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Title	Design, Fabrication and Supply of Torus Cryo Pump Housing (TCPH) with Bellows and Other Loose items
Sub-title	**MANDATORY APPENDIX : II-TCPH-APB3_13_BELLOWS**

Author	ITER-India
Contributors	ITER-India

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Written by	Reviewed by	Approved by
ITER-India	ITER-India	ITER-India

ITER-India, Institute for Plasma Research

Block A, Sangath Skyz, Bhat-Motera Road, Koteshwar,

Ahmedabad 380005, Gujarat, India

http://www.iter-india.org

CONTENTS

1. SCOPE

This appendix covers the functional specification of bellows connecting TCPH and Vacuum Vessel port extension. The bellows is constructed of relatively thin gauge material in order to provide the flexibility needed to absorb mechanical and thermal movements expected in service. This appendix specifies the requirement for procurement including design, manufacturing quality, handling, installation and inspection procedures and testing etc. The manufacturing design shall be done by supplier to ensure that the design comply with loading conditions as per the code as well as other requirement defined in this specification.

The Bidder shall notify I-I of their selected bellows manufacturer. The Bidder shall ensure that the bellows supplier qualifies the bellows design by producing a proof-of-principle bellows and subjecting it to the qualification tests specified.

Bellows being a part of TCPH system falls under the Safety Important class (SIC-1), The safety requirements as mentioned in clause 7.1 of Section-B shall be applicable.

2. DESIGN CODE

The code and standard for bellows design and manufacture is: EJMA. At the same time, the ITER Vacuum Handbook - Appendix 9 “Guide to the Supply of Bellows for use on ITER Vacuum Systems” (RDB3_08) needs to be followed in case more stringent requirement is defined regarding the design and manufacturing.

3. DESIGN SPECIFICATION

As per EJMA code requirement, the system designer has to completely review the TCPH system, flowing medium, pressure, temperature, and movement for bellows design. Particular clarification for TCPH bellows is given to the following items:

- TCPH system has been reviewed to determine the location and type of bellows most suitable for the application. Torsional rotation of the bellows should be avoided.

- The bellows material is specified and compatible with flowing medium, the external environment and operating temperature.

- The design pressure and test pressure is specified without adding arbitrary safety factors. In most case the test pressure is significantly higher than the system operating pressure.

- The movement to be absorbed by bellows includes movement of Cryostat and Vacuum Vessel(VV) and possibility of misalignment during installation.

- Internal sleeves are not required for TCPH bellows.

In order to fulfill the intended function of bellows safely and reliably, it is necessary to provide the supplier with accurate information regarding the conditions of design that the bellows will be subjected to in service. The following section introduces the basic design conditions that should be supplied to the manufacturer when specifying the bellows

3.1. Geometry

The drawings in II-TCPH-APB3_02 show the space reservation for bellows convolution which should be considered as boundary for bellows geometry during the manufacture design. The Bellow end flange dimensions shall be considered as per drawing requirement.

3.2. Interspace Monitor

Since the TCPH bellows is the primary vacuum barrier by connection with VV port extension, the concentric double bellows is implemented to form the interspace in between for leakage monitor and pumping by Service Vacuum System as per ITER Vacuum Handbook. The VCR connectors need to be implemented on the flange for this purpose. Since the TCPH bellows is two co-axial bellows which both are single ply, this requirement has no impact on the convolution design.

3.3. Pressure and Temperature

Pressure is possibly the most important factor determining bellows design. Minimum and maximum anticipated pressure should be accurately determined. If a pressure test is to be performed, this pressure should be specified as well.

The operating temperature of the bellows will affect its pressure capacity, allowable stresses, cycle life, and material requirements. 200^0 C baking temperature should be considered during manufacture design and test. The summary of all pressure loads is shown in Table.1

3.4. Displacement

The TCPH bellows is necessary to compensate all the displacement under any load condition especially for thermal expansions of the components and relative movement between the TCPH and VV port extension. The load combination which is considered for VV and Cryostat(CR) should be considered in order to get the relative displacement between two ends of the bellows in all cases.

