IDM UID
LAMFG2

VERSION CREATED ON / VERSION / STATUS
20 Dec 2019 / 4.5 / Approved

EXTERNAL REFERENCE / VERSION

Nuclear Safety Memorandum

Defined requirements for PBS53

Defined requirements for PBS53

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Seropian C.**	**20 Dec 2019:signed**	**IO/DG/SQD/EPNS**
Co-Authors			
Reviewers	**Cortes P.** **Decamps H.** **Graceffa J.** **Rotti C.** **Schunke B.**	**06 Jan 2020:recommended** **07 Jan 2020:recommended** **06 Jan 2020:recommended**	**IO/DG/SQD/EPNS** **IO/DG/ENGN/EDD/HCD/NB** **IO/DG/ENGN/EDD/HCD/NB** **IO/DG/ENGN/EDD/HCD/NB** **IO/DG/ENGN/EDD/HCD/NB**
Approver	**Elbez-Uzan J.**	**20 Jan 2020:approved**	**IO/DG/SQD/EPNS**
Document Security: Internal Use *RO: Elbez-Uzan Joelle*			
Read Access	**LG: TRO and DA-TRO, LG: Deputy Head of Dept - SD, GG: Safety, AD: ITER, AD: IO_Director-General, AD: External Management Advisory Board, AD: OBS - Environment Prot - Nuclear Safety Division (EPNS) - EXT, AD: OBS - Environment Prot - Nuclear Safety Division (EPNS), AD: DA, AD: Auditors, AD: ITER Mana...**		

Change Log			
Defined requirements for PBS53 (LAMFG2)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	Signed	15 Mar 2014	
v1.1	Signed	18 Mar 2014	Basline references added to some defined requirements
v1.2	Signed	19 Mar 2014	Clarification of references used
v1.3	Signed	19 Mar 2014	added reference PR1180
v1.4	Revision Required	19 Mar 2014	minor changes
v2.0	Signed	30 Jan 2015	Correction of minor error and typos Technical comments taken into account Comments on layout and content taken into account but keeping the SQS template
v3.0	Revision Required	21 Dec 2016	New version of Defined requirements for PBS 53.
v4.0	Signed	18 May 2018	New version considering SRO/TRO meetings.
v4.1	Revision Required	25 May 2018	Considering comments from reviewers.
v4.2	Revision Required	14 Sep 2018	Considering reviewer's comments.
v4.3	Approved	17 Jun 2019	See answers to comments in the previous version.
v4.4	Signed	16 Dec 2019	Updating in order to consider PCR 748 - VVPSS design change.
v4.5	Approved	20 Dec 2019	Considering Pierre's comment.

Table of Contents

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 53 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);

- ED: Defined Requirement or ”Exigence define”. 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.
- EU-DA: The European Domestic Agency, also referred to as F4E (Fusion for Energy)
- II-DA: The Indian Domestic Agency, also referred to as II (ITER INDIA)
- MQP: Management Quality Plan
- NSLE: Nuclear Safety, Licensing and Environmental Protection Division of IO under IO-SQS
- PA: Procurement Arrangement
- PCR: – Project Change Request
- PIA: Protection Important Activity. 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.
- PIC: Protection Important 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.

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

For appendix B:

- *CA: aerosols and gas confinement (for primary confinement envelopes or when systems cross confinement boundaries)*
- *CL: Liquid confinement (process or fire) (for primary confinement envelopes or when systems cross confinement boundaries)*
- *SH: Nuclear shielding*
- *OP: Operability before, during or after a situation*
- *AG: non-aggression SIC (when the components are inside the buildings)*
- *NF: non fire propagation (when the components are inside fire sectors or cross fire sectors)*
- REMS: Radiological Environmental Monitoring System

further:

Safety Important Components is replaced by Protection Important Component in the French order of 07/02/2012 <2> . The word "SIC" is kept in this document for the Safety Important Class to avoid confusion with regard to the procurement arrangement and contracts placed before the 1st July 2013. When referring to SIC, structure, system and components, PIC is used.

SIC Safety Important Class and Safety Important Class Component

SR Safety Related

More details are given in

ITER Abbreviation :2MU6W5

ITER Plant Break Down Structure: 29DM8W

3 References

[1] **Propagation of the Defined Requirements for Protection Important Components Through the Chain of External Interveners (BG2GYB v3.3)**

[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 lethal and the environment - EN (7M2YKF)

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

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

[8] System Requirements Document – PBS 53 see Table 1.

[9] AAR: Accidental Analysis Report (not used in this document)

Accident Analysis Report (AAR) Volume I - Event Identification and Selection (2DPVGT v1.4)

Accident Analysis Report (AAR) Volume II - Reference Event Analysis (2DJFX3 v4.10)

Accident Analysis Report (AAR) Volume III - Hypothetical Event Analysis (2E2XAM v4.9)

[10] **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 (LYH6QS v1.2)** [11] **Safety requirement Roombook (KF63PB v2.11)**

[12] **List Safety Defined Requirements (QDs) for Site & Buildings (PBS 61, 62, 63, 65) of ITER Nuclear Facility (FF92TR v2.0)**

[13] **Safety Functions, Systems, Signals Definition for I&C CSS Design (3R7ECW v3.1)**

[14] ITER_D_335VF9 – IO cabling routes

[15] ITER policy on EEE Tokamak complex CZX6S3

[16] **Guidance for EEE in Tokamak Complex (7NPFMA v1.2)**

[17] NB load specifications (SA29F9) (folder)

[18] **Load Specifications (LS) (222QGL v6.2)**

[19] Penetrations through safety barriers JLDU7W

[20] **ITER Seismic Nuclear Safety Approach (2DRVPE v1.6)**

[22] **ITER Fire Safety Approach (25SDBD v3.1)**

[23] **Layout description & guidelines for routing of plant systems in the Tokamak Complex buildings (2UZ9WX v2.1)** (Rules for segregation of SIC-1 and SIC-2 items)

[24] SRDs for PBS 53 (See table 1 below)

[25] Chemical composition and impurity requirements for materials (REYV5V v2.3)

[26] **Template for preliminary list of defined requirements (MUAWA6 v1.1)**

[27] **Fire risk assessment for NB cell cryostat circular and rectangular bellows (UBFQ6C v2.1)**

[28] **Design Seismic Floor Response Spectra in the Tokamak Complex (SVBRJZ v1.1)**

[29] **Safety assessment of SF6 system (Q6EQEW v1.3)**

[30] **EDH Part 5: Earthing and Lightning Protection (4B7ZDG v3.0)**

Table 1.

