IDM UID
Q9DVN3
VERSION CREATED ON / VERSION / STATUS
30 Jun 2017 / 2.1 / Approved
EXTERNAL REFERENCE / VERSION

Memorandum / Note

PBS 24 VVPSS for Defined Requirements

This document defines the list of Defined requirements for PBS 24 VVPSS.

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Seropian C.**	**30 Jun 2017:signed**	**IO/DG/RCO/SD/EPNS/SAA**
Co-Authors			
Reviewers	**Cortes P.** **Perevezentsev A.** **Sekachev I.**	**13 Jul 2017:reviewed** **30 Jun 2017:recommended** **30 Jun 2017:recommended**	**IO/DG/RCO/SD/EPNS/SAA** **IO/DG/COO/PED/CSED/VVPS** **IO/DG/COO/PED/CSED/VVPS**
Approver	**Elbez-Uzan J.**	**20 Jul 2017:approved**	**IO/DG/RCO/SD/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: EMAB, AD: OBS - Environmental Prot - Nuclear Safety Division (EPNS) - EXT, AD: OBS - Environmental Prot - Nuclear Safety Division (EPNS), AD: DA, AD: Auditors, AD: DA-TRO, AD: ITER Management Assesso...**		

Change Log			
PBS 24 VVPSS for Defined Requirements (Q9DVN3)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v0.0	In Work	17 Nov 2014	
v1.0	Signed	17 Nov 2014	Upload document.
v2.0	Revision Required	07 Jun 2017	This version considers the changes of the VVPSS modification.
v2.1	Approved	30 Jun 2017	Considering Alex's and Pierre's comments.

Preliminary Defined Requirements for PBS 24 VVPSS

Table of Contents

1 Scope

The scope of this document is to define the list of Defined Requirements, required by the French Order [2], for all the activities dealing with **structure, system and components (SSC) of PBS 24 – Vacuum Vessel Pressure Suppression System** 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 And, in the documents referenced herein, all PIC/SIC SSCs and SRA (safety related activities) are to be superseded by, PIC and PIA, respectively.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);

- BV: Bleed Valve
- CSU: Catalytic Scrubber Unit
- II-DA: India domestic Ageny
- NSLED: Nuclear Safety, Licensing and Environmental Protection Division of IO under IO-SQS
- MQP: Management Quality Plan
- PAR: Passive Autocatalytic Recombiner
- 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 (PIC/SIC), environmental important components (EIC) and crisis management components (CMC). PIC/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 PIC/SIC) components, associated Protection Important Activities and associated Safety Requirements is also an PIA.

- *normal operating:* operational functioning of the installation comprising all common operational states and operations of the installation, including maintenance and scheduled shutdown situations, with or without radioactive material; also, any situation defined as normal operating in the demonstration mentioned under the second paragraph of Article L. 593- 7 of the Environmental Code falls under this definition. It shall be noted that *normal operating* of VVPSS is an accidental event for the vacuum vessel;
- *incident or accident:* any event that is not expected during normal or degraded-mode operating conditions, and liable to deteriorate the protection of the interests provided for under Article L. 593-1 of the Environmental Code; the potential or real consequences of an accident are more serious than those of an incident. It shall be noted that incident or accident for VVPSS means conditions that might have an impact on VVPSS operability and efficiency during its operation for covering an accident with the vacuum vessel;

- RD: Rupture Disc
- RPrS: Preliminary Safety report
- SC: Scrubber Column
- SD: Safety DepartmentIO
- SSC: System, Structure and Component
- SRD: System Requirements Document
- VST: Vapour Suppression Tank
- VV: Vacuum Vessel
- VVPSS: Vacuuim Vessel Pressure Suppression System
- WR: Wet Recombiner

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

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

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

[7] AAR: Accidental Analysis Report

- 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)

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

[9] Safety requirements roombook (KF63PB)

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

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

[12] ITER_D_335VF9 – IO cabling routes

[13] ITER policy on EEE Tokamak complex CZX6S3

[14] Memo on penetrations through safety barriers - JLDU7W

[15] ITER_D_2E4KSJ - Safety Requirements for ITER Facility Buildings

[16] ITER_D_25SDBD – ITER Fire Safety Approach

[17] SRD-24-VP (VVPSS) – 28B2U6

[18] Load specification (LS) - 222QGL

[19]- **New VVPSS design proposal - Description (PX64Q7 v2.3)**

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

[21] Quality Classification Determination (24VQES v4.1)

[22] Magnetic Fields Tokamak Complex (ITER_D_2NM229 v 4.1]

[23] **System Load Specification for the Vapour Suppression Tanks (TU72QM v1.2)**

[24] **Tokamak Complex - Floor Response Spectra 2016 - Esteyco (TFN4DN v1.3)**

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;

- 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]),

- PED 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 NSLE Head: Approver of this document.