The summary of displacement under different load combination is shown in Table.1

Table 1: Load condition and relative displacement between VV port and TCPH

Load condition		Cat	Cycle	Relative Displacement/mm			Internal pressure /MPa	External pressure /MPa
				Radial/X	Toroidal/Y	Vertical/Z		
1	Assembly	I	1	±5	±3	±3	0.1	0.1
2	SL-1 during Assembly	I	1	±8	±6	±4	0.1	0.1
3	NO	I	300	-29	±1	+9	0	0
4	BK	I	500	-48	±1	+18	0	0
5	NO+SL-1	II	1	-32	±3	+8	0	0
6	BK+SL-1	II	1	-51	±3	**+19**	0	0
7	NO+VV VDEII	II	300	-38	**±6**	+10	0	0
8	VV ICEII(NO)	II	15	-29	±1	+6	0.106	0
9	VDEII+VV ICEII(NO)	II	15	-38	±6	+9	0.106	0
10	CR ICEII-He(NO)	II	15	-43	0	+10	0	0.03
11	CR ICEII-He(BK)	II	15	**-62**	0	+15	0	**0.03**
12	NO+ VDEIII	III	1	-46	**±10**	+12	0	0
13	VDEIII+VV ICEII or III(NO)	III	<1	-46	±10	+11	0.15	0
14	NO+ SL-1+VDEII	III	<1	-41	±8	+11	0	0
15	VV ICEIII(NO)	III	<1	-29	±1	+6	0.15	0
16	VV ICEIII(BK)	III	<1	-48	±1	+11	**0.15**	0
17	VDEII+VV ICEIII(NO)	III	<1	-38	±6	+9	0.15	0
18	CR ICEIII-He(NO)	III	<1	-47	0	+11	0	0.14
19	CR ICEIII-He(BK)	III	<1	**-66**	0	+15	0	**0.14**
20	VV LOVAIII(NO)	III	<1	-29	±1	+8	0.1	0
21	CR LOVAIII(NO)	III	<1	-24	0	+7	0	0.110
22	NO+SMHV	III	<1	-35	±5	+9	0	0
23	BK+SMHV	III	<1	-54	±5	+20	0	0
24	CR ICEIII(NO)+SMHV	III	<1	-53	±4	+12	0	0.14
25	HIG III (NO) + SMHV	III	<1	-33	±4	+21	0	0
26	HIG III (BK) + SMHV	III	<1	-52	±5	+20	0	0

Table 1: Load condition and relative displacement between VV port and TCPH (continue)

Load condition		Cat	Cycle	Relative Displacement/mm			Internal pressure /MPa	External pressure /MPa
				Radial/X	Toroidal/Y	Vertical/Z		
27	CR ICEII-He(BK)+SL-1	IV	<1	-71	±3	+17	0	0.14
28	NO+VDEIV	IV	<1	-43	±6	+17	0	0
29	VV ICEIII or IV(NO)+VDEIV	IV	<1	-43	±6	+16	**0.2**	0
30	VV ICEIV(NO)	IV	<1	-29	±1	+6	**0.2**	0
31	VDEIII +VV ICEIV(NO)	IV	<1	-46	**±10**	+11	**0.2**	0
32	CR ICEIV-He(NO)	IV	<1	-48	0	+11	0	**0.2**
33	CR ICEIV-He(BK)	IV	<1	-67	0	+16	0	**0.2**
34	NO+SL-2	IV	<1	-38	±7	+9	0	0
35	BK+SL-2	IV	<1	-57	±7	**+20**	0	0
36	CR ICEIII(NO)+SL-2	IV	<1	-55	±7	+13	0	0.14
37	CR ICEIII(BK)+SMHV	IV	<1	**-72**	±4	+16	0	0.14
38	HIG III (NO) + SL-2	IV	<1	-35	±7	+11	0	0
39	HIG III (BK) + SL-2	IV	<1	-54	±7	**+20**	0	0

4. RESTRAIN FIXTURE

Since the bellows needs to be installed inside TCPH prior to shipment to IO site, specific restrain fixture should be designed and manufactured by bellows supplier considering the requirement of protection, packing and transportation. The main purpose of fixture is to maintain the proper face-to-face dimension of the bellows during shipment and installation. The fixture can be installed and dismantled from inside of bellows and should not impact the assembly and welding process. The design should be submitted to I-I for approval.