PBS	Title	Accronyms	SRD
53-01, 02, 03	Neutral Beam Heat & Current Drive System	NB H&CD	ITER_D_28B37M V3.6
53-04	Diagnostics Neutral Beam	DNB	ITER_D_2MRU8E
53-P1, P2, P3	Power Supply for NB H&CD	NB H&CD - PS	ITER_D_2FCB9C
53-P4	Power Supply for DNB	DNB - PS	ITER_D_2ENKHK
53-PR, MI, MP, SI, SP	Neutral Beam Test Facility	NBTF	ITER_D_2WCCSG
53-S6	SF6 Gas System	SF6	ITER_D_2FUUVU

4 Roles and Responsibilities

According to Management of propagation of nuclear safety requirements in the supplier chain (BG2GYB v2.0) [1], section 5.3, the following personnel are responsible for the generation, review, approval, implementation and follow-up of this document;

- TROs for PIC – Each responsible for PBS 53. Co-author(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 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]),
- IO NSLE Head: Approver of this document.

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

- DA TRO(s) for NB 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 EU-DA JA-DA, II-DA and EU-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 DA supplier chain (ref. section 6.1 of [1]) and subsequent demonstration of same for each construction and commissioning PIA.

5 Methodology to define entire defined requirement

This chapter is dedicated to present a method to identify the applicable defined requirements.

According to **Propagation of the Defined Requirements for Protection Important Components Through the Chain of External Interveners (BG2GYB v3.1)** [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 their 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 53 PIC components is presented in appendix A.

Details of the list of defined requirements for PBS 53 is described in section 6.

6 List of Defined Requirements

According to **Propagation of the Defined Requirements for Protection Important Components Through the Chain of External Interveners (BG2GYB v3.3)** [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 SIC 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.

However, instead of describing the defined requirements in the aforementioned formats, description of the defined requirements is made in narrative way (see Appendix A) as it is chosen and agreed method and practice for IO and the DA. In addition, a table is given in Appendix B (in attachment in IDM) to provide the defined requirements in such a way to be manifest in one doument. The table in appendix B is simplified in comparison with the tables in [1]: in fact, considering the location and characteristics of PBS 53 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 so much applicable to PBS 53 PICs.

The list includes all the defined requirements for all PBS 53 PICs given in SRD-53, PR 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 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 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].

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

6.1 Safety design criteria

Short description of the HNB-system

The HNB system extends the primary vacuum boundary or first confinement from the VV along the beam line - HNB vessel – ion source vessel to the HV bushing. The bushing penetrates the NB-cell ceiling to the HV-deck and provides the first confinement boundary to the transmission line and SF6 vessel. It contains the penetrations into the primary confinement of the supply lines at high voltage for the electrical power and H2/D2 feed gas as well as for the water and air coolants. The transmission line is located in the HV-deck at L3 (part of gallery) and penetrates the tokamak building wall to the power supplies located outside. The penetration through the tokamak building wall forms the boundary of the 2nd confinement system.

Short description of the DNB-system

Like for the HNB system, the DNB also extends the primary vacuum boundary or first confinement from the VV along the beam line - NB vessel to the HV bushing. The HV transmission line penetrates the NB-cell ceiling to the HV-deck and penetrates the tokamak building wall to the power supplies located outside. The penetration through the tokamak building wall forms the boundary of the 2nd confinement system and so they are considered like a hard core component. The diagnostic neutral beam (DNB) injector shall provide a probe beam of 100 keV H^0 to be used by the CXRS diagnostic system (PBS 55 E). There is no SF6 in the transmission line.

<u>PBS 53 has the following PIC functions:</u>

- Ensuring confinement of radioactive materials during all mode of operation (note that maintenance mode is a normal operation mode)
    - through adequate and reliable double confinement barriers, and systems,
    - through adequate radioactive inventory control provisions (hypothesis vs maintenance plan)

- Ensuring minimization of radiation exposure of workers by using materials with low concentration of Co, Nb and Ta
- To close the Fast shutter (PIC/SIC-1) as fast as possible during any type of in-vessel event including ingress of air/coolant in DNB/HNB injectors,ie :
    - The closure time shall be lower than 5 s.
    - The support systems shall have a redundancy.
    - The status is failed safe closed and passive closure shall be performed in a minimum time as possible that shall not exceed a range 10-15s after initiating event
    - Leak tightness shall be effective 30 s after the beginning of the transient (complying with PR1210 – table 7.4 – line 1)
-
- Exclude unintentional opening of the absolute valve during maintenance operation
- Limit and detect coolant ingress in HNB/DNB injectors
- Limit and detect H_2/D_2 feed line leaks to exclude explosion risk and LOVA
- Limit and measure release of SF6 in tokamak building
- Limit and measure release of SF6 outside the tokamak building
- Limit the risk of an explosion of several SF6 tanks in SF6 storage area by adequate measures

The safety criteria are analysed for each PBS 53 system, sub-system and components according theirs PIC class 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.

<u>The PR is describing the following General recommendations:</u>

- Protection-Important Components shall be subject to monitoring as needed to ensure that they will perform their accredited safety functions. [3] [PR1248]

- ITER design shall be designed in order to provide redundant and, where appropriate, diverse systems as necessary to achieve the required reliability. [PR2047]

- Appropriate control, test, inspection and qualification procedures shall be implemented during design, construction, assembly, installation and commissioning in order to ensure that Safety-

Important Components (SIC) will perform their accredited safety functions (including the control/audit, update and keeping of associated records for SIC element). [3] [PR1206]

- Operation, inadvertent actuation or damage to components that are not SIC, shall not prevent SIC systems, structures, or components from accomplishing their safety functions when required. [PR1311-R]
- Prior to opening the double confinement of a hydrogen-bearing system, measures shall be taken to avoid the presence of potentially explosive conditions. [PR2041-R]

In the normal conditions the requirements are the following for what concerns the components ensuring a SIC-1 function (see appendix A:

- Single failure criterion on active components, redundancy,
- Physical separation,
- 2 redundant trains powered by 2 independent electrical networks, UPS maintained for 4 hours for on-line continuous sampling/monitoring (in case of total blackout of up to 4 hours), UPS maintained for 1 hour for the others
- 2 redundant trains powered by 2 independent networks for the support services (air compressed, N2 supply …)
- Equipment status indication (type of parameters, local, remote)
- Periodic tests requested
- Routine Maintenance test requested
- I&C classification
- Environmental Qualification requested
- Seismic Class SL2 (SC1-SF)
- QA class 1 (QC1).

