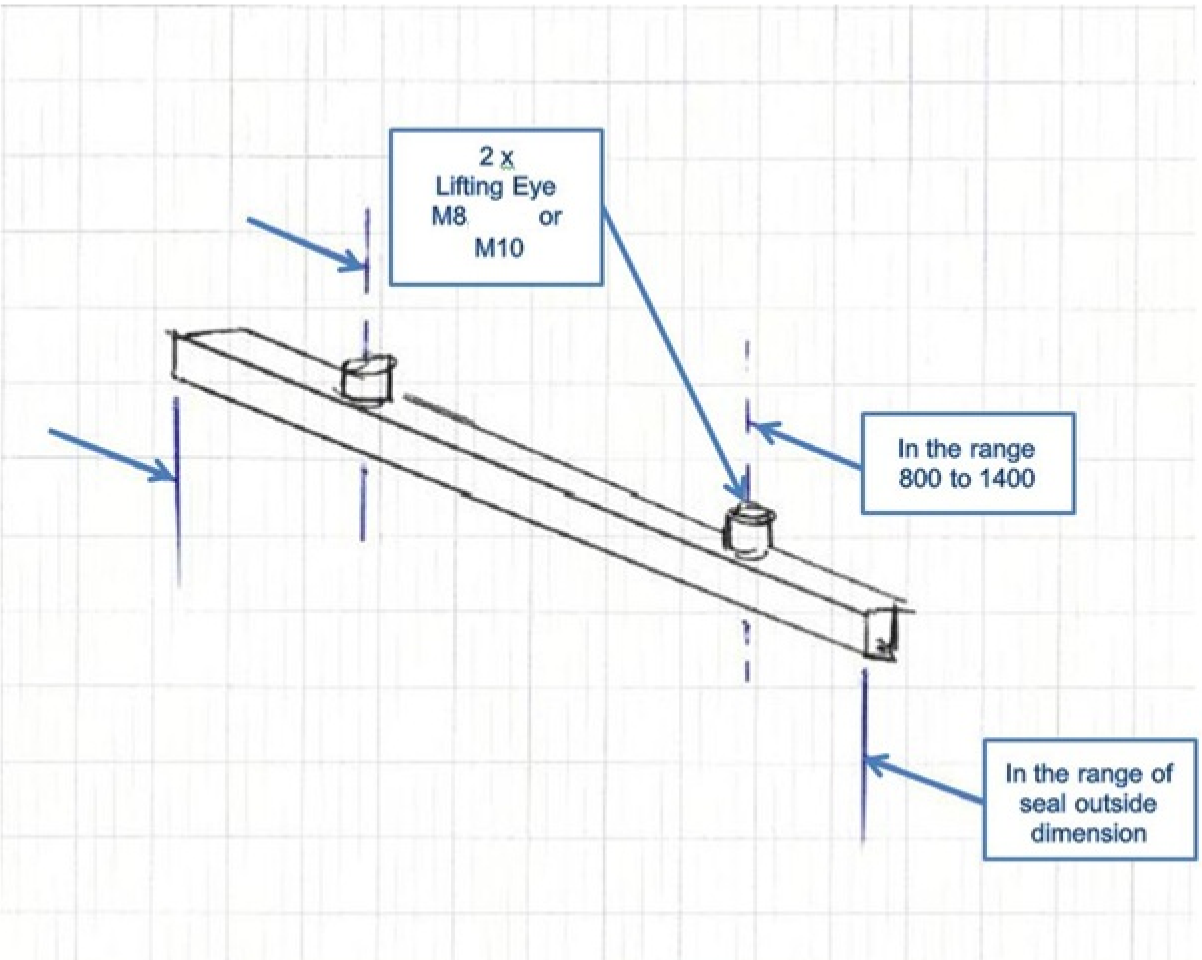


Figure 11 Interface to Lifting Device

8 Estimated Duration

The work shall be completed within 12 months after the date of the Contract signed by both Parties.

9 Deliverables, Milestones, Hold Points and Due Dates

The Supplier shall follow the subsequent due dates below:

D =: Deliverables to be submitted by the Supplier.

M =: Milestone to be initiated or completed by the Supplier, and or the IO as appropriate.

Phase	No	Description	Due Date (weeks)
Phase 1: The detailed design of the Test Rig from the IO concept	M1	Commencement of the Contract after signatures by both Parties	T0
	M2	Kick-off meeting by both Parties	T0 + 1
	D1	Minutes of Kick-off meeting	T0 + 2
	D2	Schedule Programme	T0 + 3
	D3	Final Quality Plan	T0 + 3
	D4	Draft Manufacturing and Inspection Plan & Technical Drawings.	T0 + 3
	D5	Monthly Reporting	Monthly
	M3	IO Approval on D1, D2, D3, D4 & D5 (Hold Point: T1)	T0 + 5 **(=T1 date)**
	D6	Safety Review	T1 + 1
	D7	Design Risk Assessment	T1 + 1
	M4	IO Approval of Safety Review D6 & Design Risk Assessment D7.	T1 + 2
	D8	Initial Design Review Close-out Report.	T1 + 5
	M5	IO Approval on Initial Design D8 (Hold Point: T2)	T1 + 6 **(=T2 date)**
	D9	Final Detail Design Review Close-out Report.	T2 + 12
	D10	Final Manufacturing and Inspection Plan	T2 + 12
	M6	IO Approval on D9 & D10 (Hold Point: T3)	T2 + 15 **(=T3 date)**
Phase 2: The manufacture and supply of the Test Rig and all ancillary items	M7	Commencement of Manufacture by the Supplier	T3 + 0
	M8	IO Supervision visits (Hold Points)	As stipulated in the MIP
	M9	Completion of Assembly at the Supplier premises	T3 + 13
	D11	All the test reports and certificate to satisfy	T3 + 13

