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EXTERNAL REFERENCE / VERSION

System Requirement (SRD) Document

SRD-24-CR (Cryostat)

This SRD contains all of the functional, design, safety, operational and quality requirements for the Cryostat.

Approval Process			
	Name	*Action*	*Affiliation*
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Change Log			
SRD-24-CR (Cryostat) (28B2TP)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	In Work	09 Aug 2007	
v1.1	In Work	15 Oct 2007	
v1.2	In Work	28 Apr 2008	
v1.3	In Work	06 Mar 2009	
v1.4	Signed	20 Mar 2009	
v1.5	In Work	15 Jul 2009	Comments in IDM from the reviewers are incorporated. Also the comments received during the in-person SRD review meeting held on 26th April 2009, has been incorporated.
v1.6	Signed	16 Jul 2009	Comments from Dr. Stout Daniel is added
v1.7	Approved	29 Jul 2009	Incorporating many reviewers changes since v1.6, as well as updating the version in DOORS since v1.4.
v2.0	Approved	28 Oct 2009	List of modifications to the SRD after checking consistency with the Project Requirements (PR) (27ZRW8) version 4.1: Sections 1.2, 2.1, 2.2, 2.3, 2.4, 2.5, 2.9, 2.10, 2.12, 3.1, 3.8, 6.4
v3.0	Approved	12 Nov 2010	Changes brought about by the acceptance of PCR-204 into the baseline.
v3.1	Revision Required	25 Sep 2013	Modifications in compliance with PCR-373, PCR-404 and PCR-475
v3.2	Approved	02 Jul 2015	Implementation of PCR-528, PCR-556, and CN-000252-PCR-300
v3.3	Approved	16 Feb 2018	Implementation of PCR-628, PCR-738 PCR-766, PCR-796, PIC classification bellows and propagation of requirements (defined and non-defined) as per baseline 2016

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PURPOSE

[24CRs519-I] This System Requirements Document (SRD) lists the technical requirements and constraints on this system, and shows (via the use of links) how they arise from the overall project requirements that are listed in the Project Requirements (PR) document [1]. This also leads to the identification of interfaces with the other systems of the ITER plant. This SRD also acts as the parent document for the technical requirements that need to be addressed in lower level design description documents.

[24CRs598] Table 0.1: Record of changes induced on this document by PCRs

[24CRs599]

SRD version	Section / Paragraph identifier	PCR reference
v1.0 to v2.0	Whole document	PCR-200
v3.0	Whole document (due to the editorial changes of the SRD Harmonisation process)	PCR-300
v3.1	Table 0.1, and References section (0.4) added, and the refs made accordingly in the text. Paragraphs 24CRs17, 21, 433 Sections 1.2,, 1.3, 1.4, 1.5 Paragraphs 24CRs51, 54, 61, 177(deleted), 31, 382, 383, 456, 461, 69, 78, 546, 548, 88, 463(deleted), 550(deleted), 551, 395, 87(deleted), 553, 556, 557, 348, 350, 64, 469, 113(deleted), 559, 92, 132(deleted), 137, 138, 140, 561, 143, 562, 142, 150, 158, 187, 188(title), 189, 230, 568, 457, 312, 314, 406, 480, 451, 572, 573, 571(deleted), 575(deleted).	CIE policy PCR-373, PCR-404, PCR-475
v3.2	Paragraphs impacted throughout the document	PCR-528, PCR-556, and CN-000252-PCR-300
v4.0	Paragraphs 24CRs650 to 24CRs673, **24CRs34, 24CRs527-R, 24CRs638-R** and **24CRs394-R** in chapters 1, 2,3,4 and 6	PCR-628, PCR-738 PCR-766, PCR-796, ITER_D_QERXHA - DR-11 NB Bellows Design

SCOPE

[24CRs521-I] This SRD contains all of the top level functional, design, safety, operational and quality requirements for the Cryostat (PBS 24-CR) including the torus cryopump Housing (TCPH) and associated bellows. In addition to the requirements that are specified in this SRD, this system shall comply completely with the requirements given in the Project Requirements (PR) document, in the PR annex documents, and in the Preliminary Safety Report (RPrS).

[24CRs7-I] PBS 24 includes the Cryostat system and the Vacuum Vessel Pressure Suppression System (VVPSS). These two systems are independent and with different functions, configurations and requirements. This document only describes the Cryostat (PBS 24.CR).

[24CRs678-I] Sections 1 to 6 of the SRD describe the system in its final configuration and the associated requirements that this system shall satisfy to undertake the Deuterium-Tritium operation campaigns (i.e. required capabilities to start the Fusion Power Operation (FPO) phase). The new section 7 presents specific requirements (if any) that the system shall satisfy for the planned construction and operation campaigns prior to FPO (i.e. during each of the 3 phases: First Plasma (FP), Pre-Fusion Power Operation 1 (PFPO-1), and Pre-Fusion Power Operation 2 (PFPO-2)).

DEFINITIONS

[24CRs523-I] For a complete list of ITER abbreviations see ITER Abbreviations [3].

REFERENCES

[24CRs601-I] Definition status (Complete/TBC): Parent requirements:

This SRD makes reference to the following documents, and to the Interface Control Documents (ICDs) that are listed in Section 1.5.

[24CRs602-ADi] [1] *Project Requirements (PR)* ([ITER_D_27ZRW8|https://user.iter.org/?uid=27ZRW8])

[24CRs603-I] [2] *ITER Project Change Procedure* ([ITER_D_22F4E5|https://user.iter.org/?uid=22F4E5])

[24CRs604-I] [3] *ITER Abbreviations* ([ITER_D_2MU6W5|https://user.iter.org/?uid=2MU6W5])

[24CRs606-ADc] [4] *ITER Seismic Nuclear Safety Approach* ([ITER_D_2DRVPE|https://user.iter.org/?uid=2DRVPE])

[24CRs607-ADc] [5] *ITER Vacuum Handbook* ([ITER_D_2EZ9UM|https://user.iter.org/?uid=2EZ9UM])

[24CRs608-ADc] [6] *Quality Classification Determination* ([ITER_D_24VQES|https://user.iter.org/?uid=24VQES])

[24CRs609-ADc] [7] *Accident Analysis Report (AAR) Volume III: Hypothetical Event Analysis* ([ITER_D_2E2XAM|https://user.iter.org/?uid=2E2XAM])

[24CRs610-ADc] [8] *Load Specifications (LS)* ([ITER_D_222QGL|https://user.iter.org/?uid=222QGL])

[24CRs637-ADc] [9] *Cryostat load specification document* ([ITER_D_34HHUG|https://user.iter.org/?uid=34HHUG])

[24CRs611-ADc] [10] *Electrical Design Handbook (EDH)* ([ITER_D_2DSPT6|https://user.iter.org/?uid=2DSPT6])

[24CRs612-ADc] [11] *EDH Part 3: Codes and Standards* ([ITER_D_2E8DLM|https://user.iter.org/?uid=2E8DLM])

[24CRs613-ADc] [12] *Plant Control Design Handbook* ([ITER_D_27LH2V|https://user.iter.org/?uid=27LH2V])

[24CRs614-ADc] [13] *Summary of Material Data for Structural Analysis of the ITER Cryostat* ([ITER_D_3F863L|https://user.iter.org/?uid=3F863L])

[24CRs615-ADc] [14] *Safety Important Functions and Components Classification Criteria and Methodology* ([ITER_D_347SF3|https://user.iter.org/?uid=347SF3])

[24CRs616-ADc] [15] *Codes and Standards for ITER Mechanical Components* ([ITER_D_25EW4K|https://user.iter.org/?uid=25EW4K])

[24CRs680] [16] *Order dated 7 February 2012 relating to the general technical regulations applicable to INB* (ITER_D_7M2YKF V1.6)

1 FUNCTIONS, BASIC CONFIGURATION AND SYSTEM BOUNDARIES

1.1 System Functions

[24CRs10-R] The Cryostat system shall form a vacuum tight container, surrounding the entire Tokamak.

[24CRs9-R] The Cryostat system shall provide a vacuum environment to avoid excessive thermal loads from being applied to the components that are being operated at cryogenic temperatures, such as superconducting magnet systems, by gas conduction and convection.

[24CRs17-R] The Cryostat system shall provide penetrations for connecting the elements of systems outside the cryostat to the corresponding elements inside the cryostat.

[24CRs18-R] The Cryostat system shall provide port and associated bellows for access to the VV ports.

[24CRs433-R] The Cryostat system shall facilitate in-cryostat inspection and maintenance, such as providing access for the maintenance equipment within the cryostat, and to support the local pads/rail.

[24CRs19-R] The Cryostat system shall provide openings for man access and maintenance equipment into the cryostat.

[24CRs20-R] The Cryostat system shall allow access for possible removal of the Central Solenoid (CS) coil and Pre-Compression Rings (PCR) of TF magnets.

[24CRs21-R] The Cryostat system shall provide support to the tokamak and transfer all the loads to the concrete structure of the tokamak pit through its support structures and concrete crown during the normal and off-normal operational regimes, and at specified accidental conditions.

[24CRs435-R] The Cryostat support structure shall provide air flow passage inside the cryostat space room during operations.

[24CRs22-R] The Cryostat system shall provide the support to the Tokamak Cooling Water System (TCWS), Cryostat Thermal Shield (CTS) , thermal shield manifold and other systems inside the cryostat.

[24CRs641-R] The Cryostat system includes the TCPH which encloses the torus cryopump. The TCPH shall provide enough volume for regeneration of torus cryopump.

[24CRs642-R] The TCPH shall provide support and sealing for cryopump.

[24CRs643-R] The TCPH shall connect the cryopump to the torus vacuum and provide tritium confinement and primary vacuum boundary.

[24CRs644-R] The TCPH shall provide Remote Handling (RH) docking compatibility for removal of cryopump.

[24CRs645-R] The TCPH shall provide penetrations for other system through the port.

[24CRs650-R] A Cryostat pressure relief device (PRD) shall be implemented in order to limit Cryostat maximum internal pressure of 0.15 MPa absolute during Category- IV Cryostat Ingress of Coolant Events (CrICE) and Pressure relief device shall be also designed for Cat-V, Helium, Fukushima (SL3) and Stress test scenarios conditions.

1.2 System Basic Configuration

[24CRs437-I] The main components that form the full cryostat system are the cryostat Base Section, Lower Cylinder, Upper Cylinder, Top Lid, Port duct bellows assembly, Port cell bellows assembly, Cryostat penetrations and associated bellows, TCPH and associated bellows and instrumentation for the cryostat.

[24CRs434-R;Defined Requirement] The Cryostat system includes man access ports at the lower and top cryostat areas for in-cryostat maintenance. Some of these ports are used as ventilation ports to facilitate hands-on maintenance inside the cryostat.

[24CRs24-I] The Cryostat is a cylindrical vacuum vessel, with its axis vertical, and with a flat bottom head and a tori-spherical top lid.

[24CRs27-R] The pedestal ring is a platform on which the Magnets and the Vacuum Vessel gravity supports sit.

[24CRs28-R] The pedestal ring is supported by 18 sliding bearings, installed on the concrete crown, which is radially connected to the Bio shield by 18 concrete walls and integrated with the B2 slab.