In the normal conditions the requirements are the following for what concerns the components ensuring a SIC-2 function (see appendix 1):

- Single failure criterion on active components, redundancy but with a case by case analysis,
- when redundant, physical separation
- equipment powered by safety class power supply, UPS (TBD according to the systems),
- 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 (QC1 or QC2), upon a case by case analysis.

In the accidental conditions the requirements are the following for what concerns the PBS 53 components ensuring a PIC function (see Appendix 1):

- Single failure criterion on active components based on a case by case analysis,
- when redundant, physical separation on a case by case basis,
- powered by safety class power supply, UPS maintained for 1 hour (in case of total blackout of up to 1 hour),
- 2 redundant trains powered by 2 independent networks for the support services (air compressed, N2 …)
- Equipment status indication (type of parameters, local, remote)
- To estimate potential risk of H2 explosion due to radiolysis or due to the hydrogen content in water
- To define and implement the I&C logic needed to cope with the accident

- To prevent any aggression to other PIC or to other elements of the TCWS by pipe whipping [3] [PR1192-R]
- To protect from any aggression (thermal impact cold or hot, chock, drop load, seismic load …) of surrounding components which could jeopardize the confinement barrier (defined in the environmental room book and [3]).

Human and organisational factors shall be considered at every stage of the design in accordance with the Human factor Integration Plan readable 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 B.

In the external, internal hazards and combinations loads, the general requirements are the following:

- OP : Operability before, during or after a situation,
- NF : non fire propagation
- AG : non-aggression PIC
- CA : confinement to air
- CL : confinement to liquids

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

6.2 Normal operations

Normal operation includes maintenance operations.
During normal operation, the following requirements will define the PIC functions:

a) the radiological, ventilation, waste, fire, deflagration, beryllium and electromagnetic zoning
b) limits and ALARA requirement for annual routine releases for gaseous and liquid effluents
c) collective and individual dose for workers
d) operational and decommissioning waste
e) prevention of incidents and accidents (quality, qualification, inspection, testing, defense in depth, training)
f) design parameters defined by the enveloping design base accident, safety assumptions on operating limiting conditions (OLC), maximum enveloping break sizes, inventories, concentrations, timing for isolation, passive design features, etc.)

6.2.1 Environmental conditions in specific rooms and locations

PBS 53 PIC components shall be qualified to function under the following environmental conditions for which their service required (during normal conditions or accident) [3] in [PR1538-I], [PR1549-R] and [7] chapter 6. The reference safety conditions are provided in the safety requirement roombook [11].
Atmosphere environmental conditions during normal operation:
• Temperature range: between 18°C and 35°C,
• Humidity (maximum in the room) : 60%
• Pressure: 100 kPa

The reference safety conditions for the following parameters are provided in the safety requirement room book (KF63PB) for several incidents/accidents:
• Temperature (peak and duration)
• Humidity (peak) : 100%
• Pressure (peak and duration)

Environmental conditions for outdoor PIC components are [11] :

- External temperature: -25 C,+45 C.
- Extreme winds : 166 km/h
- Extreme absolute humidity : 30 g/kg
- All environmental monitoring sensors, stations … for the outdoor components shall withstand the snow load of 150 daN/m2 without interruption of services.

All PIC outdoor components shall operate without interruption of services or equipment damage under exceptional wind speed of 166 km/h.
All PIC outdoor components shall operate without interruption of services or equipment damage under extreme temperature conditions -25°C, +45°C with in addition, the effect of solar flux 1KW/m2 in extreme hot condition [].

The HNB components that require specific attention for environmental impact are the following:

- The SF6 filled HV Bushing vessels,
- The SF6 filled HV transmission lines
- The SF6 filled storage tanks.

SF6 leak rates from equipment shall not exceed 0.1% per year towards the environment [PR1505-R]

6.2.2 Routine operations requirements

The routine operations (called also normal operation) requirements associated with protection important components and protection important activities are given in [4] and [7], with clearly identified functions [7] chapters 4 and 5:

The basic functions of HNB/DNB related to safety are the following:
- To provide the primary confinement for ACPs, tritium and dust of the VV
- To provide , confinement and detection and to limit in/ex-vessel cooling water leaks from NBI-PHTS
- To isolate the HNB/DNB from the VV by closure of the fast shutter during in-vessel event
- To avoid spreading of radiological species in NB cell during maintenance operation

The basic functions of SF6 system related to safety are the following:
- To provide confinement of SF6 in tokamak building and outdoor
- To detect and limit SF6 leaks
- SF6 may challenge detritiation systems. Leaks of SF6 shall therefore be detected and signals shall be sent to CSS in order to take proper action for confinement.

The basic functions of H_2/D_2 feed lines related to safety are the following:

- To provide adequate provision to avoid Hydrogen explosion
- To provide adequate provision to avoid LOVA due feed line leaks

Leak rates under accidental conditions

NB equipment and penetrations shall be designed or shall not challenge the leak rates defined in [3]:

- Overall safety leak rate limit for Vacuum Vessel and all its extensions: < 1% of total volume over 24 hours at 0.1 MPa pressure differential
- The penetrations of PBS 53 SSCs through safety barriers (vacuum vessel, port cell and tokamak building wall) shall be able to reconstitute some or all the features of the safety barriers they cross. These include leak tightness, radiological zoning (shielding requirements on penetration), fire sectors etc.

Other functions:

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

6.2.3 Material requirements

The NBI equipment shall be designed from material with the lowest reasonably achievable environmental toxicity. The recycling of the equipment that contains toxic materials or chemical products shall be taken into account as a design constraint.

Some materials used for the PBS53 PIC are subject to activation. The use of lower-activated materials shall be selected [3] [PR1478-R]. In particular, materials with low concentration of Co, Nb and Ta shall be selected for specific portion of the systems [18, 24, 25].

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 PBS 53 PIC components are a Quality Class 1 component, according to the Quality Classification Determination (ITER_D_24VQES). [24CRs408-R-A]

6.2.4 Penetration requirements

Any penetration (PIC or non PIC) through internal or external confinement barriers, fire barriers or radiological zones shall reconstitute the barrier properties, in particular in order to respect the zoning (fire, Be, waste, radiological). This safety function is described in [3] and in more detailed in the penetration memo [19].