Phase	No	Description	Due Date (weeks)
		FAT	
	D12	FAT	T3 + 16
	M10	IO acceptance on D11 & D12 (Hold Point: T4)	T3 + 16 **(=T4 date)**
Phase 3: Delivery to IO of the Test Rig	D13	Delivery of the Rig, a Delivery Report, and all other required documentation to the IO	T4 + 3
Phase 4: Installation on site including any post-delivery assembly, commissioning and training of IO staff.	M11	Completion of reassembly by the Supplier	T4 + 5
	M12	Completion of recommissioning by the Supplier	T4 + 10
	D14	Training of the IO staff(s) at the IO	T4 + 10
Phase 5: Handover of the Test Rig.	D15	Test Rig Handover	T4 + 10
	M13	IO Final Acceptance of D13, D14 & D15	T4 + 12

Figure 12 Deliverables and Milestone Due Dates

The deliverables shall be prepared in accordance with the following requirements:

Deliverables	Requirements/Descriptions
D1: Minutes of Kick-off meeting	A kick off meeting shall be arranged to discuss the programme of work and to ensure that all the relevant input data has been provided. This shall be at the Suppliers' manufacturing premises and shall include an inspection of the workshop and facilities used for the construction of the test Rig. This shall be arranged as soon as possible after contract. The minutes shall specify the date, place, participants, agenda, discussion points, agreement, and any other pending items.
D2 Schedule Programme	A schedule programme to indicate the dates and duration of all the activities, phases, milestone and deliverable submission, by taking account of actual dates following contract award.

Deliverables	Requirements/Descriptions
D3: Final Quality Plan	A Final Quality Plan (QP) shall be provided for IO approval in accordance with the Quality Assurance requirements provided in Section 12. Including: • Cleaning Procedure. • Vacuum Leak Testing Procedure. • Weld Test Procedure. • Surface Roughness Test Procedure for Seal Surfaces. • Leak Test Procedure. • Dimensional Measurement Procedure. And the process and methodologies with regards to the Supplier's Design Review Procedure.
D4: Draft Manufacturing and Inspection Plan & Technical Drawings.	A draft Manufacturing and Inspection Plan for approval by IO in accordance with the Quality Assurance requirements provided in Section 12. The Suppler shall also provide IO with a technical drawing of the test Rig and its major components. The drawing shall detail the key dimensions of each component with enough information so that IO can assess the design suitability. Of particular importance are the interfaces between the seal and mating flanges. A bill of proposed materials and those processes used in manufacture shall be supplied at this stage. IO shall review these proposed materials and process.
D5: Reporting	Monthly progress reports that confirm the status of work completed against the approved schedule and in accordance with the agreed QP. These reports shall be provided by the Supplier on the last Friday of each month to the IO RO by email throughout the course of the contract up until final acceptance by IO.
D6: Safety Review	A Safety Review will be conducted to check the conformance of the design to this technical specification with specific regard to the Machinery Directive, Low Voltage Directive and the general safety of the machine. The supplier shall provide are report detailing the Safety Review.
D7: Design Risk Assessment	Design Risk Assessment, including safety analysis of the design shall be provided for IO's Approval.

Deliverables	Requirements/Descriptions
D8: Initial Design Review Close-out report	Design Review Close-out Report A Review will be held between the IO and the Supplier. The supplier shall provide supporting documentation to allow the full review of: 1. Safety of the Machine. 2. How this Functional Specification is met by the design. 3. Design Calculation Review. 4. Manufacturing Plan. 5. IO Vacuum Requirements and how these are met. 6. Commissioning Plan. 7. FAT Plan. 8. Shipping Plan. 9. Reassembly Plan. 10. Recommissioning and Handover Plan. All relevant documents shall be provided by the supplier 3 weeks prior.
D9: Final Design Close-out Report	Final Design Review Close-out Report. A Final Design Review of the Test Rig shall validate the points of the Initial Design Review and include a Manufacturing and Inspection Plan which shall incorporate any comments by IO for final approval. All relevant documents shall be provided by the supplier 3 weeks prior including Technical Drawings. The approved MIP shall be in place prior to commencement of any manufacturing.
D10: Final Manufacturing and Inspection Plan	The supplier shall update D4 incorporating all comments and amendments as per Section 12.
D11: FAT Documentation	The Supplier shall deliver all relevant documentation for the FAT three weeks prior the FAT date.
D12: FAT test reports and certificate(s)	A FAT of the Test Rig shall be performed at the supplier's premises to ensure that all functional requirements of this specification have been met. This will include checking for compliance with the ITER Vacuum Handbook requirements and conformity with Machinery and Low Voltage Directives. The requirements in Section 6.19 shall be met. The Supplier shall submit the required test reports and certificate for the IO's approval