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

- IN-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.
- IN-DA QARO for PBS 24 PAs : Responsible for ensuring the requisite IN-DA and Contractor quality procedures are in place and implemented to enable above activities to occur.

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

Details of the list of defined requirements for PBS 24-VP 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/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.
- Table 4 : combination

However, instead of describing the defined requirements in the aforementioned formats, description of the defined requirements is made in narrative way as it is chosen and agreed method and practice for IO and the DA. In addition, in Appendix A, a reminder of the PIC classification is given. The table in appendix B is simplified in comparison with the tables in [1]: in fact, considering the location and characteristics of PBS 24-VP 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 assessed in order how they are applicable to PBS 24-VP components.

The list includes all the defined requirements for all PBS 24-VP PICs given in SRD [17], PR [3] and from regulations ([2], [4], [5], [9]).

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 IN-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 IN-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].

The following design comes from the referenced input data [19] that have been used in the safety analysis made to determine the defined requirements.

The VVPSS include four tanks, called Vapour Suppression Tank (VST), that contain water with capacity to condense steam from the vacuum vessel sufficient to cover for events of DBA. All tanks are equipped with igniters to initiate hydrogen combustion once flammable atmosphere is created in free volume of a tank. Each tank is equipped with several igniters powered from redundant PIC/SIC source.

The VVPSS includes relief lines to allow gas transfer from the vacuum vessel to VVPSS tanks.

One relief line of DN500 is connected to three tanks. This line is equipped with redundant rupture discs to prevent pressure in the vacuum vessel exceeding pre-selected value. This value presents a set point for the rupture of the discs.

Second relief line of DN300 is connected to one tank. This line is equipped with redundant bleed valves. Set point for bleed valves shall be selected such that they shall be opened before rupture discs should break and before start of Catalytic Scybber Unit is initiated. Purpose of such set pints setting up is to enable gaseous hydrogen transfer from the vacuum vessel to the VST1 Currently the set point re the following :

- Bleed valves : 50 kpa
- Rupture disks : 110/ 115 kPa (min and max)
- CSU : 95 kPa to 145 kPa or 110 kPa (TBD) with at least a 550 s delay after the onset of the scenario.
- Draining lines at 80 kPa

The purpose of splitting the tanks on two batches and having two separate relief lines is to provide an option for reducing amount of the water being contaminated with tritium and ACP during an accident in the vacuum vessel.

The VVPSS is equipped with the Hydrogen Mitigation System. This system (called CSU) comprises:

- Pool Scrubbing Tank (PST),
- Wet Recombiner (WR),
- Scrubber Column (SC),
- Cold Water Tank (CWT),
- Passive Autocatalytic Reactor (PAR).

The Pool Scrubbing Tank is filled with water pre-cooled to pre-selected temperature. Water in the tank can be cooled down during an accident. This cooling is arranged through two redundant cooling loops served by child water from PIC/SIC source. The tank is equipped with igniters to initiate hydrogen combustion once flammable atmosphere is created in free volume of the tank. Several igniters are powered from redundant PIC/SIC source. Gas stream passed the tank is directed to the Wet Recombiner
The Wet Recombiner is filled with mixture of catalyst/packing material. The catalyst is catalytically active to promote catalytic oxidation of molecular hydrogen. To remove heat released due to exothermic reaction of hydrogen oxidation, catalyst is sprayed with liquid water. The wet recombiner vessel has a reservoir filled with water that is circulated through the catalyst bed. Water vapour produced in hydrogen oxidation are partially condensed in the wet recombiner itself. Further condensation of vapour occurs in the scrubber column. Gas passed the Wet Recombiner is directed to the Scrubber Column.

Scrubber Column is a packed tower filled with an inert packing. The packing is fed with liquid water. Inert packing provides a surface for direct contact between water and gas for their heat exchange. In addition to vapour condensation tritium isotopic exchange occurs between water vapour and liquid water in a counter-current mode. Feed-water is being cooled down during an accident. This cooling is arranged through two redundant cooling loops served by child water from PIC/SIC source. Gas passed the Scrubber Column is directed to the PAR.

Cold Water Tank provides source of feed-water for the Scrubber Column. The tank is filled with water pre-cooled to pre-selected temperature.

