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Memorandum / Note

PBS 24 Cryostat for Defined Requirements

This document defines the list of Defined requirements for PBS 24 Cryostat

Approval Process			
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v1.6	Revision Required	27 Mar 2015	Editorial comments
v1.7	Approved	12 May 2016	New version taking into account comments from the previous version.

PBS 24 Cryostat for Defined Requirements

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1 Scope

The scope of this document is to define the list of Defined Requirements for all the activities dealing with **structure, system and components (SSC) of PBS 24 – CRYOSTAT** performing protection important functions (SSC-PIC) from the design phase until dismantling including the full lifecycle of the nuclear facility.

The term “defined requirement” replaces “safety requirement” in accordance with the INB Order (French Order 7th February 2012) [2]. And, in the documents referenced herein, all SIC SSCs and SRA (safety related activities) are to be superseded by, PIC and PIA, respectively.

This document presents the current requirements according to the current level of knowledge of design.

2 Abbreviations and Definitions

Refer to the list of ITER Abbreviations (2MU6W5);

- II-DA: India domestic Ageny
- EPNS:Environmental Protection Nuclear Safety Division of IO under IO-SD
- MQP: Management Quality Plan
- PA: Procurement Arrangement
- PCR – Project Change Request
- Protection Important Component (PIC): component important for protecting the interests of public security (including nuclear safety, radioprotection and prevention and fight against malevolent acts and civil security actions in the case of an accident), health and sanitation, the protection of nature and of the environment,. i.e. structure, equipment, system (programmed or not), material, component or software that is present in the basic nuclear installation or that is under the responsibility of the nuclear operator and that implements a function required for the demonstration mentioned under the second paragraph of Article L. 593-1 of the Environmental Code or that ensures that this function is implemented per articles 1.3 and 2.5.1 of Order 7th February 2012. PIC comprises Safety Important Components (SIC), environmental important components (EIC) and crisis management components (CMC). SIC, EIC or CMC are just sub-categories of PIC.
- ED: Defined Requirement or ”Exigence definie”. Defined requirements are the actions (technical, organizational, administrative …) to be executed in order to fulfil and maintain the safety requirement of a component pertaining to safety. A defined requirement can be attached to a PIC component or to a Protection Important Activity.
- Protection Important Activity (PIA): An activity which can impact a protection Important Component per articles 1.3 and 2.5.2 of Order 7th February 2012. These activities include design, purchase, fabrication/manufacture/construction, assembly, installation, testing, commissioning, operating, maintenance, modifications and the most of sub-activities under these ones (non-exhaustive list).

The identification of PIC (including former SIC) components, associated Protection Important Activities and associated Safety Requirements is also an PIA.

- RPrS: Preliminary Safety report
- SQS: Department for Safety, Quality and Security of IO
- SSC: System, Structure and Component
- SRD: System Requirements Document

3 References

[1] Management of propagation of nuclear safety requirements in the supplier chain (BG2GYB v2.0)

[2] Order dated 7 February 2012 relating to the general technical regulations applicable to INB - EN (7M2YKF)

[3] Project Requirements (PR) (ITER_D_27ZRW8)

[4] Preliminary Safety Report (RPrS) (ITER_D_3ZR2NC) _(not used in this document)

[5] Order dated 9 August 2013 relating to the provisions against impact on lehalth and the environment - EN (4XXNN4W)

[6] Decree for authorization of construction of ITER INB (C2JZNX)

[7] Safety Important Functions and Components Classification Criteria and Methodology (347SF3)

[8] AAR: Accidental Analysis Report

- Accident Analysis Report (AAR) Volume I - Event Identification and Selection (2DPVGT v1.4) (not used in this document)
- Accident Analysis Report (AAR) Volume II - Reference Event Analysis (2DJFX3 v4.10) (not used in this document)
- Accident Analysis Report (AAR) Volume III - Hypothetical Event Analysis (2E2XAM v4.9) (not used in this document)

[9] ASN decision related to ITER prescriptions (LYH6QS)

[10] Safety requirements roombook (KF63PB)

[11] List Safety Requirements for Site & Buildings (PBS 61, 62, 63, 65) of ITER Nuclear Facility (FF92TR v1.3)