[24CRs526-R] The skirt support, which is installed on a stage of the bio-shield wall, supports the cryostat cylinder and top lid.

[24CRs380-R] The skirt support allows radial movement of the cryostat shell in case of helium and water spillage events inside the cryostat.

[24CRs381-R;Defined Requirement] The eighteen toroidal lugs integrated with the skirt and with their corresponding female lugs installed on the bio-shield wall, confine the Cryostat and the Tokamak from horizontal movement during seismic events.

[24CRs29-R] The Cryostat ports are connected to VV port ducts and bio-shield port cells by metallic rectangular bellows, to compensate all relative movements during the normal operational and accidental conditions.

[24CRs32-R] The Cryostat is connected to cryostat vacuum pumping system and the vacuum monitoring system.

[24CRs46-R] Neutron shielding blocks are integrated into the heating and diagnostic neutral beam port ducts of the cryostat.

[24CRs524-I;Defined Requirement] The torus cryopump is attached to the TCPH by bolted connection with double metal (HELICOFLEX) seals to provide the primary vacuum and tritium confinement sealing. The interspace between the seals is monitored by Service Vacuum System (SVS).

[24CRs525-R] The TCPH includes two co-axial cylindrical bellows that are welded to the vacuum vessel port extension on one side and to the TCPH on other side. The interspace of the bellows is controlled by the SVS.

[24CRs651-R] PRDs shall be located on the Cryostat base section cylinder at B2 level using pipe ducts and rupture discs installed on the existing man access flanges.

[24CRs652-I] Release from the PRDs occurs at B2 level in the galleries.

1.3 Classification of Systems, Structures and Components (SSCs)

[24CRs34-R;Defined Requirement] The whole Cryostat structure including: Top Lid (TL), Upper Cylinder (UC), Lower Cylinder (LC), Base Section (BS), including the Cryostat Support System with the Pedestal Ring , Cryostat rectangular bellows and DNB/HNB circular bellows is PIC-2.

[24CRs527-R;Defined Requirement] The TCPH and associated bellows are SIC-1 components.

[24CRs638-R] The Cryostat Instrumentation and Control is a non-PIC.

[24CRs528-R;Defined Requirement] The Cryostat system is assigned with a seismic class SC2, ITER according to *ITER Seismic Nuclear Safety Approach* [4].

[24CRs529-R;Defined Requirement] The TCPH and associated bellows are assigned with a seismic class SC1, *ITER Seismic Nuclear Safety Approach* [4].

[24CRs125-R] The Cryostat system is categorized as vacuum class VQC-2A according to the classification in *ITER Vacuum Handbook* [5].

[24CRs126-R] All the penetrations including the port duct bellows are categorized as vacuum class VQC-2A.

[24CRs530-R] The TCPH and associated bellows are categorized as vacuum class VQC-1A according to the classification in the *ITER Vacuum Handbook* [5].

[24CRs408-R;Defined Requirement] The Cryostat system is a Quality Class 1 component, according to the *Quality Classification Determination* [6].

[24CRs531-R;Defined Requirement] For the Tritium classification, the TCPH and associated bellows shall meet specific site licensing requirements for nuclear components that provide the first and second radioactivity barrier; for example the Order dated 7th February 2012 Concerning Quality of Design, Construction and Operation of Basic Nuclear Installation.

[24CRs532-R] The Cryostat system is RH non-classified.

[24CRs533-R] No ESPN classification is applicable.

[24CRs534-R] No PED classification is applicable.

[24CRs535-R;Defined Requirement] For the Electrical Power availability classification, the Cryostat system is Class II, IP.

[24CRs536-R] For the Environmental room conditions classification, the Cryostat system is 25ºC, Air flow equivalent to 2 w/m^2 k heat transfer coefficient.

[24CRs537-R;Defined Requirement] No Fire Behaviour classification is applicable.

[24CRs653-R] The Cryostat Pressure Relief Devices (PRD) shall be classified for Safety: SIC-2.

[24CRs654-R] The Cryostat Pressure Relief Devices (PRD) shall be classified for Vacuum: VQC2A.

[24CRs655-R] The Cryostat Pressure Relief Devices (PRD) shall be classified for Quality: QC1.

[24CRs656-R] The Cryostat Pressure Relief Devices (PRD) shall be classified for Remote Handling: non RH.

[24CRs657-R] The Cryostat Pressure Relief Devices (PRD) shall be classified for Seismic: SC2.

[24CRs658-R] The Cryostat Pressure Relief Devices (PRD) shall be classified for ESPN / ESP: No classification applicable.

1.4 Design Basis Conditions and Events

[24CRs538-R;Defined Requirement] The design basis conditions include all credible combinations (inertial, pressure, thermal and EM loads) of operating loads, seismic loads (SL-1,SMHV and SL-2), outside pressure loads during operation, and internal pressure load from in-cryostat coolant ingress or air ingress event.

[24CRs540-R] The design internal pressure for the cryostat is 0.14 MPa absolute (Category I, II and III).

[24CRs394-R;Defined Requirement] The design internal pressure for the cryostat and Cryostat bellows is 0.15MPa absolute (Category-IV) with implementation of pressure relief device on Cryostat; Accident Analysis Report (AAR) Volume II and III [7].

[24CRs541-R] During operation (Category I), the cryostat is under 0.1 MPa external pressure with internal vacuum. This external pressure will apply to all cryostat pressure boundaries.

[24CRs542-R] In the event of coolant leakage outside the cryostat (Category IV) the external pressure will reach 0.12 MPa.

[24CRs36-R] The load cases and combinations for the design basis and events for the cryostat, TCPH, port duct and port cell bellows shall be defined in the Load Specification.

[24CRs681-R;Defined Requirement] The design of all ITER systems shall provide reliable means to remove the heat that is generated during normal operation, as well as the decay heat of activation products after shutdown, and the heat from potential chemical reactions, if this heat could lead to a challenge to a confinement barrier including indirectly (for example, by elevated temperatures causing a higher rate of a hydrogen-producing chemical reaction).

[24CRs682-R;Defined Requirement] ITER shall be designed to minimize hydrogen production, to avoid explosive mixtures of hydrogen with air/oxygen with the potential to challenge a confinement barrier, and to minimize the release of chemical energy as heat.

1.5 System Boundaries and Interfaces

[24CRs440-I] The Cryostat system interfaces with most of the In-Cryostat systems of basic Tokamak machine.

[24CRs378-R] PBS 11 (Magnet System):

- Physical and functional interface
- *ICD 11-24* ([ITER_D_2X585R|https://user.iter.org/?uid=2X585R])
- The cryostat shall provide supports to the magnets gravity support
- The cryostat shall provide penetrations for the CS coil and magnet feeder.

[24CRs373-R;Defined Requirement] PBS 15 (Vacuum Vessel and IV Coils):

- Physical and functional interface
- *ICD Vacuum Vessel (15) - Cryostat (24)* ([ITER_D_2NRU42|https://user.iter.org/?uid=2NRU42])
- The cryostat shall provide supports for VV gravity support
- The cryostat shall provide ports and associated bellows to connect with VV port extension
- The cryostat shall provide penetrations for pipes coming from vacuum vessel for in vessel coil, instrumentation, cooling pipes etc.

[24CRs370-R] PBS 18 (Fueling and Wall Conditioning):

- Physical and functional interface
- *Interfaces Control Document (ICD)Cryostat & VVPSS 2.4 - Fueling&Wall Conditioning 1.8* ([ITER_D_342THW|https://user.iter.org/?uid=342THW])
- The TCPH shall provide penetrations for the PIS and GIS.

[24CRs369-R] PBS 22 (Machine Assembly and Tooling):

- Physical and functional interface
- *Interface Control Document (ICD) between Machine Assembly Tooling (PBS 22) - Cryostat (PBS 24)* ([ITER_D_2NHV8B|https://user.iter.org/?uid=2NHV8B])
- The cryostat shall provide tooling for transportation and in pit alignment
- The cryostat shall provide access and temporary support for assembly.

[24CRs539-R] PBS 23 (Remote Handling System):

- Physical and functional interface
- *ICD-Cryostat (PBS 24-CR) - Remote Handling Systems (PBS 23)* ([ITER_D_33JAVY|https://user.iter.org/?uid=33JAVY])
- The cryostat shall provide the access to the transfer cask through the port duct bellows
- The cryostat shall provide the TCPH compatible with docking operation of RH cask.
- Adequate internal access for in cryostat maintenance to components located inside the cryostat shall be provided by access ports in the top lid, the cylinder, and on the base section.

[24CRs388-R;Defined Requirement] PBS 26-PH,-CV,-DR,-DY (Tokamak Cooling Water System):

- Physical and functional interface
- *Interfaces Control Document (ICD) between Tokamak Cooling Water System (PBS 26-PH,-CV,-DR,-DY) - Cryostat (PBS 24)* ([ITER_D_2M3GD7|https://user.iter.org/?uid=2M3GD7])
- The cryostat shall provide penetrations and support for cooling pipes
- Draining of the cryostat shall be supported by Cooling Water System and Vacuum System.

[24CRs366-R] PBS 27 (Thermal Shields):

- Physical and functional interface
- *Interface Control Document (ICD) between Cryostat (PBS 24-CR) -Thermal Shield (PBS 27)* ([ITER_D_2MX232|https://user.iter.org/?uid=2MX232])
- The cryostat shall provide supports for the upper and lower cryostat thermal shield and manifold
- The cryostat shall provide the penetrations for assembly and instrumentation of thermal shield.

[24CRs365-R;Defined Requirement] PBS 31 (Vacuum System):

- Physical and functional interface
- *Interface Control Document (ICD) between Cryostat (PBS 24-CR) - Vacuum Pumping (PBS 31)* ([ITER_D_35695Z|https://user.iter.org/?uid=35695Z])
- The cryostat shall provide penetrations for cryostat cryopump, roughing system, venting and purging system, instrumentation, leak detection and localisation
- The cryostat components (such as port duct bellows, TCPH bellows and man access flange) shall connect with SVS
- Draining of the cryostat shall be supported by Cooling Water System and Vacuum System
- TCPH shall provide the support and sealing flange as well as regeneration volume for torus cryopump
- The Cryostat system shall allow passive removal of decay heat, from the vacuum vessel and in-vessel components, by gas conduction and convection in certain event. The associated operation is responsibility of PBS 31.

[24CRs448-R] PBS 34 (Cryogenic System):

- Physical and functional interface
- *ICD_Cryostat (PBS 24-CR)- ITER Cryogenic System (PBS 34)* ([ITER_D_34BLTA|https://user.iter.org/?uid=34BLTA])
- The cryostat shall provide penetration for the supply and return of cryogenic helium to and from the cooling channels of the thermal shield.

[24CRs389-R] PBS 43 (Steady State Electric Power Supply Networks):

- Physical and functional interface
- *Interface Control Document (ICD) between SSEN (PBS43) - Cryostat and VVPSS(PBS24)* ([ITER_D_2KSF2D|https://user.iter.org/?uid=2KSF2D])

- The power supply networks shall provide power to the equipment for cryostat and on site temporary workshop.