Pool Scrubbing Tank, Wet Recombiner, Scrubber Column, Cold Water Tank are assembled into a Catalytic Scrubber Unit (CSU).

Passive Autocatalytic Reactor presents a vessel filled with hydrophobic catalyst which promotes catalytic oxidation of molecular hydrogen at temperature around room temperature or higher. Purpose of PAR is to provide last barrier for hydrogen oxidation prior to the gas discharge to DS. PAR is installed on ST-VS (Suppression Tank Vent System) line downstream of CSU. Gas passed PAR is driven to DS by set of blower installed in ST-VS line which connects VVPSS with DS.

The CSU is equipped with a filter installed downstream of PAR to provide final barrier for radioactive materials in form of solid particulate.

The CSU is equipped to provide source of oxygen needed for catalytic oxidation of hydrogen in CSU and PAR.

There is a demand for VVPSS to process the gas atmosphere of the VSTs during an accident while maintaining of sub-atmospheric pressure in the vacuum vessel is performed by TC-DS in an arrangement designed for the vacuum vessel maintenance. VVPSS is equipped to switch back for providing sub-atmospheric pressure in the vacuum vessel if failure of TC-DS to do so is detected.

Cleaning of the VST tanks from gas containing gaseous hydrogen will be performed in a post-accident operation using a controlled purge of the tanks through CSU and PAR.

VVPSS is equipped with mean of filling the tanks and reservoirs with demineralised water prior to operation and with mean to drain the water to Safety Drain Tank of the Tokamak Cooling Water System. VST are equipped with special devices and supply of demineralised water for washing out surface's contaminants deposited on their surface in post-accident operation.

The VVPSS is installed inside the Drain Tank Room in the Tokamak building, except the rupture discs and bleed valves assemblies, which are installed in the NBI cells.

The ST-VS line, including the blowers, beyond the Drain Tank Room is responsibility of the PBS32.

The VVPSS will be equipped with instrumentation for monitoring and control of various parameters to support its operation, for detection of abnormal operation conditions, to prevent creating hazard for DS with unacceptable impact.

6.1 Safety design criteria

As described in the SRD [17]:

- The VVPSS shall form part of the first confinement system during in-vessel LOCA accidents without affecting the safety functions.
- A pressure suppression system shall be incorporated reliably to maintain the pressure rise below the design pressure of the vacuum vessel in the case of an offnormal event such as the ingress of coolant from a failed in-vessel component. [PR2022-R]

- The VVPSS shall condense and retain the entire radioactive inventory that results from an invessel (VV) design basis loss of coolant event, together with all associated activated particles and activated/tritiated non-condensable gas.
- The part of VVPSS down stream of the pressure reliefe lines shall provide the confinement system that separates air from the hydrogen that could be generated by accidents inside the VV.
- The vacuum vessel pressure reliefe lines shall have two branches with two devices (rupture discs or bleed valves) in each branch.
- The VVPSS shall be equipped with a hydrogen reduction system.
- 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]The VVPSS is a hard core componenent and shall be design to this loads [18], [23]

- The VVPSS shall include anti-siphon protection,.
- SIC components shall be protected against the risks that are associated with potential pipe whipping from high energy fluid circuits (pressures greater than 20 bar absolute, or temperatures greater than 100ºC). [PR2030-R]

Among the functions to be ensured by the system, there is also the protection against explosion risks to be added

The safety criteria are analysed for each PBS 24 VVPSS system, sub-system and components according theirs PIC class for the following conditions [6] :

- 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 function are given in appendix A and the PIC list is given in appendix B.

In the normal conditions the requirements are the following for what concerns the components ensuring a PIC/SIC-1 function (see appendixA and B:

- Single failure criterion on active components, redundancy, with 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 …),
- Equipment status indication (type of parameters, local, remote),
- Periodic tests requested,
- Routine Maintenance test requested,
- I&C classification,
- Environmental Qualification requested,
- Seismic Class SC1-SF (event SL2),
- QA class 1.
- To perform In Service Inspection (ISI) to detect problem on weld, seals … to avoid any water/gas leaks,
- To define and implement the I&C logic needed to cope with the accident.

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

- 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 SC1-SF, or SC1-S or SC2 (event SL2),
- 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, etc.,
- To define and implement the I&C logic needed to cope with the accident.

In the accidental conditions the requirements are the following for what concerns the PBS 24VP components ensuring a PIC function without SIC classification (see appendix A and B):

- 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 define and implement the I&C logic needed to cope with the accident.