[12] ITER_D_3R7ECW - Safety Functions, Systems, Signals Definition for I&C CSS

[13] ITER_D_335VF9 – IO cabling routes

[14] ITER policy on EEE Tokamak complex CZX6S3

[15] Memo on penetrations through safety barriers - JLDU7W

[16] ITER_D_2E4KSJ - Safety Requirements for ITER Facility Buildings

[17] ITER_D_25SDBD – ITER Fire Safety Approach

[18] SRD-24-CR –CRYOSTAT - 28B2TP

[19] Load specification - 222QGL

4 Roles and Responsibilities

According to Management of propagation of nuclear safety requirements in the supplier chain (BG2GYB v2.0), section 5.3, the following personnel are responsible for the generation, review, approval, implementation and follow-up of this document;

- IO SRO: Main-author of this document. Responsible for review of exhaustive list of defined requirements and review of implementation at each PIA for PBS responsible area (ref. section 5.3 of [1]),
- TROs for PIC – Each responsible for PBS 24. Reviewer(s) of this document. Responsible for review of exhaustive list of defined requirements and review of implementation at each PIA for PBS responsible area (ref. section 5.3 of [1])
- IO EPNS Head: Approver of this document.

This document, once approved, will be sent to following II-DA nominated representatives who will take responsibility as follows;

- II-DA TRO(s) for PBS 24 PAs – Responsible for ensuring:
    - Establishment of the exhaustive list of defined requirements generated from the QDs and the propagation of the defined requirements through the II-DA (Design) supplier chain (ref. section 6.1 of [1]) and subsequent demonstration of same for each design PIA;
    - Propagation of the defined requirements through the II-DA supplier chain (ref. section 6.1 of [1]) and subsequent demonstration of same for each construction and commissioning PIA.
- II-DA SRO(s) for PBS 24 PAs – Responsible for ensuring:
    - the review of the defined requirement with regard to safety

5 Methodology to define entire defined requirement

According to Management of propagation of nuclear safety requirements in the supplier chain (BG2GYB v2.0) [1], section 5.3 and 6.1, list of PICs and defined requirements for each PBS shall be provided by IO and should be sent to the DA so that the DA should propagate them to its supply chains (i.e. suppliers, subcontractors).

On receipt of the defined requirements from IO, the DA shall establish the final exhaustive list of defined requirements and submit it for IO's review and approval.

The final exhaustive list of defined requirements has to be as detailed as possible to provide the DA's supply chains with detail guide in his own task and to help the SRO to check the correct transmission and compliance with the defined requirements through the inspections or visits to the suppliers.

The requirements list in this document are derived from the technical baseline, in particular PR and SRDs in order to check that there is no new requirement.

The list of PBS 24 PIC components is presented in appendix A.

Details of the list of defined requirements for PBS 24 is described in section 6.

6 List of Defined Requirements

According to Management of propagation of nuclear safety requirements in the supplier chain (BG2GYB v2.0) [1], the defined requirements are to be prepared in the form of tables as follows.

- Table 1: normal conditions and design basis incidents and accidents the "situations" in which the Structure, System or Component which is classified as PIC has been credited.
- Table 2: the external and internal hazards on which the SSC will have to operate.
- Table 3: design basis for combinations of incidents and accidents.
- Table 4 : combination

However, instead of describing the defined requirements in the aforementioned formats, description of the defined requirements is made in narrative way (in Appendix A) as it is chosen and agreed method and practice for IO and the DA. In addition, a table is given in Appendix A to provide the defined requirements in such a way to be manifest at a glance. The table in appendix B is simplified in comparison with the tables in [1]: in fact, considering the location and characteristics of PBS 24 PICs, the incident/accident and the relevant load conditions affecting VV and components close to VV (e.g. LOVA events, Plasma transients, Magnet Energy Fast Discharge) are not so much applicable to PBS 24 components.

The list includes all the defined requirements for all PBS 24 PICs given in SRD [18], PR [3] and from regulations ([2], [5], [6], [10]).

The following specific points are noted with respect to this list:

- The list of defined requirements is developed based on the input documents listed in Section 3 herein;
- The II-DA and its Contractors are responsible for further elaboration of IO's defined requirements specified herein to generate final exhaustive defined Requirements in accordance with Section 6.1 of [1]. Such final list will be approved by IO.
- The II-DA and its Contractors are responsible for propagating IO's defined requirements herein throughout their Contractor Supply Chain and through the respective PIAs as defined in [1].

6.1 Safety design criteria

The Cryostat System includes a cylindrical cryostat which provides a vacuum environment for the superconducting coils and other in-cryostat components operating at cryogenic temperatures. The cryostat provides penetrations for services to in-cryostat components and vacuum vessel ports. The

cryostat transfers all the loads, which derive from the tokamak basic machine and the cryostat itself during the normal and off-normal operational regimes and at specified accidental conditions, to the floor of the tokamak pit through its support structures. [3][PR141-I].
The cryostat safety function is also to allow the removal of the decay heat from the vacuum vessel and in-vessel components (see [18], [3]).