The HNB/DNB shall respect the zoning requirements [3][4][PR-1192][PR-1180] with regards to :

- avoidance of fire propagation, notably in case of a fire creating release of radionuclides/chemical products. All the penetrations crossing the fire zone shall be designed to avoid any propagation to other zones.
- Ventilation zoning: the radioactive inventory is to be controlled,
- Anti-deflagrant zoning: the areas where hydrogen is present shall meet the anti- deflagration zoning,
- Beryllium zoning: the parts of the systems likely to enclose Beryllium in accidental situations shall not release Beryllium outside the Beryllium controlled zones,
- Waste zoning: the waste zoning shall not be compromised in normal or accidental situations.

"CA"and "CL" requirements apply for any electrical and mechanical products penetrations across confinement boundaries. It also applies on primary containment envelopes (e.g. radioactive and chemical samples) inside or outside buildings.

6.2.5 Radiological and radiation protection requirements

The radiation defined requirements due to external exposure apply to shielding requirements for penetrations through VV and Bio-shield for plasma operation (Neutron, gamma also for coolant activation (N16–The emissions from dust, ACP and activated SF6 are in addition to the direct activation by neutrons. This radiation is mainly a concern during maintenance periods.

PBS 53 PIC components shall be qualified to function under the radiological conditions for which their service is required (during normal conditions or accident). The reference safety conditions are provided in the safety requirement room book [11].

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 [3] .

The radiological requirements regarding the qualification of the devices are defined inside the references [11] .

The concentration of Co in structural steels used shall not exceed 0.05 %weight. The concentration of Nb in structural steels shall not exceed 0.01 %weight [5] and shall be in agreement with [25].

Collective and individual dose for workers

The radiological safety objectives for all ITER activities are given by table 7.1 in [3].

For information, the collective annual worker dose, averaged over the operational life time of ITER shall not exceed an annual target of 0.5 person-Sv. [PR1129-R]

Per ITER policy, where hands-on maintenance activities in port cells and in other locations in the Tokamak Building requiring human access are performed, dose rate shall be as low as reasonably achievable and shall not exceed 100 μSv/h at 1.0E+6 s (~12 days) after shutdown without formal project approval. [PR1130-R]

NBI operations will have to comply with those limits.

6.2.6 Electromagnetic requirements

The selection and installation of the instrumentation and control equipment shall take into account the strength of the magnetic field in the relevant part of the building as defined in reference [24].

PBS 53 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 [11].

The location and the selection of the REMS devices shall take into account the strength of the magnetic field in the relevant part of the Tokamak Complex as defined in reference [8].

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 in the references [15][16].

6.3 Internal events/hazards

This chapter describes the events/hazards which could occur in the nuclear building.

The PBS 53 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 internal and external events (hazards):

- Internal events:
  - Fire;
  - Flooding;
  - Internal missile (PIC components shall be protected against the risk that is associated with potential missiles from high energy fluid circuits (pressure greater than 20bar or temperature greater than 100ºC) and pipe whipping or other potential sources for missiles (such as internal explosion, failure of a machine with moving parts);
  - He leaks
  - Electromagnetic field
  - Electromagnetic interference, including internally generated electrical transients such as fast transients, switching surges, voltage ripple, harmonics, and inrush
  - -Erroneous operator action.

The PBS 53 PIC components shall be designed and manufactured to minimize the risk of breaks on pipes : the quality shall be QC1.

The requirements associated with the combination of other loads are described in [22] and the safety roombook (KF63PB).

6.3.1 Loss of off-site-power supply

PIC (SIC-1 and SIC-2) components shall operate without interruption of function in case of loss of off-site power supply up to 72 hours and shall therefore be connected to UPS and emergency diesel generators.

UPS provide power from batteries up to 4 hours for DC and up to 1 hour for AC. They should be physically separated in different fire sectors (or protected against fire if they are in the same fire sector.

NBI PIC function shall be maintained in case of a loss of off-site power up to 72 hours and in case of a total loss of power supply from diesel generators up to 4 hours.

6.3.2 Fire

PBS 53 components inside nuclear buildings shall meet the following defined requirements for fire. The design shall include provisions to minimize the potential for other hazards to challenge confinement systems. These include internal aggressions such as fire or flooding, and external aggressions such as earthquake or extreme weather conditions [PR1237-I].

PBS 53 components and their support systems shall be able to continue to operate (or shall be protected adequately) during the fire conditions [3] outlined in [PR1286-R] and [PR1291-R]. They shall function in areas with large variations of pressure, temperature and humidity and in presence of soot. The failure of a PIC system shall send an alarm to CSS.

Electrical cables (PIC or not) shall be (See [14]) designed according to the requirements defined in the documents [3] , [7] in chapter 6.9 and [11] in appendix 1:

- Reduced flame propagation (according to IEC 60332-3 –flame spread for cable bunches- or NF 3207 C1
- Fire resistant according to IEC 60331 or NF 32070 CR1)
- Flame retardant (according to IEC 60332-1 –flame propagation on single cables-)
- Low smoke (according to IEC 61034) [22] chapter G.4
- Zero Halogen (according to IEC 60754-1) [22] chapter G.4
- Non toxicity (according to IEC 60754-2)

For all SIC1 and 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 53 materials in nuclear buildings shall be non-halogenated and difficult to burn.

Epoxy (FRP) and SF6 inventories need to be especially assessed (fire analysis ongoing). No normal or accident situations (including fire) shall lead to release of halogenated products in areas served by DS.

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 PBS53 shall be minimized and consistent with fire loads provisions in rooms and be designed in order to avoid the propagation of a fire. Caution is needed to epoxy, depending of the design choice to decrease fire load (see [27]).

In critical areas (see [12] appendix 2), each cable tray shall be covered by an envelope 360 degrees, 2 hours fire resistant. Their SIC 1 electrical supply and I&C trains (A and B) are routed through independent and separate fire sectors. For SIC 2 power and I&C cabling, only one train (A or B) is required to go through a fire sector. Only one train is protected. If a SIC 2 component has a single line, the power and I&C cabling line must be protected.

Basically, the routing of the trains supplying a SIC-1 or redundant SIC-2 component should be physically separated and located in different fire sectors. Exceptions are only in case where cables of two trains go through the same fire sector in the rooms, the cable trays shall be covered by a 2 hours fire protection envelope. In corridors, where two trains are present, they shall be routed from different sides of the corridors [12] appendix 1.