The functions that shall be ensured for the main subsystems/equipment are:

- CA: Confinement Aerosols
- CL: Confinement Liquid
- OP: Operation
- NFP: No Fire Propagation
- SH: Nuclear Shilding,
- AG: Non aggression on SIC,
- CHIM: Chemistry product Control

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 the Project Requirements.

These safety function in normal operation are presented in appendix A.

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

6.2 Normal operation

6.2.1 Environmental conditions

PBS 24VP SIC 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 [9].

Environmental conditions during normal operation:
• Temperature (maximum excursion range in the room) : between 18C and 35C,
• Humidity (maximum excursion range in the room) : 60%
• Pressure: 1 bar (abs)

Environmental conditions during incidents/accidents (see ref [9]):
• Temperature (0 to 100 ^{o}C)
• Humidity (peak) : 100%

• Pressure: 1 bar (abs) to 2 bar (abs) (in Drain tank room))

6.2.2 Routine operations requirements

The routine operations requirements associated with protection important components and protection important activities are given in *<6 >,* with clearly identified functions [6] chapters 4 and 5.

There is a quantified purification objective of having at least a factor 10 for tritium reduction.

The VVPSS shall provide the following main functions:

1. Mitigate overpressure event in the vacuum vessel by providing pressure relief path from vacuum vessel to VVPSS and ensuring that capacities needed for overpressure protection are available,
2. Maintain dynamic confinement in vacuum vessel during an accident by

   a) receiving vent gas from the vacuum vessel,
   b) maintaining pressure cascade,
   c) discharging excess of vent gas to atmosphere Detritiation System.

3. Purify the vent gas from the vacuum vessel prior to discharge to DS [PR2025-R] by

   a) reducing content of water vapour to level acceptable for admission to DS,
   b) reducing content of aerosols,
   c) reducing content of tritium.

4. Mitigate hydrogen explosion risk by

a) collection of hydrogen in a sealed volume of VVPSS tank,
b) reduction of hydrogen concentration to below 1% in gas to be discharged to DS,
c) monitoring hydrogen concentration on line in gas flow to be discharged to DS,
d) processing hydrogen accumulated in the sealed tank of VVPSS during post-accident operation.

5. Draining and cleaning

   a) Water containing tritium, Dust and ACP shall be drained into a storage tank before to be process to the radwaste building
   b) VST atmosphere containing tritium, Dust and ACP shall be processed before to be send to DS by use of the CSU
   c) Adequate measure shall be considered to make hydrogen combustion highly unlikely during this operation phase
   d) VST tanks shall be clean after draining in order to recover yellow radiological zoning in the Drain Tank room before any start of new plasma shot.
   e) It shall be possible to process the contaminated water from the VVPSS to allow the restart of the ITER plant within one year. [PR1776-I]
   f) The VVPSS and drain tanks shall be de-pressurised, and the gas vented through the Vent Detritiation System. [PR2025-R]

6. Baking

All surfaces, that are exposed to the primary vacuum shall be baked at a temperature greater than 180°C, including the neutral beam port (up to the torus isolation valve) and the VVPSS piping (up to the rupture disk) and bleed valves [PR427-R]

The VVPSS-ST has PIC/SIC instrumentation for monitoring and controlling various parameters (such as pressure, temperature, vacuum, and water level) but also gaseous species like O2, H2 N2 …. [17]
The VVPSS shall allow water and gas radiological monitoring. [17]

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

6.2.3 Chemical requirement :

The gas stream to be processed in VVPSS might contain molecular hydrogen, which is subject to oxidation reaction to be arranged in VST, CSU and PAR. The chemical reaction of hydrogen oxidation shall be taken into account in the system design by adequate H2 oxidation prevention/detection/mitigation system.

The chemical requirements for the water to be fed to the VVPSS shall be as for demineralised water. The VVPS tank water shall be periodically checked for water chemistry and itsquality. [17]
There is a possibility to inject inert gas following the event during the post accidenetal management.

6.2.4 Material requirement :

The material used in some equipment of the VVPSS might be subject to neutron 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.[20].

Halogenated materials shall be forbidden [17] [PR1232-R], [PR1231-I].

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].

6.2.5 Mechanical requirement

The VVPSS is a Quality Class 1 component SC1(SF), according to the Quality Classification Determination (ITER_D_24VQES)[21].

The design shall account for the transient loads that are imposed during in-vessel loss of coolant events. Details of these events are given in the Accident Analysis Report (AAR) [8].