Deliverables	Requirements/Descriptions
D13: Delivery to the IO of the Rig and Delivery Report, and any other required documentations	The Test Rig shall be delivered to the IO, together with a Delivery Report to be prepared by the Supplier, stating: 1. The IO Contract Number. 2. The Item drawing numbers. 3. Quantity. 4. CoC stating compliance with the EU Machinery Directive & EU Low Voltage Directive. 5. Inspection Results. 6. Assembly Instructions. 7. Instructions for use and maintenance.
D14: Training of the IO staff(s) at the IO	Training will consist of : 1. The safe operation of all the systems. 2. Maintenance of the systems. 3. Specific procedures for mounting and demounting a flange.
D15: Test Rig Handover	The required deliverables and due dates are summarised in Table 7 Deliverable Due Dates.

Table 7 Deliverable Due Dates

9.1 QA Documentation

The supplier shall supply a document as part of the Quality Plan proposing the following in detail:

1) Weld test procedure (6.2).
2) Surface roughness test procedure for the seal surfaces (6.6).
3) Leak Test Procedure (6.10).
4) The Vacuum Standard Cleaning Methods (6.18).
5) Dimensional Measurement Procedure.
6) Supplier's Design Review Procedure.

9.2 Drawings

The Supplier shall supply a complete set of two-dimensional detailed engineering drawings as documentation of the engineering design of the Test Rig assembly and of all the sub-components. The drawing shall include a BOM for all parts in the assemblies.

This drawing package shall include 3 paper copy sets of drawings produced from the original CAD format. Drawings shall also be provided as electronic copies in Adobe™ pdf format. All technical drawings shall clearly state the scale and the orthogonal projection used, i.e. First Angle or Third Angle projection. If a 3D CAD model is used, then a 3D model shall also be provided in ISO 10303 STEP format. IO operates CATIA as its 3D CAD system, compatible files are acceptable in addition to the STEP Files.

9.3 Inspection and Dimensional Reports

The Supplier shall supply a full inspection report for each item shipped including all materials test certification, any instructions for use and user manuals.

9.4 Design Calculations

All design calculations such as stress analysis, thermal analysis; etc. shall be documented and supplied. These documents shall reference the appropriate drawings. IO requires full disclosure of any FEA analyses used in the design.

9.5 Documentation for Operation and Maintenance of the System

The Supplier shall provide instructions for installation, operation, maintenance, decommissioning and disposal. The entire machinery file as defined in the Machinery Directive shall be supplied. These shall detail any specific issues to be aware of when the Test Rig is in use together with any associated resolution where appropriate.

The official language of the ITER project is English. Therefore, all input and output documentation relevant for this work shall be in English. The successful tenderer shall ensure that all members of staff involved in carrying out this work have a good standard of English both written and verbal in order to facilitate effective communication and to adequately draft all required technical documentation.

10 Acceptance Criteria

The Contractor shall submit the deliverables in Section 9 within the time specified therein. All the deliverables shall satisfy the technical requirements indicated in Table 7 above and any other relevant clause(s) in this Technical Specifications.

The IO shall review the deliverables and provide the written acceptance within 12 working days or provide comments for improvement. In the latter case, the Contractor shall make all the necessary modifications or iterations to the deliverables and submit a revised version.

10.1 Work Monitoring

Work monitoring shall be by face-to-face meeting, video conference, telephone calls and emailed Supplier monthly progress reports. The Supplier shall email the monthly report by close of business on the last Friday of the relevant month.

Meetings envisaged are

1. KOM at the Supplier's premises.
2. Initial Design Review.
3. Final Design Review.
4. Telephone calls to follow up progress detailed in the monthly report.
5. Surveillance Visits required by any Hold Points & MIP.
6. FAT prior to dispatch.
7. Project Close Out meeting at IO.

10.2 Monthly Progress Reports

The monthly report shall contain as a minimum the following items.

1. A cover page showing compliance with the supplier QA procedure for reporting.
2. The relevant date and date range being reported on.
3. Progress against deliverables in Table 7.
4. Progress against the agreed schedule outlining completed activity.
5. Known or anticipated delays including proposed remediation planned to maintain the agreed delivery schedule.
6. Detailed planned activities due in the next month.
7. Action status, stating Action Owner and due date for resolution or completion of the action.

It is anticipated that the report shall not be more than four A4 pages in length excluding any figures or cover pages.

10.3 Additional Requirements

Any weld inspection of a vacuum class weld is a Hold Point. IO approval is required to proceed.

11 Responsibilities

11.1 Responsibilities of IO

ITER Organisation is the Nuclear Operator and as such has the ultimate responsibility for the application of the INB Order [4] within the IO and in its chain of Suppliers.