[24CRs359-R] PBS 45 (CODAC):

- Functional interface
- *Interface Control Document (ICD) between SSEN (PBS43) - Cryostat and VVPSS(PBS24)* ([ITER_D_2NHLC7|https://user.iter.org/?uid=2KSF2D])
    - The cryostat shall provide appropriate instrumentation for its operation and control including temperature sensor, stain gauge, accelerometers.

[24CRs356-R] PBS 55 (Diagnostics):

- Physical and functional interface
- *Interfaces Control Document (ICD) Diagnostics (PBS55) - Cryostat (PBS24-CR)* ([ITER_D_356XV7|https://user.iter.org/?uid=356XV7])
- The cryostat shall provide penetrations for the outer-vessel magnetic diagnostic, Neutron Activition System, Residual Gas Analyzer and other diagnostic (such as optics, and cabling)
- The TCPH shall provide penetrations for dust monitor and diagnostic cabling/feedthroughs.

[24CRs390-R] PBS 61 (Site):

- Physical and functional interface
- *Interface Control Document between PBS 24 CR and PBS 61* ([ITER_D_42RR42|https://user.iter.org/?uid=42RR42])
- The cryostat needs on site temporary workshop and utilities for cryostat on-site manufacture and sub-assembly.

[24CRs355-R] PBS 62-11 (Tokamak Building):

- Physical and functional interface
- *Interface Control Document (ICD) between Tokamak Building (PBS 62-11) - Cryostat (PBS 24)* ([ITER_D_2EQ8ZE|https://user.iter.org/?uid=2EQ8ZE])
- The cryostat is wholly supported by the Tokamak Building through support system
- The building shall provide sliding bearings resting on the concrete crown integrated with bio shield and slab
- The cryostat provides port cell bellows at lower, equatorial and upper port to connect with port cell.

[24CRs605-R] PBS 65-CA (Compressed Air System):

- Physical and functional interface
- *Interface Control Document (ICD) between Compressed Air (PBS 65-00-CA) - Cryostat (PBS 24)* ([ITER_D_34PNNW|https://user.iter.org/?uid=34PNNW])
- Compressed Air is needed for the cryostat during maintenance operations for purges as well as pneumatically actuated controls, valves, and switches and circuit breakers.

[24CRs391-R] PBS 65-NG (Nitrogen Gas Distribution):

- Physical and functional interface
- *Interface Control Document (ICD) between Nitrogen Distribution (PBS 65-00-NG) - Cryostat (PBS 24)* ([ITER_D_2EQASE|https://user.iter.org/?uid=2EQASE])
- Gaseous nitrogen is needed for the cryostat during maintenance operations for purges.

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2 DESIGN REQUIREMENTS

2.1 General requirements

[24CRs392-R] The Cryostat shall be designed for the life time of ITER.

[24CRs452-R] The Cryostat system shall have capacity and fatigue life for a minimum of 100 vacuum pump downs in an ITER operation life, as defined in the Project Requirement document.

[24CRs393-R] The operation pressure of the Cryostat shall be below 1×10^{-4} Pa in order to avoid excessive thermal loads from being applied to the superconducting magnet systems.

[24CRs39-R] The connections between the cryostat penetrations and the vacuum vessel port extensions shall incorporate bellows to accommodate mutual thermal expansions and movements during operation, and during abnormal events.

[24CRs42-R] The bellows shall be included between the cryostat penetrations and port cells, to compensate for cryostat movement during seismic and thermal events.

[24CRs44-R] Heating and Diagnostic Neutral Beam ducts shall penetrate the cryostat, and shall be connected to the cryostat ducts through port duct bellows. The cryostat HNB/DNB ducts shall be connected to the bioshield through port cell bellows.

[24CRs48-R] The cryostat shall provide the penetrations for such items as the Magnet Feeders, In Vessel Viewing System (IVVS), Tokamak Water Cooling System (TCWS), Diagnostics, Thermal Shield Cooling System, VV In service Inspection, instrumentation of various systems, Cryostat cryopump. The element of each system shall penetrate the cryostat with stub or pipe welds on the cryostat and associated external bellows. The ex-cryostat pipes, together with their associated bellows and cryostat penetration cover plates, forms the cryostat vacuum barrier.

[24CRs58-R] The VV port extensions shall be connected to the torus cryopump Housings by discrete double bellows.

[24CRs61-R] The cryostat cryopump connect with cryostat by the bulkhead flanges which face the cryostat vacuum.

[24CRs453-R] Bellows design requirements shall be as per the design basis and load specification document.

[24CRs454-R] The design of the cryostat shall not preclude the assembly and maintenance of large components inside the cryostat.

[24CRs476-R] The in-cryostat layout shall provide adequate separation between magnet structures and safety primary heat transfer system and tritium lines, so that off-normal magnet deformation shall not damage these systems.

[24CRs544-R;Defined Requirement] The layout shall provide protection of safety important pipes and cables.

[24CRs83-R;Defined Requirement] Appropriate design provisions shall be included to limit air in-leakage in the cryostat, within an acceptable value, to prevent a potential ozone production hazard, and to prevent a water-ice build-up on the thermal shield surface that impairs emissivity.

[24CRs384-R;Defined Requirement] The cryostat shall be connected with a means for draining, to release the water after ICE inside the cryostat.

[24CRs543-R] The TCPH shall be welded to cryostat openings with enough clearance with adjacent components.

[24CRs646-R] The TCPH shall connect with VV port extension by double bellows.

[24CRs647-R] The TCPH shall provide penetrations for PIS (Pellet Injection System), GIS (Gas Injection System) and Diagnostics.

[24CRs659-R] The building load specification document shall not be challenged by the implementation of the Cryostat pressure mitigation system.

[24CRs660-R] The cryostat pressure mitigation system design will not have any impact and therefore will not request any changes affecting building civil layout or building services and associated PAs.

[24CRs683-R] ITER system elements within the Tokamak Complex (Tokamak Building, Diagnostics Building, and Tritium Plant Building) shall conform to the space envelope constraints and interface characteristics specified in the CAD assemblies, parts, and drawings in the CMM [A03].

[24CRs684-R;Defined Requirement] Use of signage shall show information in both English and French to reflect the international project culture and its host country.

[24CRs685-R;Defined Requirement] All labelling, colour coding and signage installed on the ITER site shall comply with the ITER Site Signage & Graphics Standards [R33].

2.2 System specific requirements

[24CRs545-I] Not applicable.

[24CRs686-R;Defined Requirement] Cryostat will be operational before First Plasma and covered by all load cases till D-T phase.

2.3 Structural requirements

[24CRs31-R] The cryostat bottom flat head shall be just above the pit floor level (60 mm) for the assembly requirement.

[24CRs382-R] The cryostat shall be provided with a removable central cover on top lid, in case of possible removal of CS coils and PCR of the TF magnet.

[24CRs383-R] The cryostat flat bottom shall have provision of a central cover (welded later) to support the initial Tokamak assembly.

[24CRs439-R] The cryostat bottom head shall be allowed to rest on the pit floor, in the event of internal pressure due to testing and in-cryostat ICE.

[24CRs456-R] The cryostat top lid as well as the centre cover shall be bolted with lip-seal to facilitate the replacement of major in-cryostat components.

[24CRs458-R] The cryostat shall have appropriate support provision, access for approaching and to carry out in-cryostat maintenance.

[24CRs460-R] The cryostat shell structure shall be designed for stability against buckling.

[24CRs461-R] The cryostat shall be designed to avoid excessive deflection.

[24CRs69-R] The Magnet gravity supports and the Vacuum Vessel support shall be connected to the pedestal ring. The pedestal ring shall withstand all the loads that are transferred from the Magnets and the VV.

[24CRs78-R] The eighteen sliding bearings shall support the pedestal ring from the concrete crown. The bearings shall be provide by PBS 62 and designed to withstand all operation/accidental conditions.

[24CRs546-R;Defined Requirement] The cryostat skirt supports shall be designed appropriately to withstand the gravity load and seismic force including rocking effects transmitted from the cryostat itself and in-cryostat components attached to the cryostat.

[24CRs547-R] The skirt support shall allow the movement of the cryostat cylinder in a radial direction due to thermal loads during accident events.

[24CRs71-R] The cryostat skirt supports shall be connected to the embedded parts in the bioshield.

[24CRs548-R] The toroidal lugs of the cryostat support system shall be welded to the outer edge of the horizontal plate.

[24CRs74-R;Defined Requirement] The male toroidal lugs shall be connected to the female lug in the bioshield to react to the horizontal movement of the cryostat during seismic events.

[24CRs88-R] All penetrations that connect permanent links between inside and outside equipment (such as magnet feeders and cooling water pipes) shall exit only through the permanent part of the cryostat (cylinder, or parts of the base section).

[24CRs687-R;Defined Requirement] Reliable, long-term, post-accident cooling shall be available to remove the maximum power that is transferred to the vacuum vessel under such conditions.

[24CRs688-R;Defined Requirement] Reliable separation, typically provided by two barriers, shall be provided between volumes that may contain air and hydrogen, including during off-normal conditions.

[24CRs689-R;Defined Requirement] The use of halogenated materials is forbidden in areas or volumes that are served by the Detritiation System (DS) or by the Tokamak Exhaust Processing System (TEPS). Exceptions shall require a formal project approval. (The procedure for formal project approval shall include approval of the Nuclear Safety and Tritium Plant Responsible Officers.)

[24CRs690-R;Defined Requirement] Habitable space shall provide safe ingress and egress paths

2.4 Mechanical requirements (including load conditions)

[24CRs465-R;Defined Requirement] The general mechanical loading conditions are specified in the *Load Specifications (LS)* [8] and in the detailed load specification document for the cryostat [9].

[24CRs466-R;Defined Requirement] Operation shall be restored without maintenance intervention after events in categories I and II, and with a maintenance intervention after one category III event.

[24CRs467-R;Defined Requirement] After a category IV event, the overall deformation of the components shall be limited, in order to avoid damage to other SIC components.

[24CRs459-R] The cryostat support structure system shall be designed for vertical and horizontal loads (gravity and seismic forces including rocking effects) transmitted from the cryostat itself and in-cryostat components.

[24CRs551-R] The cryostat support structure system shall transmit all operation/accidental loads from the tokamak and the cryostat itself to the building.

[24CRs552-R] The cryostat support structure system shall accommodate thermal movement of the cryostat.

[24CRs395-R;Defined Requirement] The Cryostat system shall withstand all loads that are applied during the normal and off-normal operational regimes, and at specified accidental and fault conditions.

[24CRs553-R;Defined Requirement] The Cryostat system shall withstand *Inertial loads*: these are due to accelerations due to gravity and seismic events (SL-1, SMHV and SL-2).

[24CRs554-R;Defined Requirement] The Cryostat system shall withstand *Kinetic pressure loads*: significant on the ITER Cryostat vessel due to externally applied atmospheric pressure to the internal vacuum, and internal pressure due to helium leakage or water and air ingress.

[24CRs555-R] The Cryostat system shall withstand *Electromagnetic loads*: during plasma start-up/shut-down, plasma disruption/VDE and poloidal coils quench.

[24CRs464-R] The Cryostat system shall withstand *Thermal loads*: the pedestal ring and surrounding structure during normal operation and during water, air ingress and helium spillage event.

[24CRs549-R;Defined Requirement] The TCPH shall withstand the operating loads, as well as loads that arise due to accidents.