Non PIC cables trays shall not generate missiles effect or fire departure due to short circuit in case of earthquake.

PIC components shall be either protected from possible over- or under-pressure that are induced by a fire occurring in the room in which they are located or from which they are sampling the atmosphere, or they shall be designed to withstand the pressure.

SIC-1 I&C cubicles shall include an automatic fire detection and suppression system. Alarms shall be reported to the control rooms (normal and back-up control room). SIC-1 cubicles shall not be mixed with other cubicles in the same rooms. Any exception shall be prior discussed with IO-SRO, but with the minimal requirements of a sufficient distance of 5 m between the two trains (e.g. opposite sides of a corridor). [7] chapter 6.8 and [12] appendix 1.

All the I&C cubicles (SIC-2, non-SIC, SR) located in the same room with at least one non-redundant cubicle SIC-2 shall be equipped with an automatic fire detection and suppression system. The redundant SIC-2 cubicles, can be implemented with the SR, and non-SIC cubicles in rooms equipped with an automatic fire suppression system. Alarm shall be reported to the control rooms (normal and back-up control room). The minimum distance between SIC-2 cubicles and non-SIC cubicles is 2m in cubicles rooms). [7] chapter 6.8 and [12] appendix 1.

Beside PBS 53, the NB cell hosts other PBS critical for safety. Specific calculations shall be performed in order to assess with validated codes for maximum fire conditions (see [26], analysis for the bellows). If these calculations are not available EUROCODE conditions shall be adopted: +-5 kPa and 1049ºC for 2 hours.

6.3.3 Load drop and missile effects

The design shall include provisions to minimize the potential for other hazards to challenge confinement systems. These include internal aggressions such as fire or flooding, and external aggressions such as earthquake or extreme weather conditions. [PR1237-I] Therefore, likehood of drop loads of PBS 53 on SIC-1 and SIC-2 shall be prevented as well as PBS 53 shall not become a missile dropping on other components, including during earthquakes events.

6.3.4 Flooding

The design shall include provisions to minimize the potential for other hazards to challenge confinement systems. These include internal aggressions such as fire or flooding, and external aggressions such as earthquake or extreme weather conditions. [PR1237-I] Therefore, Internal flooding is due to the fire-fighting water or collapse of tank or water pipe break. PBS53 components, monitors, cubicles and cabling shall be located above the flooding level in the rooms.
PBS 53 sensitive components, sensors, cubicles and cabling shall be located above the flooding level in the rooms. The flooding might be caused by the fire-fighting water or a NBI cooling loop pipe break. [PR1237-I].
PBS 53 PIC components shall be protected from the effects resulting from an internal flooding and they shall be able to maintain their safety functions.

6.3.5 Explosion

The design shall include provisions to minimize the potential for other hazards to challenge confinement systems. These include internal aggressions such as fire or flooding, and external aggressions such as earthquake or extreme weather conditions. [PR1237-I] Therefore, PBS53 components shall not become an ignition source for explosion in rooms with hydrogen isotopes inventories under a gaseous form which is the case for, NB.

PBS53 components shall not become an ignition source for explosion in rooms and equipment with hydrogen isotopes inventories in gaseous form. These could be the H_2/D_2 feed lines, the Regeneration line etc.

<u>Failure of H_2/D_2 line :</u>

Failure of a H_2/D_2 line shall be avoided by correct design and installation in order to exclude H_2 explosion and LOVA event. Double isolation PIC valves shall be used to mitigate LOVA event and stop H_2 leaks in case of failure. Double confinement up to the isolations valves shall be used.

- The design of all ITER systems shall be such that chemical energy inventories are controlled to avoid energy and pressurization challenges to confinement. [PR1225- R].
- Each confinement system shall include one or more static barriers, or dynamic components, to confine the inventory at risk. Static barriers require no moving parts to fulfill their confinement function (such as vacuum vessel, process piping) whilst dynamic components require moving parts (such as isolation devices or détritiation systems). [PR2018-R]
- Systems/components to ensure the confinement function shall be independent, and physically separated, to avoid common mode failure that could lead to loss of both systems. [PR1201-R]
- The H_2/D_2 line is a Quality Class 1 component, according to the Quality Classification Determination (ITER_D_24VQES).
- Valves that are part of a confinement boundary shall operate within required periods after detection of the onset of an incident or accident. [PR1189-R]
- The confinement isolation valves shall assume their safe position on loss of power [PR1190-R]

Explosion zoning is identified in [3].
PBS 53 PIC components ensuring Vacuum vessel confinement shall however take into account small internal explosion (deltaP < 2 bar) as a design basis.

<u>VV dust explosion initiating by H2 explosion into the NB vessel:</u>

[9] describes a Hydrogen and dust explosion in the vacuum vessel leading to a pressure of 565 kPa in 1.1 seconds after the explosion in the Vacuum Vessel and up to 2 bar in the NB-cell. This event shall remain as Beyond Design Basis. Lines of defense (prevention, mitigation e.g. air ingress) of this BDBA are designed to prevent this high pressure (see 7.5.4.3 of [3].

The following requirements shall be taken into account to avoid hydrogen explosion and the NB systems shall be designed accordingly:

<u>Prevention of a hydrogen explosion</u>

- Hydrogen isotopes inventories shall be controlled inside the NB equipment,
- the NB equipment shall be designed in such a way that it is preventing any event related to the spread of hydrogen isotopes from the NBI equipment, and in particular the cryopanels (e.g. H2/D2 supply shall be stopped by adequate devices like isolation valves …),
- the NBI equipment shall be designed in such a way that it is preventing any air ingress inside the NB equipment that is connected to the vacuum vessel, and to make this NB equipment resistant to internal or external hazards, by isolation systems to avoid air ingress into the NB vessel
- the NB equipment shall be designed in such a way that isolation (ie fast shutter) is established as fast as possible between the NB injector and the VV. This should be done to limit the dust propagation from the VV to the NB injector and mitigate H2 explosion risk in NB vessel during LOVA scenario

<u>Detection leading to hydrogen explosion</u>

- the release of hydrogen isotopes as well as potential loss of vacuum inside NB shall be detected as quickly as possible, in order to avoid potential hydrogen isotopes explosion. For PBS 53, it is limited to the detection of loss of vacuum.