IO shall appoint a Responsible Officer who represents the IO for all technical matters relating to this work.

IO shall make available all the necessary technical information required by the Supplier in order to perform the scope of work.

11.2 Responsibilities of the Supplier

The Supplier shall include with his response any intention to subcontract any parts of the work.

The Supplier shall ensure that the work is carried out by suitably qualified and experienced personnel.

The Supplier shall appoint a Responsible Officer who represents the Supplier for all matters related to this work and who will:

- Coordinate the planning and performance of the work including any work assigned to subcontractors.
- Maintain schedules and issue monthly progress reports.
- Verify that the quality systems are consistently followed during the performance of the contract.
- Assess and oversee quality in any subcontractors' premises

The Supplier shall be responsible for all aspects of the Seal Test Rig procurement which relate to the Supplier's scope of supply including any applicable national laws and export control restrictions.

12 Quality Assurance Requirement

12.1 Quality Management

The Supplier's Quality Assurance Programme (QAP) is subject to approval by the IO in accordance with the ITER QA Programme and shall be applied to all work carried out as a result of any contract arising from this specification.

The ITER QA Programme is based on IAEA Safety Standard GS-R-3 and on conventional QA principles and integrates the requirements of the French Order dated 7th February 2012 [3] on the quality of design, construction and operation of Licensed Nuclear Installations. For this purpose, the Supplier shall ensure that any subcontractors carrying out work placed under the prime contract comply with the QA requirements under the relevant QA classifications.

The general requirements are detailed in ITER Integrated Safety, Quality and Security Policy [24] and ITER Procurement Quality Requirements [25] and the specific requirements for the supervision of the supply chain for Protection Important Components, Structures, Systems and Activities is detailed in [26].

12.2 Quality Plan

Prior to commencement of the work, a Quality Plan [27] shall be submitted for IO approval giving evidence of the above and describing the organisation for this task; the qualification and experience of the workers involved including named individual(s) who shall act as Independent Reviewer(s) and Checkers(s) and any anticipated sub-contractors.

This Quality plan shall include the documents listed in 9.1 above.

12.3 Manufacturing and Inspection

Prior to the commencement of any manufacturing, a Manufacturing and Inspection Plan shall be approved by IO who shall mark up any planned interventions. An example summary plan is provided in [28]. Prior to the delivery of any manufactured items to the IO Site, a Release Note shall be signed in accordance with [29].

12.4 Protection Important Components and Activities

For the Protection Important Components, structures and systems, a specific management system shall be implemented by the Supplier and any subcontractor working on protective important activities, on the basis of activities defined and executed by the Supplier and Subcontractor.

This system could be included in the Manufacturing and Inspection Plan or the Quality Plan. This management system shall include the evaluation of Non Conformance Reports whether major or minor.

The use of computer software to perform a safety based task or activity such as analysis, and or modelling shall be reviewed and approved by the IO prior to its use, in accordance with [30].

12.5 Deviations and Non-Conformances

All deviations and non-conformities shall strictly follow the procedure detailed in ITER Requirements Regarding Contractors Deviations and Non Conformities [31].

A deviation is defined in the Order [4] as a non-compliance with a defined requirement or non-compliance with a requirement set by the licensee's integrated management system that could affect the provisions of the Environment Code. All deviations and non-conformities shall strictly follow the procedure detailed in ITER Requirements Regarding Contractors Deviations and Non Conformities [31].

The overriding principle is to ensure timely identification and review of deviations and non-conformances in order to determine the importance and to ensure appropriate corrective action is taken. The management of deviations and non-conformances and the analysis of trends is also part of the overall IO Project continuous improvement process.

12.6 Additional Surveillance Requirements

ITER Organisation is the Nuclear Operator and has the ultimate responsibility for the application of the INB Order [4] within the IO and in its chain of Suppliers. IO shall undertake additional surveillance for those components or activities which are classified as Protection Important as described in Section 2.2.

The Supplier shall therefore grant access to the IO and ASN representatives to its facilities and records and those of its subcontractors for the purposes of surveillance of defined requirements during the design, construction, manufacturing, commissioning, assembly, maintenance and surveillance of the Rig. This surveillance shall also include the examination of all protective important actions and follow-up and verification of any corrective actions which are to be implemented.

12.7 Documentation

All documentation related to the design, construction, manufacturing, assembly, and surveillance of the Test Rig shall be provided to the IO.

References

1 Large Seal Test Campaign Specification ITER_D_R85FLP v1.0

2 ITER Vacuum Handbook ITER_D_2EZ9UM v2.3

3 Decree No.2012-1248 dated 9 November 2012 authorising IO to create a licensed nuclear facility called "ITER" ITER_D_CZK7M5.