[24CRs664-I]

[24CRs665-R] The Cryostat Pressure Relief Devices (PRD) shall withstand all loads that are applied during the normal and off-normal operational regimes, and at specified accidental and fault conditions.

[24CRs666-R] The Cryostat Pressure Relief Devices (PRD) shall remain functional during all operational and during CrICE events.

[24CRs667-R] The Cryostat Pressure Relief Devices (PRD) shall be able to adapt to Cryostat thermal movements.

2.5 Seismic requirements

[24CRs106-R;Defined Requirement] The Cryostat system shall resist a seismic level SL-1 without any need of repair or intervention [8].

[24CRs556-R;Defined Requirement] The Cryostat system shall resist a seismic level SMHV and SL-2 without significant leakage of the cryostat.

[24CRs353-R;Defined Requirement] The combination of loads from earthquakes with other loading events, as defined in the *Load Specifications (LS)* [8], shall lead to no damage to the cryostat vessel.

[24CRs468-R;Defined Requirement] The Cryostat penetrations and port duct and port cell bellows shall resist a seismic level SL-1 without any need of repair or intervention.

[24CRs557-R;Defined Requirement] The Cryostat penetrations and port duct and port cell bellows shall resist a seismic level SMHV and SL-2 without significant leakage of the cryostat.

2.6 Fire protection requirements

[24CRs163-R;Defined Requirement] None of the components of the cryostat shall be flammable. Electric cables, and other materials that run through a fire sector, and that are required to operate in the event of fire, shall be fire-resistant (CR1 cables, or cables that are protected by a fire-resistant material for radiologically-controlled buildings).

[24CRs691-R;Defined Requirement] The components of two redundant SIC-1 systems shall be located in independent and separate fire sectors (fire sectors are defined in Section 7.9.7). Each train (A and B) of the electrical supply and the I&C cabling of the SIC-1 cubicles shall be routed through independent and separate fire sectors. The SIC-1 cubicles shall be located in dedicated rooms that do not contain SIC-2 or SR or non-SIC cubicles.

[24CRs692-R;Defined Requirement] The SIC-1 cubicles shall be equipped with automatic fire detection and suppression systems.

[24CRs693-R;Defined Requirement] Doors and penetrations through fire barriers shall offer the same degree of fire resistance as the rest of the fire barrier. In the event of an internal fire, doors shall maintain their integrity, insulation and leak tightness with a pressure difference equal to +/-0.05 bar between the affected fire sector and the adjacent areas.

2.7 Electrical requirements

[24CRs99-R] The electrical requirements shall be in compliance with the latest approved version of the *Electrical Design Handbook (EDH)* [10].

[24CRs348-R;Defined Requirement] The Cryostat system shall require no more than 21 kVA from 0.4 kV class II-IP power supply, for cryostat instrumentation and pedestal ring heating.

[24CRs350-R] The Cryostat system shall require no more than 2000 kVA from 15 kV class IV power supply, for the site workshop utilities.

2.8 Earthing and insulation requirements

[24CRs165-R] The cryostat shall be electrically earthed straight through the structural supports without the use of electrically insulating breaks or grounding resistors.

[24CRs166-R;Defined Requirement] -R

Electrical earthing shall be in compliance with the latest approved version of the *Electrical Design Handbook (EDH)* [10].

2.9 Instrumentation and control requirements

[24CRs558-R] The temperature on the cryostat shall be monitored near PF4 to observe the ohmic heating in the wall.

[24CRs104-R] The temperature on the cryostat shall be monitored on the base section, to observe any cryogen spills.

[24CRs396-R] Relative movements of the cryostat and deformation of some bellows shall be monitored.

[24CRs397-R] Strain at certain locations on the cryostat shall be monitored.

[24CRs398-R;Defined Requirement] Accelerations at several locations of the cryostat shall be monitored.

[24CRs64-R;Defined Requirement] The vacuum monitoring system and leakage detection system are part of the vacuum pumping system.

[24CRs469-R] The Cryostat Venting System shall have an appropriate instrumentation and control system supplied by vacuum pumping system. This instrumentation shall include venting/gas purging valves.

[24CRs470-R] The cryostat instrumentation and control should follow the latest approved version of the *Plant Control Design Handbook* [12].

[24CRs287-R;Defined Requirement] To prevent the build-up of ice on the cold mass, with a consequent ozone formation hazard, the air in-leakage rate into the cryostat shall be measured by the cryostat leak detection system.

[24CRs694-R;Defined Requirement] The redundancy SIC-2 cubicles can be implemented with the SR, and non-SIC cubicles at dedicated and separate places in the same room. The minimum distance between SIC-2 and non-SIC cubicles shall be 2 m. This room (and not the cubicles themselves) shall be equipped with automatic fire detection and suppression systems.

[24CRs695-R;Defined Requirement] Concerning the SIC-2 cubicles for which there is no redundancy requirement, their implementation in the same room as SR and non-SIC cubicles shall be possible if all the cubicles (SIC-2, SR and non-SIC) are equipped with automatic fire detection and suppression systems.

[24CRs696-R;Defined Requirement] In any given room, all the SIC-2 cubicles shall be on the same Train (A or B) for power supply and I&C cabling.

2.10 Computer hardware and software requirements

[24CRs168-R] The computer hardware and software requirement should follow the latest approved version of the *Plant Control Design Handbook* [12].

2.11 HVAC requirements

[24CRs161-R] Provisions shall be made to control the temperature of the cryostat wall and ports/penetrations to remove ohmic dissipation resulting from currents that are induced by tokamak operation, and to prevent the cryostat wall temperature from dropping below 0ºC during the machine down time, or normal operation time.

[24CRs438-R] The cryostat space room between the cryostat wall and bioshield shall be maintained at an appropriate temperature and pressure.

2.12 Vacuum requirements

[24CRs516-R;Defined Requirement] The port cell bellows shall be designed for 0.16 MPa absolute, and the leak rate shall be not greater than 100% (by volume) per day at 300 Pa pressure differentials.

[24CRs123-I] The nominal pressure inside the cryostat, at the start of normal operation conditions, is less than 10^{-4} Pa total gas pressure.

[24CRs124-R] The leak rate for the completed Cryostat (including all in-cryostat components and attachments) shall be less than 1×10^{-4} Pa m^3/s.

[24CRs129-R] The maximum acceptable out-gassing rate, and the maximum allowable leak rate, shall be in accordance with those specified in the *ITER Vacuum Handbook* [5].

[24CRs172-R] The cryostat roughing pumping and cryo-pumping systems shall provide the services to pump down the cryostat.

[24CRs559-R] The capability to purge the cryostat with dry air or gaseous nitrogen at room temperature shall be provided.

[24CRs130-R] Prior to cool-down, the cryostat shall be evacuated to a base pressure of 10^{-4} Pa at room temperature.

[24CRs475-R;Defined Requirement] For double bellows, inter-space vacuum monitoring shall be incorporated in the design.

2.13 Thermal management requirements

[24CRs92-R] The cryostat wall temperature shall be maintained at room temperature during normal operation.

[24CRs455-R] The cryostat temperature shall be maintained at room temperature at the pedestal ring and basement section location during the normal operating.

[24CRs399-R] The pedestal ring and horizontal plate area shall avoid undue thermal stress and sub-zero temperature formation outside the cryostat.

[24CRs93-R;Defined Requirement] Under the design basis accident conditions that are defined in Section 1.4, the cryostat metallic structure shall tolerate being subject to transient contact by low temperature or high temperature fluids (such as due to the loss of magnet, thermal shield or primary heat transfer system coolant).

[24CRs108-R;Defined Requirement] The cryostat wall temperature shall not drop below the dew point of the ambient air during operation and machine down times.

2.14 Electromagnetic requirements

[24CRs117-R] The toroidal electrical resistance of the cryostat cylindrical section shall be greater than 10 $\mu\Omega$ so as not to affect plasma breakdown.

[24CRs118-R] Primary cooling pipes and manifolds shall not require electrical insulation from the cryostat wall.

[24CRs120-R] The cryostat shall not cause a significant increase in the volt-second requirements for the PF coil system, or unduly increase the stray magnetic field in the plasma during start-up.

2.15 Nuclear shielding requirements

[24CRs560-R;Defined Requirement] The cryostat penetration port ducts for neutral beam heating and diagnostics shall be adequately shielded.

[24CRs697-R;Defined Requirement] The total quantity of hydrogen inside the vacuum vessel and connected volumes (HNBI, DNBI, cryopumps) including the hydrogen contained in the circuits or the cryopanels and the one that is produced by chemical reactions (such as between beryllium and coolant water or steam that leaks from a failed in-vessel component) shall be limited to below 4 kg H2 (that is, the quantity at which deflagration would lead to a maximum pressure exceeding the vacuum vessel safety assessment pressure value, 0.2 MPa). This limitation implies the need to avoid elevated temperatures that would accelerate the beryllium/steam reaction, including the termination of plasma power in the event of loss of cooling of plasma-facing components, and the limitation of dust accumulation on hot surfaces.

[24CRs698-R;Defined Requirement] The As Low As Reasonably Achievable (ALARA) principle shall be applied to minimize occupational doses.

[24CRs699-R;Defined Requirement] The ALARA procedure shall be applied before work in a radioactive zone is authorized.

[24CRs700-R;Defined Requirement] Radioactive and other hazardous liquid and gaseous effluents that arise from operation shall be limited to the maximum extent possible in the design, and their impact shall be maintained As Low As Reasonable Achievable (ALARA) during operation.

2.16 Chemical requirements

[24CRs114-I] Not applicable.

2.17 Materials requirements

[24CRs137-R;Defined Requirement] All the Cryostat components material shall be selected in accordance with the properties specified in the Materials Properties Handbook as per ITER project requirements[1].

The cryostat shall be made of dual mark stainless steel type 304L/304 plates as allowed in ASME Section VIII, Division 2, or equivalent material from other codes, and shall be as per ASTM standard. Necessary consideration for any specific requirement of control of trace element in the chemical composition (Co & Nb) shall be considered. The methods for controlling the corrosion behaviour during operation shall be established for all systems.

[24CRs136-R;Defined Requirement] The residual magnetic field inside the cryostat shall not exceed 1 mT for enabling access for personnel or remote handling equipment and accordingly, the ferrite content of the base material SS304L/304 shall be as per the material specification document, and the magnetic permeability requirement shall be as per the ASTM standard [12].

[24CRs138-R] All bellows shall be austenitic stainless steel or appropriate material.

[24CRs139-R;Defined Requirement] Flexible seal materials shall be compatible with tritium and the appropriate levels of neutron/gamma radiation.

[24CRs140-R] The TCPH shall be manufactured using same material with cryostat main components.

[24CRs670-R;Defined Requirement] The Cryostat Pressure Relief Devices (PRD) shall be made shall be made of stainless steel type 304L or304 plates as allowed in ASME Section VIII, Division 2, or equivalent material from other codes, and shall be as per ASTM standard. Necessary consideration for any specific requirement of control of trace element in the chemical composition (Co and Nb) shall be considered.

[24CRs671-R] The ferrite content of the PRD base material SS304Lor304 shall be as per the material specification document, and the magnetic permeability requirement shall be as per the ASTM standard.