5. MATERIAL

Since the material of Cryostat is dual mark 304/304L and material of VV is 316L (N)-IG austenitic stainless steel, the material of bellows is recommended to be same material either with Cryostat or with VV. If the supplier prefers to use other material, the property of the material should meet the vacuum and permeability requirement base on ITER Vacuum Handbook and material specification.

For the material of fixture, the material which can affect the main materials (e.g. corrosion attack during storage, etc.) is not allowed.

Bellow End flanges shall be manufactured as per drawing and material requirements as per II-TCPH-APB3_12 Material procurement.

6. MANUFACTURE AND INSPECTION

The manufacturing quality control program should be guaranteed by the manufacturer for the design and compliance to this specification. These requirements pertain to the inspections and tests necessary to substantiate product conformance to drawings, specifications and contract requirements. The program shall assure systematic and adequate quality control throughout all areas of contract performance; for example, product development, material selection, fabrication, processing, assembly, inspection, testing, delivery preparation and shipment, storage and maintenance, for which comprehensive written procedures shall be used and maintained.

6.1. Welding

The qualification, production and testing of welds shall be in accordance with the Vacuum Handbook Attachment 1 (RDB3_07). Alternately equivalent ASME code can be acceptable after approval by I-I.

6.2. Qualification Testing

Prior to the manufacturing of bellows assemblies, the manufacturer should qualify the bellows design. The supplier should submit for acceptance a qualification plan (as part of the quality plan) detailing the tests to be performed on bellows assemblies. After the completion of all manufacturing processes the bellows assemblies should undergo the following qualification tests. Detailed requirement can refer to ITER Vacuum Handbook Appendix 9 (RDB3_08)

- Pressure testing
- Fatigue life testing
- Helium leak testing

Some important examination and testing shall be witnessed by I-I and IO. The detailed witness points will be defined in the Manufacture and Inspection Plan (MIP/IP) from bellows supplier. The inspection and test reports shall be submitted to I-I for approval.

6.3. Testing and Inspection

After the completion of all manufacturing processes the individual bellows assemblies should undergo leak testing and dimension inspection. Other detailed requirements can refer to ITER Vacuum Handbook Appendix 9 (RDB3_08).

6.4. Cleaning

Detailed requirement can refer to ITER Vacuum Handbook Appendix 9 (RDB3_08)

6.5. Protection

Since the bellows needs to be install inside TCPH prior to shipment to IO site, the proper protection should be considered and designed to protect the bellows from damage during the packing and transportation. The design of protection needs to be submitted to I-I for approval. Detailed requirement can refer to ITER Vacuum Handbook Appendix 9 (RDB3_08).

6.6. Marking

Detailed requirement can refer to ITER Vacuum Handbook Appendix 9 (RDB3_08).

6.7. Packaging & Delivery

The packing should guarantee that no any damage will happen for the TCPH bellows even the packing break. Additional steel cover is recommended to protect the bellows. Other detailed requirement can refer to ITER Vacuum Handbook Appendix 9 (RDB3_08).

6.8. Transportation

Bellows shall be transported with tags which furnish the installer with instruction covering the installation of the particular bellows. These tags should be left on the bellows until installation.

6.9. Installation

The bellows supplier should recommend the proper lengths at which the bellows should be installed. The installer must take all necessary measures to protect the bellows during installation and limit the installation tolerance which will cause the extension or compression of bellows as specified. Avoid denting, welding spatter, arc strikes, or the possibility of allowing foreign matter to interfere with the proper flexing of the bellows.

6.10. Documentation

In addition to the documentation requirements of current mandatory appendix, Bidder shall also submit the documents as per ITER Vacuum Handbook Appendix 9 (RDB3_08) and II-TCPH-APB3_11_TCPH_Documentation_and_Acceptance for I-I approval.