4 Order dated 7 February 2012 relating to the general technical regulations applicable to INB ITER_D_7M2YKF.

5 Environmental Code. Ordinance 2000/914 dated 18 September 2000. As amended. Available: http://www.legifrance.gouv.fr

6 ITER Abbreviations ITER_D_2MU6W5

7 IO Concept Model File ENOVIA Ref QR7Y6S

8 Technical Specification for the Metallic Seal ITER_D_R7G4UT

9 Design Review Procedure ITER_D_2832CF v3.2

10 Safety of machinery, General principles for design Risk assessment ISO 12100:2010

References Continued

11 DIRECTIVE 2006/95/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 12 December 2006 on the harmonisation of the laws of Member States relating to electrical equipment designed for use within certain voltage limits

12 DIRECTIVE 2006/42/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast).

13 British Standard Institute Published Document, PD 5304:2005.

14 ITER Vacuum Handbook - Attachment 1 Welding ITER_D_2FMM4B v1.2

15 Material Specification flanges and back plate 304L (EN Grade 1.4307)

16 Materials Specifications, INCONAL Alloy 718 (EN 10302: 2008. EN Grade 2.4668)

17 IO Concept drawing sheets ENOVIA Ref QRBSM5 DRG 036981

18 Material Specifications, SS660 (EN 10269:1999, EN Grade 1.4980)

19 Elastomer Seals and assembly aid for the ITER large seal test Rig ITER_D_R7ACHT

20 Swagelok Male VCR Part number Male Nut SS-4-VCR-4,

21 BoltSafe Sensor CMS Type www.boltsafe.com

22 ITER Numbering System for Components and Parts ITER_D_28QDBS

23 EN ISO 3266:2010 Forged steel eyebolts grade 4 for general lifting purposes.

24 ITER Integrated Safety, Quality and Security Policy ITER_D_43UJN7

25 ITER Procurement Quality Requirements ITER_D_22MFG4

26 ITER Overall Supervision Plan of External Interveners Chain for Protection Important Components, Structures and Systems and Protection Important Activities ITER_D_4EUQFL

27 ITER Project Management and Quality Program: Quality Plan ITER_D_22MFMW

28 ITER Requirements for Preparing and Implementing a Manufacturing and Inspection Plan ITER_D_22MDZD

29 ITER Requirements Regarding Contractors Release Notes ITER_D_22F52F

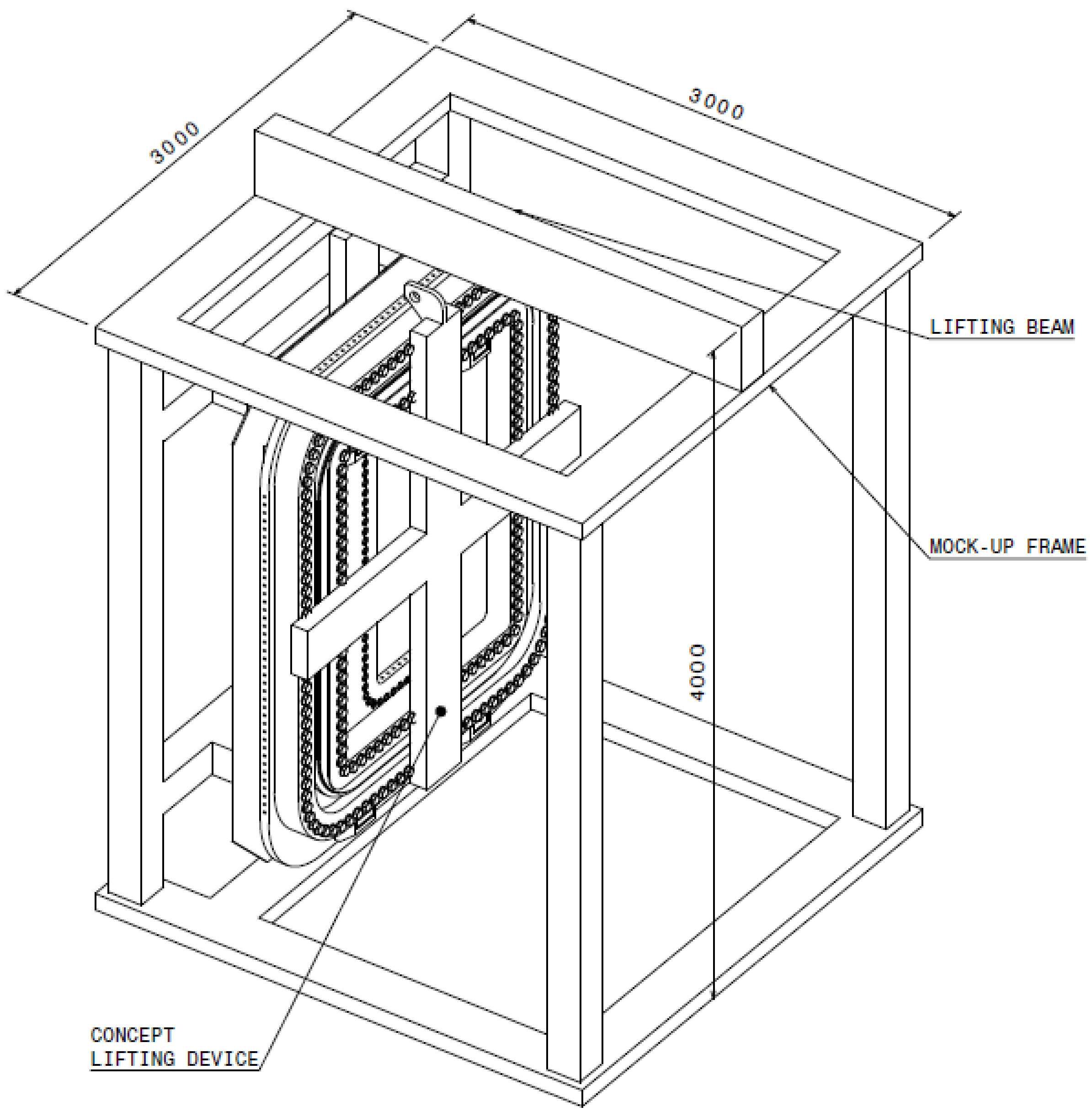
30 Quality Assurance for ITER Safety Codes ITER_D_258LKL