[24CRs672-R] For the Cryostat Pressure Relief Devices (PRD) any sealing material shall be radiation hard; metallic sealing shall be preferred.

2.18 Manufacturing requirements

[24CRs561-R] The cryostat shall have four main sections assembled in the Tokamak pit lowered from the top. These sections are welded in the pit to form the full cryostat except top lid that will be bolted structurally with lip seal welded.

[24CRs639-R] The orientation in the toroidal direction shall be according to the port allocation specified by the ITER top level project requirements.

[24CRs115-R] The inner surface of the cryostat wall and all internal components shall be thoroughly cleaned in accordance with the requirements of the *ITER Vacuum Handbook* [5] prior to initial pump down.

[24CRs472-R] The cryostat system shall be designed for maximum shop manufacture and sub-assembly and testing consistent with the ITER site transportation limits.

[24CRs154-R] The cryostat system shall be designed so as to minimize critical path assembly activities in the tokamak pit.

[24CRs143-R] The design shall be such that parts of the cryostat can be sub-assembled at the ITER site, and transported and lifted into the pit.

[24CRs562-R] Field joints of cryostat sections in the pit shall meet the welding and testing requirements as per the ASME Section and *ITER Vacuum Handbook* [5].

[24CRs144-R] Necessary weld qualifications for the factory weld joints as well as field joint shall be performed prior to production weld.

[24CRs145-R] The surface of the components shall be protected from damage and contact with foreign materials throughout the manufacturing and transportation activities.

[24CRs400-R] The vacuum exposed surface of the cryostat shall have average surface roughness (Ra) not greater than 12 μm measured using the electric stylus method to meet the high vacuum requirement, as specified by the *ITER Vacuum Handbook* [5].

[24CRs563-R] The vacuum exposed surface of the cryostat shall be properly surface treated to ensure that the emissivity of the surface is not greater than 0.5 at room temperature.

[24CRs142-R] Some qualification R&D shall be needed for achieving an acceptable tolerance in cryostat fabrication.

[24CRs234-R;Defined Requirement] The rectangular bellows shall be qualified by prototype testing.

2.19 Construction requirements

[24CRs564-R] Cryostat segments shall be fabricated in industry.

[24CRs565-R] Cryostat segments shall be transferred to ITER site for sub assembly.

[24CRs150-R] The welding of the major subassemblies to form sections shall be performed in temporary work shop outside of the Tokamak building.

[24CRs401-R] The fabricated segments of the cryostat shall be sub-assembled, at the ITER site temporary workshop, into four main sections: base section, lower cylinder, upper cylinder and top lid.

[24CRs149-R] Cryostat sections shall be assembled in the pit.

[24CRs701-R;Defined Requirement] Air flow within the buildings shall be directed from lower to higher zones of contamination.

[24CRs702-R;Defined Requirement] Designated areas within the buildings shall resist the effects of accidents such as pressurization failure, explosion, loss of secondary confinement for radioactive inventory, pipe whip, and fire, if failure threatens safety equipment or workers.

[24CRs703-R;Defined Requirement] Structural integrity of buildings shall be ensured in case of underpressure, for example due to failure of vacuum boundaries (even in worst-case scenarios).

[24CRs704-R;Defined Requirement] Zoning shall be established in the nuclear buildings, to protect people, equipment, and the environment from the effects of perceived hazards during all phases of the facility life cycle. For the ITER facility, zoning applies to: Ventilation, Radiological, Anti-deflagration, Beryllium, Magnetic, Radiofrequency, Fire, Waste.

[24CRs705-R;Defined Requirement] The radioactive inventory shall be controlled in the fire sectors of the buildings by physical means, administrative means, or both, in order to limit the radioactive inventory that is potentially vulnerable to a single fire.

2.20 Assembly requirements

[24CRs402-R] The four main cryostat sections shall be transported to, and assembled in, the Tokamak pit.

[24CRs403-R] Field joints in the pit of cryostat sections shall meet the welding and testing requirements as per ASME Section and *ITER Vacuum Handbook* [5].

[24CRs152-R] Provisions shall be made for the cryostat initial assembly and testing as a part of the entire cryostat assembly scheme.

[24CRs153-R] Provisions shall be made for the detection and in-situ repair of leaks on all assembly joints, and for replacement or repair of all bellows and flexible ducts.

2.21 Installation requirements

[24CRs156-R] Installation requirements for Cryostat system shall be defined in the ITER Assembly Procedure.

2.22 Testing and inspection requirements

[24CRs158-R] The cryostat vacuum/pressure boundary shall allow NDT and vacuum leak testing for the welded joints performed both at the supplier site and on the ITER site according to the fabrication stages.

[24CRs159-R] The design shall allow for a structural pressure and leak test following complete assembly of the cryostat, and all elements penetrating the vacuum/pressure boundary.

[24CRs404-R] The dimensional inspections during fabrication and assembly processes shall be performed in accordance to the applicable code and technical specifications.

[24CRs624-R] For SIC part of the cryostat, welding and inspections are QRA. Unscheduled inspections are authorized.

[24CRs706-R;Defined Requirement] The integrated commissioning shall include a mechanical verification of position, loads, stresses, strains, magnet wedging, vibrations and temperatures under operational conditions.

2.23 Decommissioning requirements

[24CRs170-R;Defined Requirement] The Cryostat system parts consisting of activated stainless steel at end-of-life, shall require remote cut-up and crating, for shipment to a disposal site. During the deactivation and decommissioning phase, the components of ITER shall be protected against corrosion, to prevent spreading of contamination or unacceptable hazards to the public or workers.

[24CRs640-R] Prior to performing the disassembly, tools and structural frames will be introduced into the cryostat to provide necessary additional support The access on top lid is available to extent cryostat confinement in order to make it possible to perform handling operations inside the cryostat and any additional cutting operations on the removed components.

2.24 Other services

[24CRs648-I] None.

[24CRs707-R;Defined Requirement] The routing/piping of confinement barriers shall be such as to avoid potential damage to confinement systems by movement of equipment during maintenance.

[24CRs708-R;Defined Requirement] Prior to opening the double confinement of a hydrogen-bearing system, measures shall be taken to avoid the presence of potentially explosive conditions.

[24CRs709-R;Defined Requirement] The marking (signing) of the radation zones from greyish blue to red shall follow the norm (ref. MF M 60-101) and shall be clearly posted on all access routes to the zones. The marking of the radiation zones shall be modified according to every change to the zoning.

[24CRs710-R;Defined Requirement] Waste zones shall be established within the nuclear facilities and Cryostat does not have any waste zone.

[24CRs711-R;Defined Requirement] All solid, liquid and gaseous toxic products needed for ITER construction and operation shall be identified and their quantity and characteristics estimated for normal operation, including maintenance operations.

3 SAFETY REQUIREMENTS

3.1 Safety design criteria

[24CRs473-R;Defined Requirement] The layout of cooling water pipes and cryogenic lines shall prevent common cause failure, with consequent concurrent release of water and helium into the cryostat. All systems shall be designed in accordance to the ITER Human Factor Integration Plan (HFIP).

[24CRs712-R;Defined Requirement] Specific design provisions shall be undertaken to avoid that solid, liquid and gaseous toxic products affect workers during normal operations and to avoid spread of these materials into rooms accessible to workers.

3.1.1 Safety Functions

3.1.1.1 Cryostat

[24CRs187-I;Defined Requirement] The cryostat system has no confinement function.

3.1.1.2 TCPH

[24CRs189-R;Defined Requirement] The TCPH and associated bellows are classified as SIC-1 for the confinement function, as stated in the *Safety Important Functions and Components Classification Criteria and Methodology* [14]

3.1.2 Safety Importance Classification and Seismic Requirements

[24CRs95-I] Not applicable.

3.2 Safety limits

[24CRs209-R;Defined Requirement] External air leaks shall be maintained below the ozone hazard threshold of 0.1 Pa m^3/s.

[24CRs713-R;Defined Requirement] In accordance with the European Directive 94/9/EC(ATEX), hazardous locations shall be classified, and anti-deflagration zones established, according to the frequency with which an explosive atmosphere may form, and the length of time for which this atmosphere lasts:

Zone 0: location where an explosive atmosphere consisting of a mixture of air and inflammable gases, vapours or mist is present permanently, frequently or during long periods

Zone 1: location where an explosive atmosphere consisting of a mixture of air and inflammable gases, vapours or mist is liable to be present occasionally under normal operation

Zone 2: location where an explosive atmosphere consisting of a mixture of air and inflammable gases, vapours or mist is not likely to be present under normal operations or, if present, only for short periods

Zone 20: location where explosive atmosphere in the form of combustible dust cloud is present in the air permanently, frequently or during long periods

Zone 21: location where explosive atmosphere in the form of combustible dust cloud is liable to be present occasionally under normal operation

Zone 22: location where explosive atmosphere in the form of combustible dust cloud is not likely to be present under normal operation or, if present, only for a short period.

[24CRs714-R;Defined Requirement] If there is no potential for an explosive mixture, the area shall be defined as having ”no zoning”.

[24CRs715-R;Defined Requirement] Beryllium zones shall be established in accordance with the ITER zoning criteria and Access to beryllium zones shall be restricted Proper signage shall be placed in areas according to beryllium zoning requirements.

[24CRs716-R;Defined Requirement] The radiofrequency exposure for personnel who are working in areas that are adjacent to sources of hazard shall comply with the following limits that are recommended by the International Commission on Non-Ionizing Radiation (ICNIR).

[24CRs717-R;Defined Requirement] The exposure limit for workers expressed as Equivalent Power density for ICRH plane waves shall be less than 1.0 mW.cm-2. The power density for ECRH and LHCD waves shall not exceed 5 mW.cm-2.

[24CRs718-R;Defined Requirement] For solid radioactive and other hazardous wastes that arise throughout the plant life (from construction through to decommissioning and dismantlement) the quantity and the level of radioactivity, or toxicity, shall be minimized by design and operation.

3.3 Monitoring requirements

[24CRs227-R] Monitoring of external air leaks shall be provided by PBS 31.

[24CRs719-R;Defined Requirement] Oxygen levels in zones that are accessible to personnel, where there is a potential risk of anoxia, shall be monitored, with appropriate alarm systems.

[24CRs720-R;Defined Requirement] The cryogenic installations are exposed to the risk of anoxia and they shall comply to the general requirement on monitoring of oxygen levels in zones accessible to personnel.

3.4 Safety-specific instrumentation

[24CRs224-I] Not applicable.

3.5 Safety related testing and inspection

[24CRs230-R;Defined Requirement] The TCPH and associated bellows shall meet specific site licensing requirements for nuclear components providing first and second radioactivity barrier (for example, the Order dated 7th February 2012 Concerning Quality of Design, Construction and Operation of Basic Nuclear Installation).

3.6 Qualification requirements

[24CRs566-I] Not applicable.

3.7 Safety related operations and procedures

[24CRs238-I;Defined Requirement] Not applicable.

3.8 Occupational safety

[24CRs567-R;Defined Requirement] In-cryostat inspection and repair shall be performed in accordance with the safety guidelines derived from the Occupational radiation exposure study.

[24CRs568-R;Defined Requirement] Cryostat system shall have provision for safe human entry inside the cryostat during the maintenance.