As part of the first confinement barrier, the VVPSS leak rate under its overpressure (or vacuum) conditions shall be the same as for the VV (1 volume %/day at 0.1 MPa pressure differential). [18] The VVPSS tanks, along with the relief line structure, shall be anchored and supported to the building floor/wall/roof appropriately to the respective embedment in the building.

The VVPSS and relief line support system shall accommodate thermal excursion. [17]

The VVPSS shall be designed to the loads combination defined in [18].
THE VVPSS is HHCC and is designed to a service level A or B during a stress test scenario [23].

6.2.6 Penetration requirements

Any penetration through internal or external confinement barriers, fire barriers or radiological zones shall reconstitute the barrier properties. This safety function is decribed in [3] and in more detailed in the penetration memo [14].

The VVPSS line shall respect the zoning requirements with regards to :
- radiation zoning (gamma, neutrons) from the internal parts of the penetrations crossing walls,
- avoidance of fire propagation, notably in case of a fire creating of 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-deflagrant 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 apply on primary containment envelopes (e.g. radioactive and chemical samples) inside or outside buildings.

For non-PIC elements, the penetration rules shall be compliant with the PR [3] and the penetration memo [14] in order to respect the zoning (fire, Be, radiological). So the penetration of non-PIC element , if any, crossing zonings shall be SIC from a confinement point of view.

6.2.7 Radiological requirements

PBS 24 VVPSS 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 [9] 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 [9].

The radiological requirements regarding the qualification of the devices are defined inside the references [14][15].

For radiological hazards, the dose limits given by the ITER General Safety Objectives shall be respected during normal operation, as well as in off-normal events (incidents and accidents). Decontamination may be required to re-establish the applicable levels based on the severity of the event (see Section 1.4). [3][17]

The Vacuum Vessel Pressure Suppression system and drain tanks shall be de-pressurised and the gas vented through the Vent Detritiation System in post accidental managment. The VVPSS shall be provided with a means (Suppression Tank Vent System, ST-VS) to remove non-condensable gases, if present. [3]

The maintenance programme of VVPSS shall be defined and be consistent with the need to get a collective dose ALARA, and in any case lower than 500 p.Sv/y for all ITER activities [3].

6.2.8 Electromagnetic requirements

The selection and installation of the instrumentation and control equipment shall take into account the strength of the electromagnetic field in the relevant part of the Tokamak building [22].
PBS 24 VVPSS 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 [14][15].

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

6.2.9 Baking requirements

All other surfaces exposed to the primary vacuum shall be baked at a temperature greater than 180°C, including the NB port (up to the torus isolation valve) and the VVPSS piping (up to thrupture disk)[3].

6.2.10 I&C requirements

The I&C requirements are as follows:

- The sensors and components needed to reach safe state are classified PIC/SIC 1 cat A and redundant.
- The sensors not needed to reach safe state are classified PIC/SIC 2 cat C.
- The PIC/SIC sensors and components are powered supply by class II network .
- The redundant electrical cubicles have to be implemented in redundant PIC/SIC 2 rooms [trains A and B].
- The VVPSS piping (up to the rupture disk) during the pre-pulse and pulse shall be controlled at 100°C, rangeability ±10°C, accuracy ±2%. [PR1773-R]

6.3 Internal events/hazards

The requirements associated with the combination of loads are described in [18].

6.3.1 Fire

Fire inside the VVPSS tanks is not considered due to the inert gas atmosphere and the big amount of water.

Only fire outside VVPSS components (in the rooms) is possible and may be a cause of the failure of VVPSS components. In such conditions, the VVPSS lines shall be protected from the effects of a fire as defined in the following requirements.

For the PIC elements of VVPSS line (valves, rupture disks …) the following shall be applied:

PBS 24 VVPSS Line components inside nuclear buildings shall meet the following defined requirements.

- PBS 24 VVPSS PIC/SIC 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 NB cell or DT room conditions [3] in [PR1286-R] and [PR1291-R]; in particular with regards to presence of high variations of pressure, temperature, humidity, soots. Their failure shall send an alarm to CSS.
- PBS 24 PIC/SIC components and their support systems shall be able to continue to operate for all loads combination with fire defined in [18]

The VVPSS shall be adequately protected for all postulated internal fires in the Drain Tank room and in NB Cell.[3][16].

Electrical materials shall be (See [12],[13]) designed according to the following [3] and [6] chapter 6.9 and [10] appendix 1:

- For all electrical cables, reduced flame propagation (according to IEC 60332-3 –flame spread for cable bunches- or NF 3207 C1
- Support services (Air compress …) shall operate during fire
- Flame retardant (according to IEC 60332-1 –flame propagation on single cables-)
- Low smoke (according to IEC 61034) [16] chapter G.4
- Zero Halogen (according to IEC 60754-1) [16] chapter G.4
- Non toxicity (according to IEC 60754-2)
- For all PIC/SIC1 and PIC/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 VVPSS 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 VVPSS 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.