<u>Mitigation of hydrogen explosion</u>

- the detection of a LOVA inside NB or of the release of hydrogen isotopes shall trigger an explosion mitigation system. This explosion mitigation system may consist in a at least to

close the fast shutter and by other mitigation systems like inert gas injection (shall be confirmed by safety analysis)
- NBI layout shall be designed in such a way that missile effects would not compromise the containment barriers in an explosion event.

Common mode failure and Single Failure Criteria shall be taken into account in the design of these lines of defense. They shall be SL2 designed and powered supplied by UPS from two independent electrical networks if use of two active components.

6.3.6 Helium leaks

PBS 53 sensitive components shall be located at a distance higher than 5 meters from helium lines (cryo pump supply) inside the NB-cell. For the NB-vessel a He spill from the cryo-pump is a system specific load and shall be assessed.

PBS 53 components shall be protected from the effects resulting from an helium leak in the galleries, port cells, NB cell, in particular due to cold gas temperatures atmospheres (down to -170C for a very short period of time very close to helium lines but the material surfaces temperatures is higher), with pressures up to 1.2 bar abs, potential clogging sampling lines due to freezing.

6.3.7 LOCA accidents

These accidents concern LOCA in the NB cell on NBI PHTS or IBED PHTS.

These accidents are characterized by:

- A maximum pressure in the NB cell up to 1.6 bar abs
- An increase of temperature (i.e.saturation temperature at the given Nb cell pressure ($T_{sat}(P_{Nbcell})$) during the accident),
- Presence of steam and water,
- Presence of tritium and active corrosion products.

PBS 53 PIC functions shall continue to operate in those conditions.

LOCA on NBI-PHTS shall be detected and design provision shall be set up in order to limit water inventory release in NB cell or VV. Valves that are part of a confinement boundary shall operate within required periods after detection of the onset of an incident or accident. [PR1189-R]. The confinement isolation valves shall assume their safe position on loss of power [PR1190-R]

6.3.8 LOVA accidents

As generic requirements, Loss of Vacuum accidents shall be prevented by design. The following generic requirements apply:

Confinement of hydrogen and prevention of air ingress into the first confinement systems with flammable inventories:

The H_2/D_2 line is designed with surrounding pipes and with isolation valves to prevent and limit LOVA and H_2 leaks.

Fast shutter shall be closed during LOCA and/or LOVA event as fast as possible (in order of magnitude of 1 s).

Reliable separation, typically provided by two barriers, shall be provided between volumes that may contain air and hydrogen, including during off-normal conditions. Isolation shall be provided to prevent air ingress into the vacuum pumping system, fuelling system or Tritium Plant in the event of air ingress into the vacuum vessel. [PR1228-R]

Air ingress into VV shall be limited to 50 kg (limit consequences of dust and hydrogen explosion to 2 bar abs. in the VV) [PR1223-R]

Helium spill to VV shall be limited to 45 kg. Non-condensing inert gas prevents VVPSS from functioning [PR1315-R].

For information, during operation with an all-tungsten divertor, the inventory of beryllium dust and tungsten dust on surfaces that become sufficiently hot to be reactive with steam or air during incidents shall not exceed 11 kg for beryllium dust and 76 kg for tungsten dust. (The 11 kg Be or 76 kg W is the quantity which, if fully reacted with steam, leads to 4 kg hydrogen in vessel. Deflagration of more than this quantity exceeds 0.2 MPa peak pressure, the limit for the vacuum vessel (and windows, and so on).) [PR1152-R]

6.3.9 Other accidents

Other events affecting the NB vessel e.g. system specific accidents like electrical arcs should be taken into account as loads or prevented and mitigated in order to comply with [PR1311-R]

High Energy pipes

The internal hazards due to High Energy pipes are pipe whipping, fluid jet impingement, flooding, and contamination risks.

The criteria of HE pipes are defined as follows: either Operation pressure above 20 bar abs, or operation temperature above 100ºC.

The operation pressure and temperature of NB coolant is above 20 bars and 100ºC for certain components (acceleration grids, ion dump). The risk due to pipe whip or jet fluid should be taken into account. The fueling lines should be protected from high energy piping in the neighborhood.

Missiles

Likelihood of missiles on NB shall be prevented

6.4 External Hazards

External hazards concerns hazards which could happened outdoor,

The PBS 53 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;
- External fire
- Light airplane crash.
- External explosion

This applies mainly to the transmission line and its penetration through the Tokamak building wall. The penetration has to be designed against the loads of the above events and maintain the wall requirements and prevent propagation of the loads to the parts inside the tokamak building. If spare parts and or mobile devices are used as a back-up of PBS 53 PIC components for any of the external hazards, they shall be stored and housed in accessible rooms protected against any of the internal and external events/hazards considered for the facility.

6.4.1 Earthquakes

The design shall include provisions to minimize the potential for other hazards to challenge confinement systems. These include internal aggressions such as fire or flooding, and external aggressions such as earthquake or extreme weather conditions. [PR1237-I]

The floor response spectra used for design of the PBS 53 components are given in the system load specifications [17] and [28]. 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-SC1.

In addition, the following requirements are implemented:

Equipment classified PIC SIC-1 and SIC-2 : They shall be classified SC1-SF when they ensure an active function..

Equipment classified PIC but neither SIC1 nor SIC-2 : The PIC components shall be classified as SL2-SC1-S, except for potential cases when their function can be backed up by mobile equipment, or through using available spare parts that are protected in rooms designed against internal and external hazardsSL2 earthquakes.

All the components that participate to supervise in real-time the radiation status
All the components that participate to supervise in real-time the radiation status inside the facilities are designed to avoid any missile effects on SIC components in case of SL-2 or SMHV earthquakes (SC2).

When they are located outside the buildings, the function itself shall be maintained following an SL2 earthquake, but this can be performed by mobile components/spare parts that are housed in rooms designed against internal and external hazardsSL2 earthquakes.

The post-earthquake safe state of NBI is as follows:

- Confinement of radioactive materials in the processes
- Confinement of SF6 and Cesium in the process
- No risk of explosion in NB system,
- Fueling stopped
- Power supplies stopped and no beam accelerated
- Long term evacuation of the inventories onto the hydride beds of the SDS
- To have the possibility to evacuate SF6 to the storage tanks

It means the following “defined requirements” shall be met:

- Confinement of NBI shall be ensured during and after SL2 to avoid radiological and hydrogen isotopes releases as well as release of SF6 and Cesium.
- PIC Pressure relief valve and isolation systems shall withstand and operates during and after earthquake level SL2, and backed up by emergency power supply

- Hydrogen explosion mitigation systems shall be designed SL2
- Long term evacuation of the inventories onto the hydride beds of the SDS .