[24CRs241-R;Defined Requirement] Cryostat system shall have necessary supports to reach the location to be inspected/repaired during the maintenance.

[24CRs240-R;Defined Requirement] Design and operation (shielding, remote operations, and equipment design) shall minimize the radiation dose to personnel in the course of maintenance and decommissioning.

[24CRs478-R;Defined Requirement] Design and operation shall minimize the vacuum hazard to workers during maintenance.

[24CRs721-R;Defined Requirement] The collective annual worker dose, averaged over the operational life time of ITER, shall be ALARA and in any case shall not exceed an annual target of 0.5 person.Sv.

[24CRs722-R;Defined Requirement] The dose rate and the level of atmospheric and surface contamination, in the rooms that are accessible to personnel, shall be monitored using fixed and/or mobile equipment, depending on the potential or proven hazards.

[24CRs723-R;Defined Requirement] Fixed radiation monitoring equipment shall display readings at a central control location, and at points of access to the monitored rooms, so that personnel can assess the radiological status of the rooms before entering.

[24CRs724-R;Defined Requirement] For radiological zones, other than orange and red (see Section 7.9.2), the individual sources of radiation shall be clearly indicated, and shall be communicated to workers prior to entry.

[24CRs725-R;Defined Requirement] Human access shall be forbidden in radiological red and orange zones (see Section 7.9.2), without special authorization from the ITER Director-General.

[24CRs726-R;Defined Requirement] Human access to radiological yellow zones (see Section 7.9.2) shall be subject to specific authorization procedures.

[24CRs727-R;Defined Requirement] ITER Organization shall develop and implement a suitable Radiation Protection Program (RPP) that will include worker classification and access control as well as a system of authorization and associated procedures.

[24CRs728-R;Defined Requirement] The ITER RPP shall be reviewed periodically to check its efficiency, and to optimize it where possible.

[24CRs729-R;Defined Requirement] Personnel exposure to ionizing radiation shall be monitored via a network of detectors that are located in rooms together with, as appropriate, active and passive dosimeters that are worn by the personnel and individual medical surveillance. This includes but is not limited to monitoring of tritium, neutron, gamma, radon gas, particles, and 14C.

[24CRs730-R;Defined Requirement] The evacuation alarm activation level shall be 1 DAC in areas with human habitation of a potentially-contaminated sector. An alert will be set at 0.1 DAC to inform the workers to place everything in a safe state before evacuating. (Derived Atmospheric Concentration is defined as the airborne concentration that leads to the maximum allowed dose for workers (20 mSv), if breathed during the maximum annual work duration (2000 hours), without any external dose. For tritium only exposure, 1 DAC is equal to 3x105 Bq/m3.)

[24CRs731-R;Defined Requirement] At levels higher than 1 DAC, specific authorization shall be required to enable access of personnel equipped with appropriate individual protections.

[24CRs732-R;Defined Requirement] Only internal exposure hazard shall be taken into account, the derived atmospheric concentration (DAC) is used as defined in PR1242.

[24CRs733-R;Defined Requirement] Radiation zones shall be established in accordance with the risks of internal exposure (through inhalation of airborne contamination and skin transfer) and of direct external exposure. Each zone corresponds to a dose rate range, and has associated time and access conditions.

[24CRs734-R;Defined Requirement] The radiological zoning shall be based on total dose and it shall be defined for each plant operation state. Access conditions for the personnel to the radiological zones shall be implemented

[24CRs735-R;Defined Requirement] Total dose rate shall be the sum of external dose rate and internal dose rate. Internal dose rate can be calculated, using airborne concentration, as a ratio of “Derived Air Concentration” (DAC) (see definition of DAC in PR1242). In case of exposure of the eye lens (crystalline), these values shall be multiplied by 0.3 (150/500). Human access shall be forbidden without special authorization.

[24CRs736-R;Defined Requirement] French regulations classify workers as Type A and Type B. Type A workers shall include those whose exposure to ionizing radiation may lead to a dose greater than 6 mSv during 12 consecutive months, and Type B workers include those exposed to ionizing radiation and not classified Type A.

[24CRs737-R;Defined Requirement] Thresholds and conditions of exposure of personnel to magnetic fields shall be established. Proper signage shall be placed in areas where the magnetic thresholds might be exceeded. Magnetic field zones and access and control conditions shall be established.

[24CRs738-R;Defined Requirement] Information shall be provided on panels at relevant places to inform people about the risks, the individual protection systems needed, the state of the equipment, alarms and other information relevant to occupational health and safety

[24CRs739-R;Defined Requirement] The wear of appropriate individual protection equipement shall be mandatory before access to a zone with safety risks.

[24CRs740-R;Defined Requirement] If personnel must enter a zone that is contaminated by radioactive or hazardous substances, they shall wear appropriate personal protective equipment, as required for their protection and to limit the spread of contamination.

[24CRs741-R;Defined Requirement] The inventory for all solid, liquid and gaseous toxic products shall be limited to the maximum extent possible in the design, and their impact maintained As Low As Reasonable Achievable (ALARA) during operation.

[24CRs742-R;Defined Requirement] In order to improve safety on the ITER site, all identification, labelling and signage shall be standardised to reduce the likelihood of error.

3.9 Environmental impact requirements

[24CRs243-R;Defined Requirement] Venting of the cryostat, during the DT phase of operation, shall be through the detritiation system. Before venting the vacuum vessel, the vessel and in-vessel components shall be baked to remove as much tritium as possible.

[24CRs743-R;Defined Requirement] Definition status (Complete/TBC):FI Parent requirements: PR852

Liquids that are used in ITER systems may contain activation products, which shall be removed before the liquids can be released into the environment or solidified as waste. All liquids shall be rendered to a safe, stable form during the deactivation phase, further cooling shall be unnecessary.

[24CRs744-R;Defined Requirement] No radioactive material processing shall lead to a high-level radioactive waste stream.

[24CRs745-R;Defined Requirement] Solid radioactive waste shall be transported (if required) from its source location to the treatment facility using appropriate containers and transport systems that ensure the maintenance of the required level of confinement and radiation shielding.

[24CRs746-R;Defined Requirement] All effluents (airborne and waterborne) shall be identified, and their quantity and characteristics shall be estimated for normal operation and maintenance. This shall include, as a minimum, radioactive materials, hazardous materials, direct radiation, magnetic fields, and thermal emissions.

[24CRs747-R;Defined Requirement] Fluid effluents shall be monitored, characterized, controlled and discharged per approved procedures.

[24CRs748-R;Defined Requirement] Systems that contain water or liquid effluents shall be suitably monitored (including periodic inspection) in order to detect, as soon as possible, a leakage, and shall be equipped with an appropriate alarm system.

[24CRs749-R;Defined Requirement] Potential liquid effluents that are generated by the fire suppression substances, or a leak of an effluent-bearing system, shall be collected, to prevent dispersion of radioactive or toxic substances.

3.10 Safety system reliability requirements

[24CRs249-R] The frequency of air breaks for the cryostat shall be less than 10^{-2} per year. (This is to prevent damage from ice formation.)

[24CRs750-R;Defined Requirement] Appropriate measures (for example, confinement, monitoring, decontamination, exposure limitation, access control) shall be implemented in order to minimize worker exposure to beryllium and beryllium compounds throughout ITER lifetime (including ITER construction and its non-nuclear phase).

[24CRs751-R;Defined Requirement] ITER shall include appropriate systems to enable the removal of accumulated heat (from electrical equipment) under any design basis situations, in order to protect the personnel and SIC components.

3.11 Other safety requirements

[24CRs252-I] There are no other safety requirements.

[24CRs752-R;Defined Requirement] Temporary access areas or changing rooms for workers to put on and remove any protective equipment that is required to protect against internal/external exposure to ionizing radiation or hazardous substances (such as beryllium) shall be provided, as needed, especially for maintenance operations on ventilation and filtration components. They shall be implemented as close to the working area as possible, and shall include waste collection areas.

[24CRs753-R;Defined Requirement] Plasma scenarios for H, He and D operation shall necessarily encompass a wide range of plasma parameters up to the maximum technical capability of the tokamak in order to address:
Development of the discharge scenario required for full D-T phase reference operation, including features such as plasma current initiation, current ramp-up, formation of a divertor configuration and current ramp-down

Commissioning of core tokamak systems, such as Poloidal Field system, Correction Coils system, in-vessel coil systems up to the maximum value of plasma current and toroidal field (15 MA / 5.3 T)
Progressive commissioning of the Plasma Control System, together with interlock and protection circuits and safety-important systems, as required by the technical performance of the tokamak and the level of plasma performance achieved

Development of the "Progressive Start-up" strategy as per the RPrS [R08] for determination of maximum loads on vessel and in-vessel structures due to disruptions and vertical displacement events

Characterization of hydrogenic retention and dust production, and demonstration of techniques for their control

Commissioning of appropriate mitigation techniques against the consequences of plasma transients and loss of control

Demonstration of power handling capabilities of plasma-facing components within the heat load limitations of H, He, and D plasmas including semi-detached divertor operation and low impurity level

Achievement of type-I ELMy H-modes for sufficient durations to allow an adequate physics basis for the implementation of full D-T plasma operation including aspects such as H-mode power threshold scaling and energy and particle transport at the ITER scale

Finalization of nuclear commissioning with a minimum amount of tritium.

4 OPERATION AND MAINTENANCE

[24CRs255-R] The configuration of the cryostat shall provide access between all in-cryostat components and cryostat wall for machine assembly, maintenance and repair.

4.1 Operation

4.1.1 System operation states

[24CRs290-R] The cryostat and tokamak start-up schedule shall be:

- Rough pump the cryostat and dehydrate by purging and venting with dry gas
- High vacuum pump the cryostat to a pressure of 10^{-4} Pa
- Cool the thermal shields to liquid nitrogen temperature and magnets to liquid helium temperature.

[24CRs405-I] The operating states of cryostat are listed in the following table.

[24CRs429] Table 4.1: Operating states of cryostat

[24CRs509]

ITER Operation State Plant subsystem	Construction/Long Term Maintenance (LTM)	Short Term Maintenance (STM)	Test & Conditioning State (TCS)	Short Term Stand-by (STS)	Plasma Operation (POS)
Duration	>30 days	1-30 days		<8 hrs	
Cryostat Pressure	Atmosphere / [Vacuum]	Vacuum	Vacuum	Vacuum	Vacuum

4.1.2 Operational conditions

[24CRs414-I] Not applicable.

[24CRs754-R] Cryostat will be operational before First Plasma.

4.1.3 Main control room

[24CRs416-I] Not applicable.

4.2 Maintenance

[24CRs457-R] Cryostat shall have provision for venting for maintenance purposes.

[24CRs308-R] As much maintenance as feasible inside the cryostat shall be done hands-on, and the cryostat penetrations shall allow for the installation of access ways to enable personnel to access the maintenance zones.

[24CRs310-R] Adequate internal access to components located inside the cryostat shall be provided by access ports in the top lid, the cylinder, and on the base section.

[24CRs101-R] The cryostat top lid shall be designed such that parts of the vacuum/pressure boundary can be cut away to give access for maintenance of magnets, and re-welded and tested following completion of these maintenance operations.