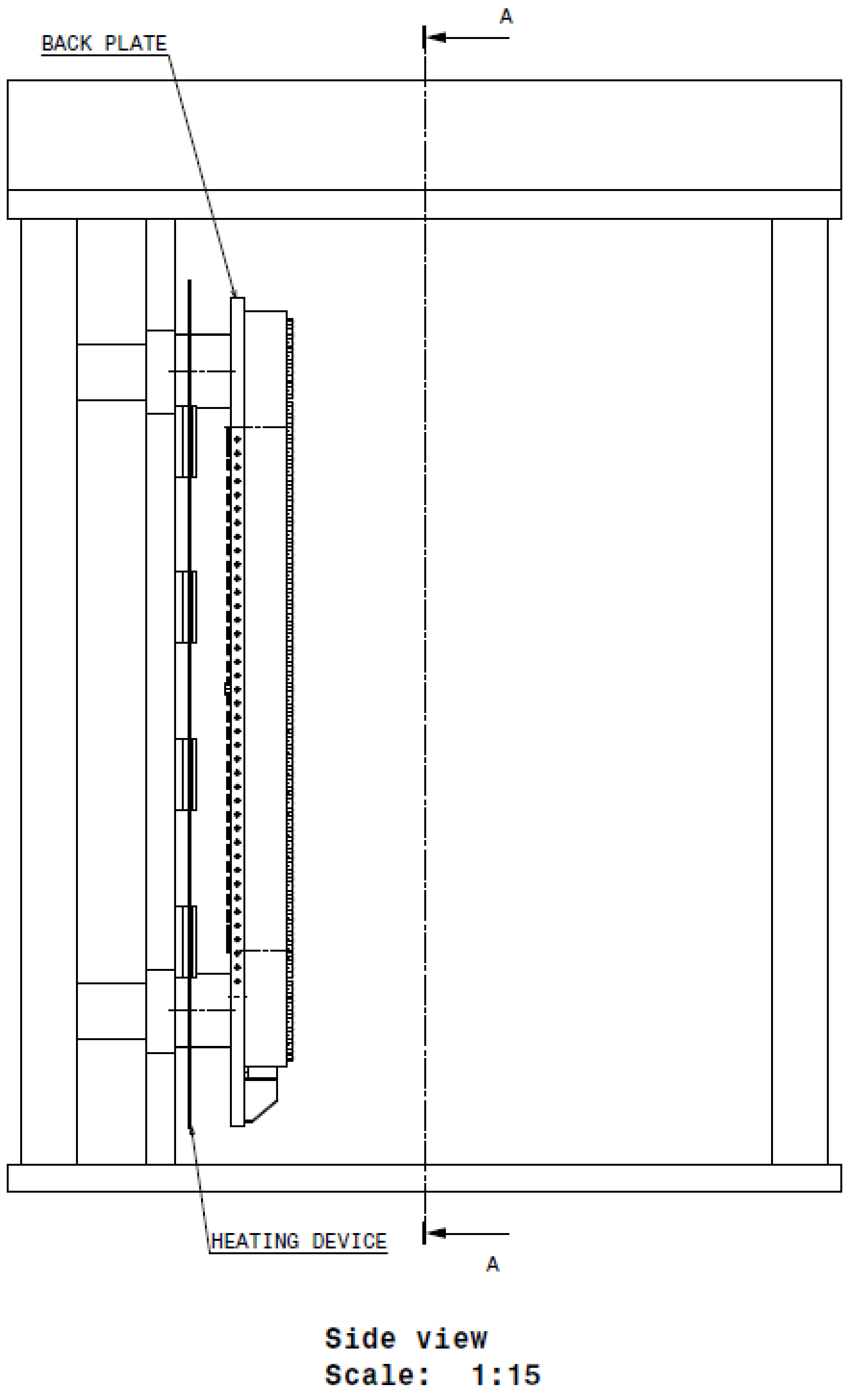
31 ITER Requirements Regarding Contractor Deviations and Non Conformities ITER_D_22F53X