6.4.2 Lightning

The PBS 53 system shall be protected against lightning. The design solution should be designed according to the electrical handbook (see [30]),

6.4.3 External outdoor flooding

The design shall include provisions to minimize the potential for other hazards to challenge confinement systems. These include internal aggressions such as fire or flooding, and external aggressions such as earthquake or extreme weather conditions. [PR1237-I]

The external flooding inside ITER site is induced by :

- A centennial rain +20%. This corresponds to a flow rate of 6.66l/m2/minute during undetermined period of time. ,
- a failure of the rain water drainage system on ITER site
- a rupture of a water pipe on ITER site due to an earthquake.

The components of PBS53 system inside the building are not concerned by the external flooding (Buildings defined requirements QD0302B).
The components of PBS53 system concerned are only the external components for power supply or for SF6 storage and shall be designed to such loads.

6.4.4 External fire

The risk of external fire is constituted by the following:

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

The PBS 53 components concerned by the external fire are the power supply, transmission line and SF6 storage tanks. In case of their failure there should be no direct impact on the nuclear buildings or buildings hosting SIC-components like emergency power supply and fast discharge units for magnets.

In addition there should be no indirect impact on the safety systems mentioned before by e.g. causing a failure of cryo-storage tanks.

6.4.5 External explosion

The external explosion is represented by an incident compressive wave with a triangular shape and a straight front, with a maximum overpressure of 0.05 bar and a duration of 300 ms. The wave is assumed to come from any horizontal direction, and reflexions and focalisations. The effects of reflections and focalisations may generally be taken into account by the way of a global weighting coefficientto be applied on the incident pressure wave. Unless specified, this coefficient shall not be less than 2 for vertical wall in front of wave, and 1.5 for roofs.

The PBS 53 components concerned by the external explosion are the power supply, transmission line and SF6 storage tanks. In case of their failure there shall be no direct impact on the nuclear buildings or buildings hosting SIC-components like emergency power supply and fast discharge units for magnets.

In addition there shall be no indirect impact on the safety targets mentioned before by e.g. causing a failure of cryo-storage tanks.

6.4.6 Airplane crash

A mitigation system on the penetration on B11 wall at the level of each of the 4 penetrations shall be implemented (inside or outside the tokamak) in order to prevent any propagation of this accidental scenario into the TKM building by PBS 53 and/or its interfaces.

For SF6 storage, no specific requirement is needed (see [29]). But this scenario is not excluded and shall be considered in case of any design changes.

7 Conclusion

The current document presents the list of the defined requirements for PBS 53. The analysis has shown that there is no additional requirement from the technical baseline.

Appendix A: Reminder of the protection important classification for all functions ensured by PBS 53

Table A1: Safety Important Classification of the NB sub-systems:

Sub systems	Safety function	Classification	Rationale
Confinement of radioactivity (and Beryllium) (CA,CL) a) Static Process confinement barriers b) Active confinement barrier assuring continuity of barrier in case of penetrations (isolation valves)			
Primary Vacuum boundaries	- Confinement of dust and tritium in the VV and the NB which is an extension of the VV - Prevention of air/SF6 ingress	SIC-1	High tritium/hydrogen and dust inventory
Parts of process boundary outside the NBI **penetrating** into the NBI which are open to primary vacuum -fuelling lines ion source, neutralizer - Regeneration line - Vent line	Confinement of in-vessel sources up to isolation valves. Confinement of process inventory Prevention of air ingress	SIC-1	Confine dust and tritium in the VV. Prevent air ingress (dust and hydrogen explosion in the VV)
Parts of process boundary outside the NBI **penetrating** into the NBI which are connected to non-SIC components inside primary vacuum - water cooling and cryo-lines lines - includes cooling-, feed- and air circulation line	Confinement of in-vessel sources up to isolation valves. Confinement of process inventory	SIC-1	Confine dust and tritium in the VV. Prevent water or helium ingress into VV (prevent hydrogen production on hot surfaces and pressurization of the VVPSS by non-condensable gases.

Redundant Isolation valves to the NBI - cooling/cryo-lines - feed lines - cryo-pump regeneration line - vent line	Confinement of in-vessel sources and limiting air/coolant/non-condensable gas ingress into VV [single failure criteria *]	SIC-1	Confine dust and tritium in the VV. Limit air or coolant ingress into VV (limit consequences of dust and hydrogen explosion to 2 bar abs. in the VV
Isolation valves on building penetrations or on fire sectors	Confinement of process inventories within confinement and fire sectors and limiting spill to sectors to 70 g-T see also safety function protection of confinement - limiting hydrogen release - prevent propagation of fire	SIC 1	The tritium inventory is limited to 70 g Limit environmental releases
Isolation valves for process sub systems	Limit spill to 70 g-Tritium in each fire sector	SIC 1	
Safety I&C for SIC-1 isolation valves	detection and action for isolation	SIC 1	
Failed safe position and radiological monitoring	Radioprotection	SIC 2	Radiological criteria acceptance

* **Single failure criteria, Event sequence:**

Initial failure (e.g. pipe break) → first safety action fails (valve does not close) →2nd action successful (2nd valve closes)

Protection of confinement (AG, NF)			
a) management of pressure (isolation valves to limit coolant spills, pressure relief etc.)			
b) management of chemical energy: limit of operational/accidental temperatures (shutdown of fusion and heating power) , limit spills & inventories, explosion proof design (pressure) or prevention			
c) management of magnetic energy (shielding, mechanical design, insulation, material selection etc.)			
d) management of heat removal and long term temperatures,			
e) fire detection/mitigation,			
f) mechanical impact (including seismic, load drop, pipe whip etc.),			
g) management of mobilizable radioactive inventories (administrative limits, detritiation dust removal)			
h) External and internal hazards (flooding, airplane crash, fire, explosions, missiles, fire, extreme weather conditions)			
Sub systems	Safety function	Classification	Rationale
Beam/Power shut down	Protection of non-SIC in-NB-vessel components from heat-up in case of loss of cooling	SIC	No damage to the FS and 1st confinement barrier.
Limit Hydrogen inventory on cryo-pump	Management of chemical energy: Limit possible explosion in the NB to < 2bar absolute	Administrative limit	Adiabatic pressure < 2 bar requires as rule of thumb that the total amount of hydrogen < 1.5 mol/m^3 in a single volume. Factor 2 lower (<0.7 mol/m^3) is the guideline to account for dynamic effect (reflection of pressure wave)
Deuterium/Hydrogen feed line	Management of chemical energy: Limit possible explosion in the NB cell to < 2 bar absolute	ATEX, administrative limits	Double piping/ inerting Safety requirements on the - 6 bar feed line double walled in air recirculating pipe - NB feed supply to ion source from SDS SDS might be using gas bottles or storage beds). - NBI feed supply to Neutralizer from SDS or bottles.