[24CRs312-R;Defined Requirement] The design of the access port penetrations in the cryostat shall be such as to allow the deployment of the equipment used to enable personnel maintenance access inside the cryostat to designated components such as the magnet feeder breaks boxes, tightening of PCRs for TF magnets and tightening CS vertical compression, for in-situ maintenance.

[24CRs314-R;Defined Requirement] The cryostat and bellows shall be designed such that the following maintenance operations can be conducted without breaking cryostat vacuum:

- Remote maintenance of divertor cassettes through the lower port
- Remote cutting and welding of the divertor coolant pipes inside VV
- Remote maintenance of blanket modules through the equatorial ports
- Remote cutting and welding of the blanket coolant pipes inside VV
- Remote access of all equipment introduced into the VV ports through Cryostat port/penetration.

[24CRs479-R] Short term maintenance is allowed according to the following pattern:

- Daily checks, controls, conditioning of equipment, fluids preparation within less than 8 hours of elapsed time.
- Routine maintenance shall not be required with intervals less than 2 operational weeks. Routine maintenance covers minor adjustments, calibration, replacements of equipment. Routine maintenance shall be performed within less than 2 days elapsed times.
- Short term maintenance must take into account the zoning constraints (access control, environmental conditions) and corresponding time constraints.

[24CRs297-I] Major shutdowns are scheduled to allow for major scheduled replacements, overhauls/refurbishments, repairs of equipment. ITER requirements for this maintenance interval could be up to two years.

[24CRs298-R] No scheduled maintenance shall be required outside these defined periods unless it can be performed during normal plasma operation (hidden maintenance).

4.2.1 Maintenance plan

[24CRs133-R] Planned maintenance in the VV and its ports shall not require breaking the cryostat vacuum.

[24CRs406-R] Access to the interior of the cryostat for repair shall require breaking the cryostat vacuum. It shall be provided at three levels:

- Top of the cryostat via a central access hatch and 4 perimeter hatches
- 4 divertor port level hatches
- 7 hatches (4 of them shared with instrumentation) at the lower horizontal intermediate floor
- 4 hatches at the lower level cryostat cylinder of base section.

[24CRs323-R] Internal inspection of the cryostat might be required following an accident. To the greatest extent possible, such inspections shall be performed hands-on, using specially installed shielded access ways to allow personnel access from outside the bioshield to the location that is to be inspected.

[24CRs407-R] Magnets or vacuum vessel sector replacement should be possible provided it occurs before the machine and cryostat become inaccessible due to the high background radiation dose.

[24CRs480-R] A maintenance plan shall be prepared by the supplier. The minimum information required within this maintenance plan is the following:

- Scheduled operations (such as controls, checks, adjustments, calibrations, overhauls,and replacements) derived from Safety and Security regulations, and identified as necessary by the supplier in order to ensure the best operation of the system in its intended operational scenario. At least task identification and interval is required.
- Critical unscheduled operations (such as replacements and repairs) that may impact ITER availability and/or introduce needs for additional support (spares, procedures, training, tools and test equipment, infrastructure).

[24CRs755-R] No Maintenace equipment Cryostat, Not related to Cryostat(design/manufacturing /assembly)

[24CRs756-R;Defined Requirement] The Maintenance Classification is intended to support the performance of relevant engineering analyses, and an adequate implementation of the ITER limit for annual collective radiation dose exposure, as established in [PR1129-R]. Therefore, this classification is maintenance environment oriented, and shall be assigned to any maintenance task that is defined by the ITER Designer or ITER Operator.

[24CRs757-R;Defined Requirement] Maintenance tasks are identified from RAMI analysis and Safety Analysis in order to meet the Project's safety and availability requirements. They shall be specified and verified as part of the design process for ITER systems, under the responsibility of their TRO.

[24CRs758-R;Defined Requirement] Maintenance Class 1 shall be associated to any maintenance task which requires use of RHE or HAE.

[24CRs759-R;Defined Requirement] In order to manage the ITER maintenance planning in a proper way, MC1 is divided into three sub-classes as follows:

Maintenance Class 1-1 (MC1-1) shall be defined for any maintenance task which represents 1% or more of the ITER annual collective radiation dose exposure limit.

Maintenance Class 1-2 (MC1-2) shall be defined for any maintenance task which is in the range from 0.1% to 1% of the ITER annual collective radiation dose exposure limit.

Maintenance Class 1-3 (MC1-3) shall be defined for any maintenance task which represents less than 0.1% of the ITER annual collective radiation dose exposure limit.

[24CRs760-R;Defined Requirement] Maintenance Class 2 shall be associated to any maintenance task which is not classified as MC1 and which requires special PPE (Personal Protective Equipment) for workers, such as air suit or breathing mask.

In order to manage the ITER maintenance planning in a proper way, MC2 is divided into two sub-classes as follows:

·Maintenance Class 2-1 (MC2-1) shall be defined for any maintenance task which deals with Beryllium and require Beryllium waste management.

·Maintenance Class 2-2 (MC2-2) includes any other MC2 maintenance tasks that are not classified as MC2-1.

4.2.1.1 Spares

[24CRs482-R] Recommendation for spares provisioning shall be provided, both for scheduled and unscheduled maintenance, taking into account operating conditions. The final decision on spares provisioning will be made by IO.

[24CRs491-R] In order to avoid inventory increase, it is required that the supplier make maximum use of off-the-shelf equipment and components catalogues identified by IO.

[24CRs492-R] It is required that the supplier commit to the capability for continuous spares provisioning over the ITER life cycle. The supplier shall inform IO of any risk regarding a components' obsolescence, and make all pertinent recommendation to fix that risk.

4.2.1.2 Operation and maintenance procedures

[24CRs484-R] Documents must be provided to IO for operation and maintenance of the system equipment on site. These publications shall comply with the ITER template for operation and maintenance procedures. Data shall be provided both as paper and electronic media.

4.2.1.3 Operation and maintenance training

[24CRs486-R;Defined Requirement] Initial training must be provided for the ITER Operation and Maintenance crew. The training shall conform to the training rules set up by IO. The training scope is identical to that of the operation and maintenance procedures.

[24CRs761-R;Defined Requirement] Appropriate training shall be mandatory before access to a zone that has cryogenics-related safety risks.

4.2.1.4 Special tools and test equipment

[24CRs488-R] Any special tool and test equipment needed for maintenance of the system's equipment on site shall be provided to IO. Any such equipment, that would be additional to items delivered as manufacturing means, installation means, test and commissioning means shall be fully justified.

[24CRs493-R] Special pieces of equipment needed for packaging, handling, storage and transportation are also in the scope of the requirement. The supplier shall also state the degree of protection for any packaging equipment. This degree of protection shall be identified based on the IO-defined environmental conditions.

4.2.1.5 Facility requirements

[24CRs490-R;Defined Requirement] The supplier shall identify any facility requirements (such as property class, security, and utilities) of equipment which need to be tested and maintained outside the Hot Cell Facility (control cubicles, for instance).

[24CRs762-R;Defined Requirement] The Host Member shall accept for disposal industrial, radioactive, and toxic waste that is generated during the course of the ITER construction, operation and deactivation and also responsible for dismantling the facility and disposing of the waste after deactivation Facilities to process low-level and very-low-level radioactive waste for periods up to six months before disposal shall be provided. Facilities to store intermediate-level radioactive waste for periods up to 20 years prior to disposal by the Host country shall be provided. Facilities and equipment to treat radioactive liquid waste shall be provided. Solid waste packages shall be controlled prior to transport and disposal. Suitable management routes shall be implemented for all radioactive waste generated throughout ITER lifetime. Waste from a radioactive waste zone shall be processed in a radioactive treatment facility. Suitable management routes shall be implemented for all radioactive waste generated throughout ITER lifetime.

[24CRs763-R;Defined Requirement] ITER Organization shall provide the site Host Member with all records, "as-built prints", information and equipment pertinent to dismantling after deactivation. ITER Organization shall develop a plan to put the plant in a safe, stable condition while it awaits dismantling.

[24CRs764-R;Defined Requirement] ITER Organization shall guarantee the security of its "Installation Nucléaire de Base (INB)" as defined in French laws and regulations, including the equipment and facilities required for the operation of this installation and its related installations and equipment, during their construction, operation, deactivation, and in providing for decommissioning, in accordance with the Headquarters Agreement signed between the French Government and ITER Organization [R25].

4.2.2 Remote handling

[24CRs309-I;Defined Requirement] The cryostat will not require remote handling for its maintenance.

4.2.3 Hot cell

[24CRs423-I;Defined Requirement] There are no Hot cell requirements for the cryostat.

4.3 RAMI

4.3.1 Reliability, Availability, Maintainability, Inspectability requirements

[24CRs510] Table 4.3.1: Reliability, Availability, Maintainability, Inspectability requirements

[24CRs511]

Main Functions (3)	Availability	Internal basic Functions (9)
To enable vacuum to be maintained	99.4%	To prevent ingress of water and coolant
		To limit in-leakage of air
To minimize ozone hazard	100%	To prevent cryostat wall temperature from dropping below 0°C
To retain cryostat structural integrity	100%	To transfer gravitational loads from tokamak and cryostat
		To withstand any imposed EM pressure
		To monitor temperature
		To monitor strain
		To monitor acceleration
		To monitor displacement

4.3.1.1 Test and validation

[24CRs300-R;Defined Requirement] Reliability characteristics shall be demonstrated by the supplier as part of the system qualification process. The warranty period will also be used as a validation period for the reliability characteristics of the system equipment. Deviations from requirements will be identified and compensating / correcting actions identified and implemented. Responsibility identification, budgeting and planning will be established based on Reliability-Centered Maintenance procedure for the implementation of necessary actions.

[24CRs495-R] Maintainability characteristics shall be demonstrated by the supplier as part of the qualification process. Critical on-line controls or replacements will be realized during integrated commissioning. These demonstrations shall ensure accuracy of elapsed times and efficiency of support equipment needed for task performance.

4.3.2 Risk reducing

[24CRs428-I;Defined Requirement] The RAMI requirements given previously, in terms of availability targets, could be achieved only if some risk reducing actions and/or compensating provisions related to the design, test, operation and maintenance are taken into account. Hereafter are listed these actions which are advocated in various project phases (design, test, operation and maintenance) in order to lower the criticality of function failures whose initial value is higher than the limit above which the risk level is considered as unacceptable by the project.

[24CRs504-I] Where appropriate, these advocated actions may be replaced by others if it is ensured that those would lead to equivalent benefits in risk reduction.

[24CRs765-R;Defined Requirement] Under normal situations, with no detectable atmospheric contamination permitted in green or yellow zones, the trefoils shall only indicate the risk of external exposure

4.3.2.1 Design requirements

[24CRs497-I] The RAMI Analysis required considering the following action during the design phase of the system.

[24CRs512] Table 4.3.2: Design requirements

[24CRs513]

Basic Function	Action
To prevent ingress of water and coolant	Consider feasibility of increasing the proportion of pipes passing through the cryostat that are guarded

[24CRs766-R;Defined Requirement] Hazard identification and risk assessment (HIRA) process shall be implemented in design phase in order to:

identify workplace OHS hazards whose control shall have impact on ITER systems design

assess the level of risk related to them in order to control them.

[24CRs767-R;Defined Requirement] Systems that contribute to mitigation measures - to reduce the severity of an event - shall have a high reliability. This includes using automated systems, reducing the reliance on human intervention.