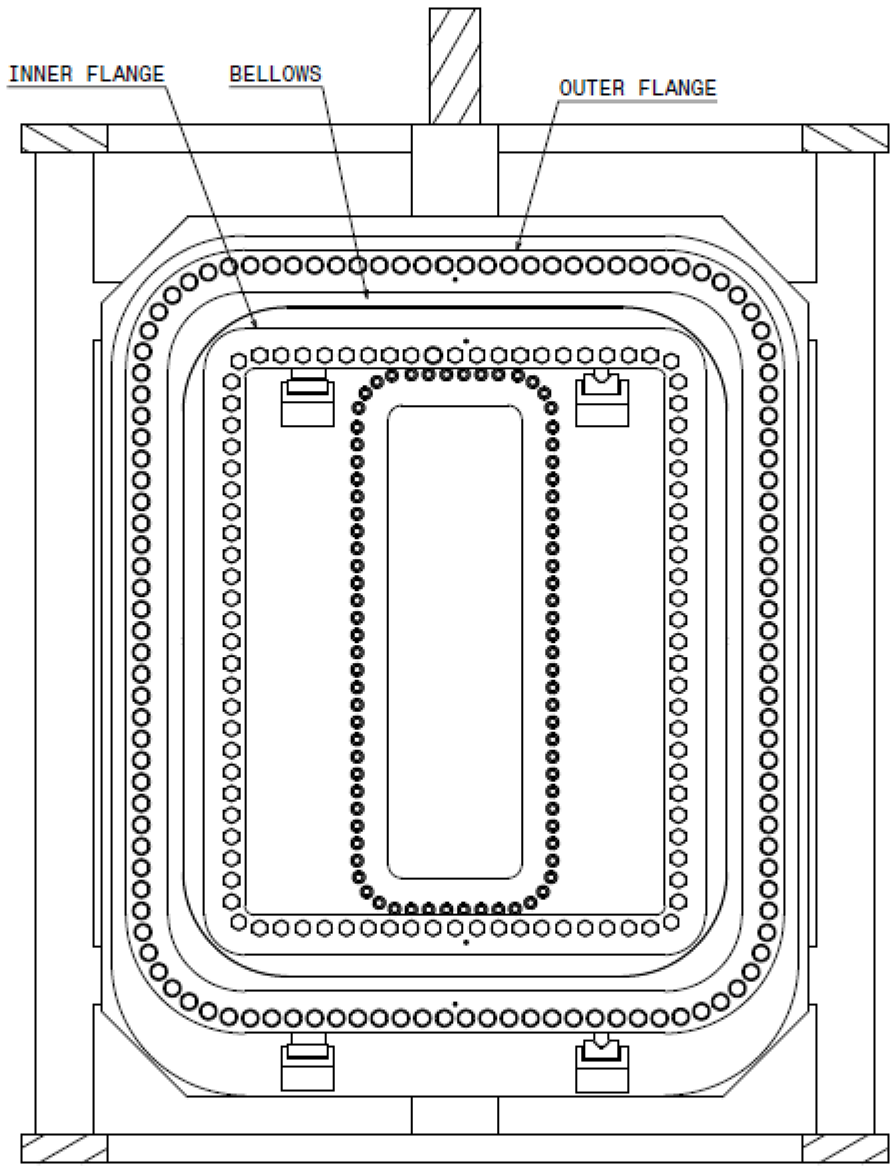
13 Appendix A

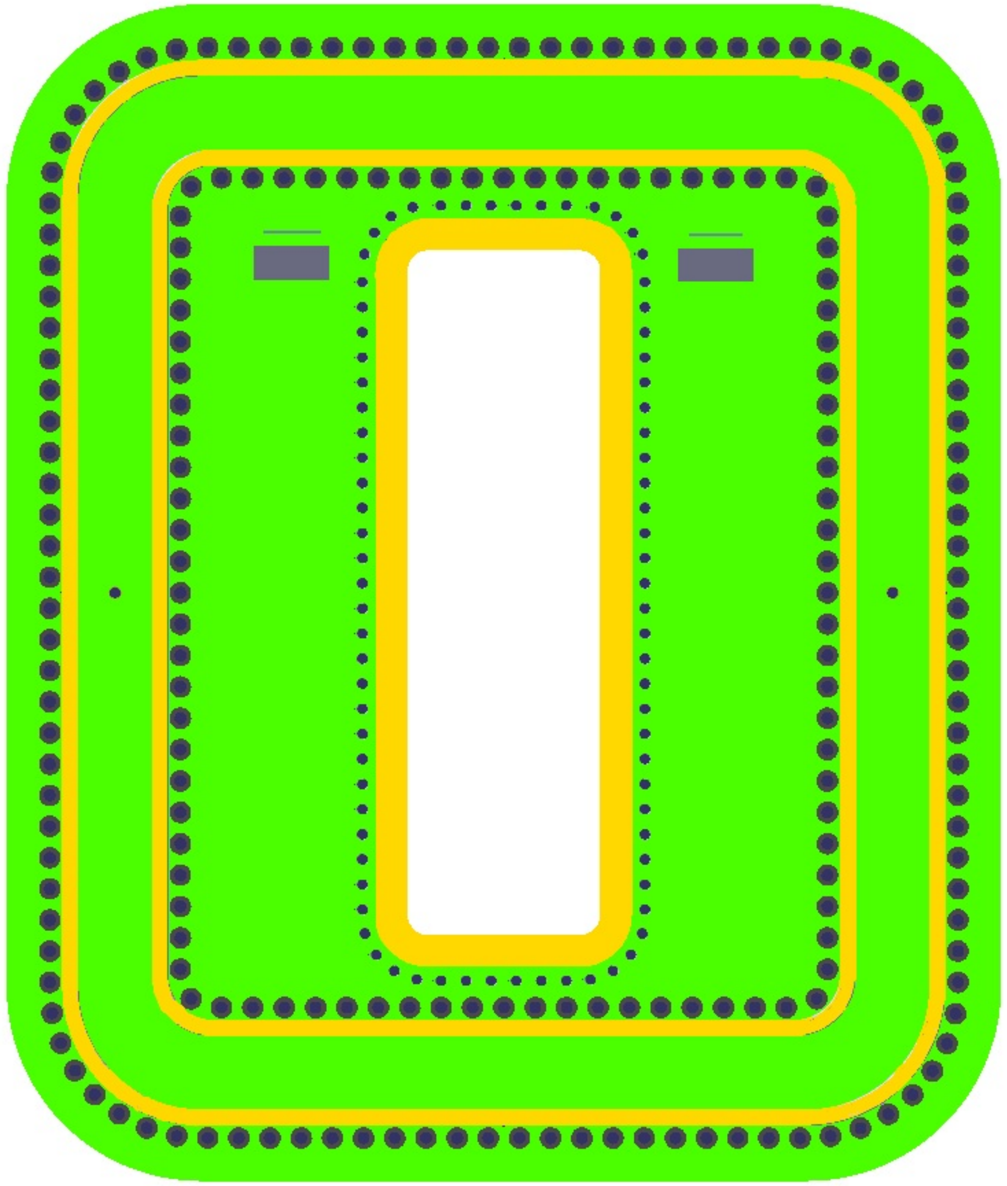
Please refer to the drawing 036981 attached as PDF

13.1 IO Concept Design

View Name	View
General Isometric View	 Isometric view VACUUM SEALING TEST CONFIGURATION (heating system covers and insulation removed for clarty) Scale: 1:20

View Name	View
Side Elevation Insulating Covers Removed for Clarity	

View Name	View
End Elevation: Future Bellows Configuration	 Section view A-A VACUUM SEALING TEST CONFIGURATION

View Name	View
Back Plate Interface	

Colour Key	
Green UHV	
Yellow SEAL SURFACE	
Grey INSERTS / OTHER PARTS	

14 Appendix B - Scoping Calculation for Rig Heating Loads

Desired Temperature Increase

$T_{bo} := 240$ $T_{amb} := 20$

$\Delta T := T_{bo} - T_{amb}$ $\Delta T = 220$

Materials for Flanges and Base is 304L, Bolting materials assumed to be Inconel Alloy 718

Masses are:

$m_{base} := 2630\,kg$ $m_{outer} := 1350\,kg$ $m_{inner} := 1050\,kg$

$m_{304} := m_{base} + m_{outer} + m_{inner}$ $m_{304} = 5030\,kg$

$m_{bolts} := 370\,kg$