The safety criteria are analysed for the following conditions [4] :

- Normal conditions and design basic incidents and accidents the “situations” in which the system which is classified as PIC has been credited,
- The external and internal hazards on which the system will have to operate,
- Design basis for combinations of incidents and accidents.

The safety functions of Cryostat include the following (see [18]) :

- Cryostat support function
- shall allow passive removal of decay heat, from the vacuum vessel and in-vessel components, by gas conduction and convection in certain even..

The support function of the cryostat is passive.

The heat removal function is associated with the need to remove the heat from the residual heat from the vaccum vessel within 3 days following the events [18]. If this is ensured by a passive function, the safety criteria are to have a quality class 1 provision, with maintenance, inspection and periodic tests. If it is ensured by an active function, the requirements are the following for what concerns the components ensuring a SIC-2 function (see appendix 1 for the):

- Single failure criterion on active components, redundancy, physical separation
- equipment powered by safety class power supply, UPS,
- 2 redundant trains powered by 2 independent networks for the support services (air compressed, N2 …)
- Equipment status indication (type of parameters, local, remote)
- Periodic tests requested
- Routine Maintenance test requested
- To ensure I&C reliability and classification to activate the active components
- Environmental Qualification requested
- Seismic Class SL2 (SC1-SF, or SC1-S or SC2),
- QA class 1 or 2, upon a case by case analysis.
- To perform In Service Inspection (ISI) to detect problem on weld, seals … to avoid any water/gas leaks
- To perform ISI to detect problem on active elements like the valves, pumps …
- To define and implement the I&C logic needed to cope with the accident

Human and organisational factors shall be considered at every stage of the design in accordance with the Human factor Integration Plan mentionned in the paragraph 6.17 of project requirements.

These defined requirements in normal operation are presented in the table in appendix A.

These defined requirements in external and internal operation and combinations loads are presented in the tables in appendix 2.

6.2 Normal operation

6.2.1 Environmental conditions

PBS 24 PIC components shall be qualified to function under the following environmental conditions for which their service required (during normal conditions or accident). The reference safety conditions are provided in the safety requirement roombook (10).

Environmental conditions during normal operation in the TKM building:
• Temperature (maximum excursion range in the room) : between 18C and 35C,
• Humidity (maximum excursion range in the room) : 60%
• Pressure (-80Pa up to -140 Pa)

Environmental conditions during incidents/accidents in the rooms outside the cryostat are given in [10]:
• Gallery air Temperature : -15C to +110 C (-170 C locally during He leak)
• Humidity (peak) : 100%
• Pressure (up to 1.2 bars)

6.2.2 Routine operations requirements

The routine operations requirements associated with protection important components and protection important activities are given in *<4>* and *<7>,* with clearly identified functions protection important activities are given in <4> and <7>, with clearly identified functions [7] chapters 4 and 5:

The Torus Cryopump Housing and IVV penetrations are SIC-1 components The cryostat is SIC-2 component [18], as per PCR 528..

For all the components of PBS24 :

- Qualification/certification of materials or functions [PR1549-R]
- Human factors [PR1092-I] and [PR1093-R]

All the components shall be qualified and certified according to the rules established by the French safety authority <2> and <5>.

Long term, readible and safe (protected from internal and external events and hazards without common mode failure) archiving requirements are needed for the data associated with PIC function.

6.2.3 Material requirement

The material used for the cryostat are subject to activation. The use of lower-activated materials shall be selected [3] [PR1478-R]. In particular, Materials with low concentration of Co and Nb shall be selected.
The used material shall be selected to comply with the potential for the public and workers to be exposed to radiological and other hazards shall be limited by design, construction, operation, and preparation for decommissioning [3] [PR1111-R]
For solid radioactive and other hazardous wastes arising 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] [PR1436-R]
The cryostat is a Quality Class 1 component, according to the Quality Classification Determination (ITER_D_24VQES). [24CRs408-R-A].

6.2.4 Mechanical requirement

The main safety mechanical function of the cryostat is the support. The cryostat shall withstand to the loads defined in [18] and [19] in order to lead to cliff edge effect scenarios l ike the base mate rupture.