The routing of the trains supplying a PIC/SIC-1 or redundant PIC/SIC-2 shall 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 room, the cables shall be covered by a 2 hours fire protection envelope.

Non- PIC/SIC cables trains shall not generate missiles effect or fire departure due to a short circuit in case of earthquake.

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

6.3.2 Drop load and missile effects

It could be necessary to replace consumed materials as catalyst, packing material, filter during life time of ITER. The safety design requirements are therefore as follows.

The risk of load drop during the maintenance phase shall be considered in general and in specific in the design of the VVPSS.

A load drop shall not lead to damage PIC components, and in particular confinement systems. .

The layout of the DTR and NB Cell shall take into account the risk of load drop on VVPSS components in order to protect VVPSS from the risk of load drop.

6.3.3 Flooding

Internal flooding could be induced by failure of barriers in VVPSS and PBS26 water holding tanks installed in the Drain Tank Room (DTR).

Internal flooding lead to contamination spill in DTR rooms. The defined requirements related to confinement barriers contribute to reduce the flooding risk in DTR room.

The internal barrier failure could be detected by tritium monitoring system and flooding detection in the DTR room. However, some parameters of VVPSS operation could contribute to detection of flooding, eg. as monitoring of levels in holding tanks or flow in the pipes.

Additional safety requirement shall be considered to limit the flooding risk.

The tanks shall be designed, to the maximum possible extent, to have the penetration in the top of the capacity above the water level.

The tanks shall be located in leak tightness retention. This is defined requirement taken in charge by PBS 62 [10].
The water level in the tanks shall be monitored by PIC/ SIC 2 cat C sensor.
There shall be a water spill detection in the retention of 100 % volume classified PIC/SIC1, considering single failure criteria, SL2 design (This is defined requirement taken in charge by PBS 62 [10).

The design of water collection retention shall ensure the risk of water leakage along the anchors between the building embedded plate and the tank sole plate is avoided.

Electrical components as cubicles and pumps shall be placed above the highest possible water level induced by flooding taking into account extinguishing water.

A leak detection system shall be available. It shall provid the detection of failure of the confinement system and to alert the operators in the event of such a failure [PR2071-R] [PR2069-R] [PR1927-I] .

6.3.4 Explosion

During in-vessel event, Tritium and hydrogen is released into the VVPSS. In case of LOVA event or Wet bypass, air will flow also to the VVPSS. A mixture oxygen and hydrogen will be located in the VVPSS sky and inflammabilty limit could be reached to start hydrogen combustion.

To prevent/detect/mitigate this scenario, hydrogen reduction in VVPSS is based on

- Hydrogen combustion initiated by ingniters installed in the relevant water holding tanks,
- Hydrogen oxidation in the wet recombiner,
- Hydrogen oxidation in the PAR.

All these processes needs sufficient amount of oxygen be available. For effective operation of the wet recombiner and the PAR reliable source of air is provided to the CSU.

6.3.4.1 Process

Based on the conceptual design and the understanding of the proposed equipment the following risks of explosion inside the process have been identified:

- Radiolysis of water in the tanks,
- Mixing of hydrogen with air in the tanks, in components of the Catalytic Scrubber Unit and in PAR,
- Hydrogen transfer in pipes.

6.3.4.2 Radiolysis of water in the tanks

The radiolysis shall be assessed for the vessels holding radioactive contaminated water for a reasonably long time. Assessment should assume

- Highest content of tritium and gammar emitters,
- Highest filling ratio of the vessels with water,
- Radiolysis rate of 0.45 H_2 mole production for 100 eV.

If potentially explosive hydrogen mixture can be formed, then either the tanks shall be designed to withstand the resulting pressure and temperature or measures to prevent an explosion shall be incorporated into the design.

6.3.4.3 Mixing of hydrogen with air in the tanks, in components of the Catalytic Scrubber Unit and in PAR

Purpose of the Catalytic Scrubber Unit and PAR is to reduce hydrogen content to below 1vol.% in the gas to be discharged to DS. PAR is intrincically safe if hydrogen concentration at the inlet is below 5vol.%. The components of the CSU and the PAR shall be designed to ensure effective and safe processing of hydrogen with targets:

- Hydrogen concentration at inlet of PAR is below 5vol.%,
- Hydrogen concentration at outlet of PAR is below 1vol.%.