High-voltage parts	Prevention of arcs damaging first confinement of HV bushing, SIC lines in transmission line, vessel and beam duct	PIC	No damage to the 1st confinement barrier (to comply with [PR1311-R])
VVPSS box and interfaces	Protection of VVPSS from fire, SL-3 event	SIC-1	The VVPSS is a critical system in the ITER safety approach
in building penetrations	Prevention of fire propagation in Cell and on HV-deck.	Classification default: same as penetration	see reference Penetrations through safety barriers JLDU7W
ex building penetration	Prevention of propagation of external events (air plane crash, extreme weather etc.)		
Mechanical support of SIC components	Integral part of the safety function	Default classification: Same as supported safety function	Failure of support should not prevent or have an impact on the supported safety function

Limiting Exposure (SH)			
a) Shielding to limit exposure			
b) Access control			
Sub systems	Safety function	Classification	Rationale
Shielding	Protection of public and worker from ionizing radiation Protection of SIC I&C	SIC-1	Large penetration through VV and, Bioshield need additional measures
Magnetic shielding	Protection of worker from magnetic fields and RF emissions Protection of SIC IC	SR	
NB-Cell, HV deck, external area	Access control during plasma operation and maintenance		
Support of systems for confinement and limiting exposure (OP)			
a) Services for functioning of systems implementing safety functions such as instrumentation and control, electrical power, compressed air for valve actuators, etc.			
b) Monitoring of safety functions.			
a) Triggering and performing of actions	Part of the supported active safety function	Default classification: same as safety function SIC-1 function: redundancy (single failure criteria required) SIC-2: case by case	Failure of support should not prevent or have an impact on the supported safety function`
b) Monitoring of safety functions	For normal operation and accident management	SIC-2	

Table 1 –Safety functions and SIC Classification rational

The SIC components must be designed to all load combination of their system itself and the loads from all accidental and normal environmental conditions resulting from the ITER design base event analysis. A failure of system itself should not lead to more severe environmental conditions in its location.

Table 4: Safety Requirements for a typical category of equipment and its penetrations which should comply with safety requirement of the room e.g. total leak rate and fire resistance (see also room book)

Equipment Category	**CA :** aerosols and gas confinment	**CL :** Liquid confinement (process or fire)	**SH :**nuclear shielding	**OP :** Operability	**AG :** non aggression SIC	**NF** : non fire propagation
Vacuum Vessel and Extension (Primary Vacuum)	To provide the same confinement of Vacuum Vessel [ref 27ZRW8] ≤1% volume/dat @ 0.1 MPa Δp	To provide the same confinement than the Vacuum Vessel [PR]	N/A	N/A	N/A	N/A
Isolation of Vacuum Vessel Extension	To provide the same confinement of Vacuum Vessel [ref 27ZRW8] (after isolation) ≤1% volume/dat @ 0.1 MPa Δp	N/A	N/A	To provide isolation to ensure confinement (CA) within the required time	N/A	N/A
Shielding	N/A	N/A	Provide adequate shielding: Interspace <100uSv/h @10^6s Port Cell <10uSv/h @24 hr respect Port Cell, Gallery and external zonings, as defined in [ref 2E4KSJ, FF92TR]	N/A	Not to damage surrounding equipment important to safety	The action of a fire shall not: - Degrade the functions of the Penetrations - Allow the spread of fire to other Fire Sectors EUROCODE 2H
PBS53 penetration gallery through safety barrier	To provide the same confinement than the gallery [ref 2E4KSJ] ≤100% volume/dat @ 300 Pa Δp ≤820 % volume/dat @ 20kPa Δp	To provide the same confinement than the gallery [ref roombook]	Provide the same shielding than the gallery wall [ref 2E4KSJ, FF92TR]	N/A	Not to damage surrounding equipment important to safety	The action of a fire shall not: - Degrade the functions of the Penetrations - Allow the spread of fire to other Fire Sectors EUROCODE 2H

PBS53 penetration Port cell through safety barrier	To provide the same confinement than the Port Cell [ref 2E4KSJ] ≤100% volume/dat @ 300 Pa Δp ≤1420 % volume/dat @ 60kPa Δp	To provide the same confinement than the Port Cell [ref roombook]	Provide the same shielding than the Port Cell wall [ref 2E4KSJ, FF92TR]	N/A	Not to damage surrounding equipment important to safety	The action of a fire shall not: - Degrade the functions of the Penetrations - Allow the spread of fire to other Fire Sectors EUROCODE 2H
Support function	N/A	N/A	N/A	Stability, Support of SIC in all conditions	If failure of support, not effect on SIC	The action of a fire shall not: - Degrade the functions of the Penetrations - Allow the spread of fire to other Fire Sectors EUROCODE 2H
Protection against other aggression	N/A	N/A	N/A	The action of any additional aggression shall not: - Degrade the safety functions	Not to damage surrounding equipment important to safety	The action of a fire shall not: - Degrade the functions of the Penetrations - Allow the spread of fire to other Fire Sectors EUROCODE 2H

These requirement have to be applied to all hazards and loads of category I to IV. The designer has to define if the load is relevant for the equipment.

Appendix B

Tables B-1 to B-4 provides the defined requirements for the loads and loads combination applicable to PBS 53.
These tables are in attachment in IDM.

Note) the requirements have to be given for each "design conditions". The general requirements are the following:

- *CA: aerosols and gas confinement (for primary confinement enveloppes or when systems cross confinement boundaries)*
- *CL: Liquid confinement (process or fire) (for primary confinement enveloppes or when systems cross confinement boundaries)*
- *SH: Nuclear shielding*
- *OP: Operability before, during or after a situation*
- *AG: non-aggression SIC (when the components are inside the buildings)*
- *NF: non fire propagation (when the components are inside fire sectors or cross fire sectors)*

ANNEX B

Remark: These tables need to be refined together with the TRO to identify the exact function, location and connections of the components.
These tables are presented in the excel file in attachment.