To comply with this safety function it is needed to :

- The Cryostat System shall withstand Inertial loads: these are due to accelerations due togravity and seismic events (SL-1 and SL-2). [24CRs553-R-A]
- 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. [24CRs554-R-P]
- The Cryostat System shall withstand Electromagnetic loads: during fast transients (such as plasma disruptions DW VDE, 36 ms). [24CRs555-R-A]
- 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. [24CRs464-R-A]
- The cryostat shall withstand any imposed electromagnetic loads that are applied during plasma start-up/shut-down, plasma disruption/VDE and poloidal coils quench. [24CRs121-R-A]

6.2.5 Penetration requirements

Potential penetration requirements for the cryostat are related to the equipment that will allow to remove the residual heat from the vacuum vessel. If such penetration through fire or confinement barriers exist, they shall reconstitute the barrier properties. This safety function is decribed in [3] and in more detailed in the penetration memo [15].

6.2.6 Radiological requirements

PBS 24 PIC components shall be qualified to function under the radiological conditions for which their service required (during normal conditions or accident). The reference safety conditions are provided in the safety requirement roombook [10] and in the PR [3].

These conditions are expressed in terms of dose rates (Gy/h) and integrated doses (Gy) for the component qualification.
The radiological conditions inside the tokamak complex are defined inside the document [8].

The radiological requirements regarding the qualification of the devices are defined inside the references [15][16].

6.2.7 Electromagnetic requirements

PBS 24 PIC components shall be qualified to function under the magnetic conditions for which their service required (during normal conditions or accident). The reference safety conditions are provided in the safety requirement roombook (KF63PB) and in the PR (3).
The requirements are expressed in terms of :
• Electromagnetic interference (EMI)
• Magnetic field and derivative magnetic field

The electromagnetic requirements regarding the qualification of the devices are defined inside the references [15][16].

Magnetic materials (relative permeability >1.05) shall not be used within the cryostat boundary without formal project approval. [PR1465-R].

6.3 Internal events/hazards

The requirements associated with the combination of other loads are described in [22].

6.3.1 Fire

Fire inside the cryostat is considered like a Beyon Design Basis accident. So none of the Cryostat component shall be flammable [18].

PBS 24 components inside nuclear buildings shall meet the following defined requirements:

- PBS 24 PIC components and their support systems shall be able to continue to operate (or shall be protected adequately or shall be isolated) in fire conditions in gallery or CSR conditions [3] [PR1286-R] [PR1291-R]; in particular with regards to presence of high variations of pressure, temperature, humidity, soots. The failure of the device used for the heat removal function of the VV shall send an alarm to CSS [PR1262].
- PBS 24 PIC components and their support systems shall be able to continue to operate for all loads combination with fire defined in [19].

Electrical material would concern only for the I&C of the removal heat function [18]. For them, the electrical materials shall be (See <14>) designed according to the following [3] and [7] chapter 6.9 and . [11] appendix 1:

- For all electrical cables, reduced flame propagation (according to IEC 60332-3 –flame spread for cable bunches- or NF 32070 C1
- Flame retardant (according to IEC 60332-1 –flame propagation on single cables)
- Low smoke (according to IEC 61034) [17] chapter G.4
- Zero Halogen (according to IEC 60754-1) [17] chapter G.4
- Non toxicity (according to IEC 60754-2)
- For SIC2 components cables, fire resistant according to IEC 60331 or NF 32070 CR1)
- For Cables of redundant trains routed in the same fire sector, free spatial distance (5m) or fire barrier (2 hours) shall be maintained between the cables of two redundant trains.
- PBS 24 materials in nuclear buildings shall be non-halogenated and difficult to burn.
- Reconstitution of fire barriers properties shall be performed when crossing fire boundaries. The penetrations ducts and electrical cables at boundaries of fire sector shall be barrier 2 hours (REI-120).
- As a preventive measures, fire sources from PBS24 shall be minimized and consistent with fire loads provisions in rooms, and would it not occur, be designed in order to avoid the propagation of a fire.

6.3.2 Drop load and missile effects

There is no drop load for the cryostat.

6.3.3 Flooding

Internal flooding would affect only the function related to the heat removal of the VV. The components used for this function shall operate in case of flooding or be located above the flooding level of the rooms [18].

6.3.4 Explosion

There is no requirement on the cryostat due to an explosion.

6.3.5 Helium leaks

PBS 24 PIC components shall be designed to withstand from the effects resulting from an helium leak in particular due to cold temperatures (down to -170C for a very short period of time very close to helium lines), and pressure goes up to 2 bar abs in cat IV event [24CRs394-R-A] (Cr ICE IV)[19].
Various sized helium leaks are assumed and they are classified in category II, III and IV. [19]
Cryostat shall be designed to withstand to this type of phenomena and manage pressure and temperature effects and the consequences like contraction due to low temperature or deformation due to pressure [18][19].