$C_{p304} := 500 \frac{J}{kg \cdot K}$ Average value across temperature range under consideration

$C_{pInc718} := 435 \frac{J}{kg \cdot K}$ Value taken from Special Metals data sheet at 20°C

$Q_{304} := m_{304} \cdot C_{p304} \cdot \Delta T$ $Q_{304} = 553 \cdot MJ$

$Q_{Inc718} := m_{bolts} \cdot C_{pInc718} \cdot \Delta T$ $Q_{Inc718} = 35 \cdot MJ$

Estimating the Heat Load needed to heat items to Tbo from ambient temperature

$Q_{est} := Q_{304} + Q_{Inc718}$ $Q_{est} = 589 \cdot MJ$

So assume a loss of 15% as the rig will have insulated covers - these are also excluded from the heated mass.

Assume max heat up rate desired is 20C/hr $rate := 20 \frac{K}{hr}$

$Z := 0.85$

$t := \frac{\Delta T}{rate}$ $t = 660 \cdot min$ $t = 11 \cdot hr$

Thermal Power required is: $P_{elec} := \frac{Q_{est}}{(t \cdot Z)}$ $P_{elec} = 17 \cdot kW$

Assume heating around half outside surface of flanges,

$A_{outer} := 150\,mm \cdot [2 \cdot (2276\,mm + 2713\,mm)]$

$A_{inner} := 150\,mm \cdot [2 \cdot (1682\,mm + 2119\,mm)]$

$Area := \frac{1}{2} (A_{outer} + A_{inner})$

$Power\_Den := \frac{P_{elec}}{Area}$ $Power\_Den = 1.33 \cdot \frac{W}{cm^2}$