Safety I&C classified PIC/SIC1, shall be designed to detect igniter's availability. Safety I&C classified PIC/SIC1 shall be designed to send a signal of the igniter's failure to the CSS-N. Safety I&C classified PIC/SIC2 with redundancy shall be designed to manage air supply.

6.3.4.4 Hydrogen transfer in pipes

Concentration of hydrogen in pipes connecting the vacuum vessel to VVPSS, connecting components of VVPSS between each other might be well above low end of flammability limit. Where applicable dilution and inerting with nitrogen should be considered and implemented into design.

Safety I&C classified PIC/SIC2, cat C with redundancy shall be designed to monitor hydrogen concentration in the gas pumped from the vacuum vessel prior to switching the vaccum vessel from VVPSS to N-DS. In event of hydrogen concentration is above 1vol.% such switch shall not be allowed.

Safety I&C classified PIC/SIC2, cat C with redundancy shall be designed to monitor hydrogen concentration in the gas to be send from the VVPSS to DS. In event of hydrogen concentration is above 1vol.% DS shall be automatically isolated from the VVPSS.

Safety I&C classified PIC/SIC2, cat C with redundancy shall be designed to monitor air flow to the CSU. In event of air supply failure VVPSS shall be automatically isolated from DS.

Safety I&C classified PIC/SIC1 shall be designed for the detection of the failure of the systems.

6.3.5 Helium leaks

An Helium leak in gallery concerns a spillage of cryogenic coolant from the magnet cryogenic cooling loop inside the cryostat space room, which is assumed connected to the gallery. This event may occur during plasma operation, between pulses or during a shut-down period with vacuum in the cryostat being maintained. [18].
Various sized helium leaks are assumed and they are classified in category II, III and IV. [18]
VVPSS shall be designed to operate to this type of phenomena and manage pressure and temperature effects [17][18].

6.3.6 Accidents involving LOCA and/or LOVA accidents

During a LOCA or LOVA event, the main function of the VVPSS is to confine the radiological material and maintains the vacuum vessel under sub-atmospheric pressure. [3]

The thermal hydraulic characteristics of the VVPSS shall keep the peak VV pressure (following a design basis in-vacuum vessel loss of coolant event) below the design value of 0.15 MPa absolute for Cat I, II, and III events. There shall be an adequate margin to encompass uncertainties both in the total amount and flow rate of the loss of coolant. [18]

While meeting the safety function, the VVPSS shall limit the in-vessel pressure due to LOCA accidents in the VV.[17]

The relief line shall have provision to bypass the rupture disc devices by means of bleed line that connect the Vacuum Vessel to the VVPSS tank by way of vacuum valves that can be opened during small water spillage. This provision also facilitates the release of radioactive inventory through the bleed line, if an aggravating failure, such as a breached vacuum window, occurs at the same time as the small in vessel water leak. [17] The valves on the bleed line valves shall open at 50 kPa, The valves opening shall be in agreement to cope with the accident [19]. Valves that are part of a confinement boundary shall get into position required within required periods after detection of the onset of an incident or accidents.[3]

Adequate system shall be implemented in order to avoid explosion durimg ICE/LOCA event. [18] (see also chapter 6.3.4). In case of explosion (inside the VV, inside the tanks, or inside the CSU), the VVPSS shall be designed to comply with the safety function which is the confinement.
In case of VV pressurization, the rupture discs of the VVPSS shall be designed so that impulsive loading of the VVPSS,following disc opening, is minimized. [17]
The set point for the first rupture disc shall be less than 0.15 MPa, in the ranege 110 to 115 kPa. [17]

The bleed valves open at 50 kPa. They shall operate at the thermalhydraulics condition encountered in this type of scenario [17].

Valves that are part of a confinement boundary shall operate within required periods after detection of the onset of an incident or accidents. The confinement isolation valves
shall assume their safe position on loss of power [3].

The drainage of contaminated water from VVPSS tank to PBS 26 components following a LOCA or LOVA event shall be possible in an automatic mode, and shall be backed-up by a manual mode from outside the VVPSS room.

6.3.7 Loss of vacuum inside VVPSS :

VVPSS leaks are investigated as accidents. A leakage is postulated an Air ingress enters and pressurizes the VVPSS. [18].
The ST-VS system, and in particular the CSU, is used to maintain the VV under sub-atmospheric condition during a LOVA event.

6.3.8 VDE, MD, MFD

PBS 24 PIC VVPSS shall not subject to this type of accident[17][18].