[24CRs768-R;Defined Requirement] Preventive measures shall be considered in the design phase to reduce the frequency or the probability of an event and that should establish the rules to follow for the construction, installation and utilization of equipment in order to protect people and equipment from OHS risks.

4.3.2.2 Test requirements

[24CRs499-I;Defined Requirement] The RAMI Analysis required considering the following actions during the testing phase of the system.

[24CRs514] Table 4.3.3: Test requirements

[24CRs515]

Basic Function	Action
To prevent ingress of water and coolant	Ensure adequate testing in place to demonstrate pipe weld leak tightness
To limit in-leakage of air	Ensure testing demonstrates adequacy of bellows leak-tightness
	Ensure leak testing demonstrates adequacy of weld leak-tightness in foreseen conditions

[24CRs769-R;Defined Requirement] These provisions shall consider potential corrosive, inflammable and explosible issues associated with toxic products.

4.3.2.3 Operations requirements

[24CRs501-I] The RAMI Analysis did not highlight any Operation requirements.

4.3.2.4 Maintenance requirements

[24CRs503-I] The RAMI Analysis did not highlight any Maintenance requirements.

5 QUALITY REQUIREMENTS

[24CRs569-R] The cryostat system including TCPH and rectangular bellows shall be designed, manufactured, tested, commissioned, operated, maintained and decommissioned in compliance with the ITER Quality Assurance Program.

[24CRs325-R] The vacuum acceptance standard for the cryostat shall be as per the *ITER Vacuum Handbook* [5].

[24CRs571-R] The cryostat system including TCPH and rectangular bellows shall meet the QC1 requirement.

6 APPLICABLE CODES AND STANDARDS

[24CRs451-R;Defined Requirement] The Cryostat system, including TCPH, shall be designed and manufactured using the ASME section VIII, Div.2 as a reference code.

[24CRs572-R;Defined Requirement] The design and fabrication of the cryostat shall be performed in accordance with the *Codes and Standards for ITER Mechanical Components* [15] and *ITER Vacuum Handbook* [5].

[24CRs329-R] The electrical components shall be as per the Electrical Design Handbook *EDH Part 3: Codes and Standards* [11].

[24CRs333-R] The code for cryostat pressure boundary shall be the ASME Section VIII, Division 2. For design, Category I and II Loading Events specified in the *Load Specifications (LS)* [8].

[24CRs507-I] For events and event combinations in category III and IV design criteria and allowable limits are defined in additional technical specifications.

[24CRs573-R] Piping Bellows in the cryostat pressure boundary shall be designed and fabricated in accordance with ASME B31.3 Appendix X and EJMA code. The Vacuum bellows shall also refer to *ITER Vacuum Handbook* [5].

[24CRs338-R] The large size rectangular bellows for port duct and port cell shall be designed and manufactured in accordance with the ASME section VIII Division 1 appendix 26. The EJMA Standard can be used for the details of the design.

[24CRs340-R] The supports and the steel structures that are attached to the cryostat shall be designed and fabricated in accordance with ASME Section VIII, Division 2.

[24CRs342-R] The components of the cryostat with a vacuum interface shall be designed in accordance with the relevant chapters of the *ITER Vacuum Handbook* [5].

[24CRs673-R;Defined Requirement] The Cryostat Pressure Relief Devices (PRD) shall be designed and manufactured according to ASME VIII Div.2 Ed.2013 code.

7 ADDITIONAL REQUIREMENTS FOR THE STAGED APPROACH PHASES

[24CRs771-I] Cryostat is not impacted by Staged approach

8 APPENDIX: PR STATEMENTS FOR INFORMATION (FI)

[24CRs770-I;Defined Requirement] This Appendix lists defined requirements and information from the PR (Ref. 27ZRW8) that are identified as applicable For Information to the system. These PR statements must be propagated down the chain of interveners for the system to ensure they are aware of it (there is no need to demonstrate compliance with each statement).

PR ID	Project Requirements	Object Type	Defined Requirement	Applicability of system
PR2372	Since the publication of the Decree for the ITER INB creation authorization (9 November 2012) [R31], this decree is the top level safety requirement document for ITER.	Information	Yes	FI
PR2373	The ASN Decision 2013-DC-0379, dated 12 November 2013 [R32], establishes the prescription for the design and the construction of the licensed nuclear facility INB No. 174 called ITER.	Information	Yes	FI
PR2312	[R08] ITER INB Preliminary Safety Report (English version) ([ITER_D_3ZR2NC V3.0|https://user.iter.org/?uid=3ZR2NC&version=v3.0])	Information	Yes	FR
PR2321	[R12] ITER Seismic Nuclear Safety Approach ([ITER_D_2DRVPE V1.6|https://user.iter.org/?uid=2DRVPE&version=v1.6])	Information	Yes	FR
PR2337	[R19] ITER Remote Handling Code of Practice ([ITER_D_2E7BC5 V1.2|https://user.iter.org/?uid=2E7BC5&version=v1.2])	Information	Yes	FR
PR2344	[R22] The ITER Human Factor Integration Plan ([ITER_D_2WBVKU V3.0|https://user.iter.org/?uid=2WBVKU&version=v3.0]) - updated version to be confirmed?	Information	Yes	FI
PR2364	[R29] Etude d'impact - Partie 1: Analyse de l'état initial du site et de son environnement (ITER_D_7A7RDB V1.0)	Information	Yes	FI
PR2369	[R30] Order dated 7 February 2012 relating to the general technical regulations applicable to INB (ITER_D_7M2YKF V1.7)	Information	Yes	FR

PR2374	[R31] Decree No. 2012-1248 dated 9 November 2012 authorising IO to create a basic nuclear facility called «ITER». (ITER_D_CZK7M5 V1.1)	Information	Yes	FI
PR2375	[R32] ASN Decision 2013-DC-0379 dated 12 November 2013 establishing the prescriptions applicable to ITER Organization for the licensed nuclear facility INB No. 174 called ITER - FR (ITER_D_LYH6QS v1.1) - updated version	Information	Yes	FI
PR4955	[R34] ITER Preliminary Functional Analysis (ITER_D_TVG7YK v1.5)	Information	Yes	FI
PR4954	[R35] Staged Approach Configuration - PBS Level 3 (ITER_D_SNE6G8 v3.1)	Information	Yes	FI
PR1945	The Radiological and Environmental Monitoring System (REMS) performs radiological monitoring to assist in protection of personnel from ionizing radiation, including from tritium.	Information	Yes	FI
PR1950	Waiting periods, of up to 24 hours for contact dose rates to subside, may be required in the TCWS vault and other areas that surround the tokamak, after D-T operations commence.	Information	Yes	FI
PR1962	The Host Member has made available to ITER Organization a land area of approximately 181 ha for the duration of the ITER project (construction, operation and deactivation): a period of at least 35 years [R18], [R23].	Information	Yes	FI
PR3095	An ITER Maintenance Classification is applicable to any maintenance task that is defined by an ITER Designer or by the ITER Operator.	Information	Yes	FI
PR4965	Maintenance Class 1 (MC1) includes any planned or unplanned maintenance activities that must be performed in environment of radiation exposure and/or radioactive contamination. Such a maintenance environment is expected in the Nuclear Buildings.	Information	Yes	FI
PR3103	Maintenance Class 2 (MC2) includes any planned or unplanned maintenance activities that must be performed in environment of toxic and/or other hazardous but without risk of radiation exposure or radioactive contamination.	Information	Yes	FR

PR3106	Maintenance Class 3 (MC3) includes any planned or unplanned maintenance activities that are not classified as MC1 or MC2.	Information	Yes	FI
PR1092	The HFIP defines a systematic application of Human and Organizational Factors throughout the ITER project, from concept to decommissioning with reference to all systems and activities (particularly in view of operation and maintenance optimization) where Human Factors plays an important role from a safety and availability point of view.	Information	Yes	FI
PR1119	Counter measures limited in time and space should be addressed by considering consequences in relation to guidelines such as: · The avoidance of the need for public evacuation, for which a guideline is 50 mSv of avertable dose in a period of no more than one week, according to IAEA recommendations and French regulations · The limitation of the need for short-term sheltering, for which a guideline in French regulations is 10 mSv · The limitation of the need to ban the consumption of food products, by studying the likely contamination levels and predicting the extent (in space and time) of such banning, if any. ---	Information	Yes	FI
PR1158	In some foreseen normal operations or off-normal events, a confinement system may be temporarily removed from service, or become inoperable. These include: in-vessel maintenance, confinement testing, confinement maintenance; and single system failure.	Information	Yes	FI
PR1231	Halogenated materials include all solids liquids and gases that contain fluorine, chlorine, bromine or iodine. In industrial applications, halogenated materials are often present in such items as process gases, electrical cable insulation, floor and wall coatings, paints and cleaning solvents.	Information	Yes	FI

PR1349	Note 3: If the source is always present, these values can be interpreted as a dose-equivalent rate.	Information	Yes	FI
PR1357	Anti-deflagration zoning provides a means of locating explosion risks in the buildings, in order to implement suitable risk prevention measures, both in terms of building design and of the use of their systems and equipment.	Information	Yes	FR
PR1394	Note that the two defined areas (Fire Sectors and Confinement Sectors) can be congruent.	Information	Yes	FI
PR1390	A fire sector is a volume that is composed of a room or group of rooms that are delimited by walls that are designed to keep an internal fire (within the volume) from spreading outside (or to keep an external fire from spreading inside) for a duration that is sufficient to extinguish the fire.	Information	Yes	FI
PR1392	A confinement sector is a volume that is composed of a room or group of rooms with characteristics that are designed to limit the dispersal of toxic or radioactive materials outside this volume in the event of fire.	Information	Yes	FI
PR2263	Occupational Health and Safety (OHS) is related to the prevention or mitigation of all risks of injury or long term illnesses from workplace exposure other than nuclear risks.	Information	Yes	FI
PR2264	IO staff and contractors might be exposed to a wide range of “non-nuclear” hazards, such as: · Beryllium · Cryogenic hazards, including oxygen deficiency hazards · Explosion risk (hydrogen or other) · Fire risk · Electrical hazards · Laser risk · Circulation of and interaction with heavy plant (truck, cranes). ---	Information	Yes	FI

PR1438	The ITER facility utilizes large quantities of cryogens in the cryoplant and tokamak areas during operation. Risks include: · Asphyxiation by displacement of oxygen in the event of large spills · Material-behaviour changes by contact with cryogens · Burns from contact with cryogens · Pressurization from rapid expansion of cryogenic gases. ---	Information	Yes	FI
PR1457	Criteria and guidelines for Safety Important Class (SIC) are provided in Section 7.7.	Information	Yes	FI
PR1549	Qualification testing to verify the acceptability of a specific design will be conducted in accordance with approved procedures that address, at a minimum: · Use of adequate instrumentation · Provisions for test monitoring · Specification of suitable environmental conditions · Delineation of test prerequisites, such as calibrated instrumentation, appropriate equipment, trained personnel, and data acquisition equipment · Demonstration of acceptable performance under conditions that simulate the appropriate adverse design conditions · Delineation of performance specifications, including acceptable deviations from baseline (or mean) benchmarks. ---	Information	Yes	FI

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