6.3.6 Accidents involving LOCA accidents

These accidents concern a LOCA in the vacuum vessel, in the drain tank rooms, in the vault, in the port cells, in the NB cell. LOCA accidents in the gallery shall be made impossible.
As there is no LOCA accident inside the cryostat and inside the gallery (and in the CSR), there is no requirement for the cryostat.

The equipment needed to perform the heat removal function of the VV shall not be impacted by a LOCA.

6.3.7 Loss of vacuum inside Cryostat

Cryostat leaks are investigated as accidents. A maximum leakage is postulated to be 0.2 m2 that is estimated on the basis of a bellow failure [19]. Air ingress enters and pressurizes the cryostat. Air condenses on cold surfaces, but the weight of the air-ice mass is negligible compared with that of the coils. This event is defined here as Cr LOVAIII [19].
PBS 24 PIC components shall be designed to whistand to this accident [18] (related to the heat removal of the VV.

6.3.8 VDE, MD, MFD

Other accidents than LOVA, LOCA and He leaks affecting the Cryostat and the vacuum vessel (VDE, MFD, etc.) may impact PBS 24 components, and especially the safety function which is the support. The cryostat shall be designed to such loads as described in [18] and [19]. Detailled are already written in chapter 6.2.4 : Material requirement of this document. PBS 24 PIC components shall be designed to whistand to these accident[18][19].

6.4 External Hazards

The PBS 24 PIC components shall consist of redundant, independent, segregated systems in order to minimize the probability of CMF (Common Mode Failure) in the presence of the following external events (hazards):
- Earthquake (SL-2 and SMHV);
- Lightning;
- External electricity supply interruption/variation;
- Extreme environmental conditions;
- Flooding;
- Light airplane crash.

6.4.1 Earthquakes

The floor response spectra used for design of the PBS 24 components are given in the reference [17].

The defined requirements for each seismic level are presented in the table in appendix B.
The PIC components are designed to operate before, during and after a seismic event SL1 without any special maintenance or test.
The PIC components located inside the buildings shall in any case be at minimum classified as SL2-SC2.
The Cryostat System is assigned with a seismic class SC2. [18][24CRs528-R-A]

In addition, the following requirements are implemented:

- The combination of loads from earthquakes with other loading events, as defined in the LS, shall lead to no damage to the cryostat vessel. [18][19]

6.4.2 External flooding

The PIC components of PBS 24 are not subject to external flooding.

6.4.3 External fire

The risk of external fire is constituted by the following:

- forest fire,
- possible presence of vehicles,
- possible presence of flammable materials.

The PIC components of PBS 24 are not subject to external fire.

6.4.4 External explosion

The PIC components of PBS 24 are not subject to external fire.

6.4.5 Airplane crash

The PIC components of PBS 24 are not subject to external fire.

7 Conclusion

There is no new requirement compared to the technical baseline.

Appendix A –

Reminder of the protection important classification for all functions ensured by PBS 24

The cryostat consists of the following system:

- The cryopump housing : SIC-1
- IVV penetrations : SIC 1 (if PCR708 is approved, this component will be transferred to PBS15)
- All other parts of the cryostat system : SIC2
- heat removal mitigation system of the vacuum vessel as per SRD [24CRs16-R-A] SIC2 (if attributed to PBS24)

It is possible to define 2 types of safety requirements. The safety requirement to maintain in safe condition the system itself and the safety requirement depending of the availability of the system. With this definition, it is possible to sort the safety requirement for the Cryostat in 2 categories :

1. Main system safety functions:

   There are 2 safety functions:

   - Support for cryostat
   - Confinement for TCPH and IVV
   - Stress sensor I&C (if attributed to PBS24)

2. Safety support function of the system or of the main safety functions

   There are 2 safety functions associated with the protection of the vacuum vessel :

   - Air ingress to extract the decay heat
   - I&C to cope with the Air ingress (if attributed to PBS24):

Appendix B - Summary table of defined requirements for PBS 24

The safety criteria that a system or a component shall comply during an accident are the following. They are used to fill the tables 1,2 and 3.

CA : for the aerosols and gas confinement

CL : For the liquid confinement

SH : for nuclear shielding

OP : Operability

AG : Non Agression on SIC

NF : Non Fire propagation

INV : ITER inventory control

CHIM : Chemistry products control

The last table (table4_xx) contains the status (position open/close, set point value …) of the considered element or functions versus an accident scenario.

For systems measurement and I&C, these elements must be functional whatever the accidental scenario. Excluded scenario must show the evidence that the considered system cannot be impacted by the consequences of accident thanks to new safety requirement.