6.4 External Hazards

The PBS 24VP 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 (SL3, SL-2 and SMHV);
- External electricity supply interruption/variation;

- Intrenal flooding;

Other external hazards, such as lightning, aircraft crash, enternal flooding, are considered not applicable because VVPSS is globally located in the tokamak building which ensures protection from such hazards.

In case of SL3, the bleed valves shall be opened thanks to a failed status open. The design shall cope with this load in in order to comply with the safety function which is the confinement [18].

6.4.1 Earthquakes

The maximum accelerations resulting from earthquakes are laid down in the floor response spectra for the Tokamak complex buildings. This spectrum will be provided by IO and shall be taken into account for design [24].

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

The defined requirements for each seismic level are presented in [19] and [23]. B.

The earthquake could induce fire, flooding or missiles. The combination of earthquake with the secondary effect shall be considered. All the combinations loads for earthquake are defined in [18].

The PIC components are designed to operate before, during and after a seismic event SL1 without any special maintenance or test.

THE VVPSS, being a hard core component, shall be designed to a stress test condition [23].

THE VVPSS shall be designed to all the combinations loads with earthquakes [18].

Deformation of the VVPSS structure during and following SL-2 earthquake shall not result in loss of the confinement function, with the rupture disc and its structural support elements to ensure functionality. [17]

The design of the VVPSS shall be such that loss of service as a result of an external hazard does not impact the safety performance of the VVPSS.

The stability of tanks, pipes and components shall be ensured during and after SL2.[18]

Confinement of VVPSS shall be ensured during and after SL2 to avoid radiological and hydrogen isotopes releases.

Over pressure devices and isolation systems shall be operational during and after earthquake level SL2.

Safety I&C, overpressure and isolation valves shall be operational during and after SL2.

The VVPSS rooms shall be designed in order to avoid missiles generated by earthquake which impact VVPSS, it could be missiles generated by drop of VVPSS component or other systems.

6.4.2 External flooding

The PIC components of PBS 24 VVPSS 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 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 shall also be taken into account. The effects of reflections and focalisations may generally be taken into account by the way of a global pondering coefficient to 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 PIC/SIC components of PBS 24 VVPSS are not subject to external explosion.

6.4.5 Airplane crash

The PIC components of PBS 24 VVPSS are not subject to air plane crash.

Appendix A –

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

Based on the deisgn provided in [19], the VVPSS (Vacuum Vessel Pressure Suppression System) consists of the following system:

- VVPSS tank, also called VVPSS-ST
- VVPSS line,
- Bleed valves,
- Rupture Disks.
- The CSU
-

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 VVPSS in 2 categories :

1. Main system safety functions:

   There are 2 safety functions:
   - Confinement,
   - Radiation protection.

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

   There is one safety function associated with the protection of the first two functions ensured by the VVPSS systems or by other systems at ITER :
   - To meet the zoning requirements (fire, radiological, etc)
   - safety support function of protection against explosion risks by preventing/detecting/mitigating PIC systems, including confinement systems

- safety support function of protecting the vacuum vessel and connected systems from overpressurisation in case of LOCA, LOVA, LOCA and LOVA

Appendix B - Summary table of defined requirements for PBS 24 VVPSS

Tables B-1 to B-4 provides the defined requirements for the loads and loads combination applicable to PBS 24 VVPSS.

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

- CA : for the aerosols and gas confinement
- CL : For the liquid confinement
- SH : for nuclear shielding
- OP : Operability
- AG : Non Agression on PIC/SIC
- NF : Non Fire propagation
- INV : ITER inventory control
- CHIM : Chemistry products control

The PIC/SIC classification of VVPSS sub-systems is defined in the Table 1 for liquid sub-systems, as for example water tanks, and in the Tablefor gas sub-systems, as for example Rupture Discs, Bleed Valves, Wet Recombiner, Scrubber Column, PAR.

Table 1: Safety classification of sub-systems.

Safety function	Sub-system	Classification	Rationale
Confinement	VST	PIC/SIC-1	Tank containing radioactive fluids (water, vapour,

			gas)
Confinement	Pool Scrubbing Tank	PIC/SIC-1	Tank containing radioactive fluids (water, vapour, gas)
Confinement	CSU Water Tanks	PIC/SIC-1	Tank containing radioactive fluids (water, vapour, gas)
Confinement	Wet Recombiner's water reservoir	PIC/SIC-1	Vessel containing radioactive fluids (water, vapour, gas)
Management of water level, detection of water temperature deviation from operation range in the tanks	VST's safety I&C	PIC/SIC-2 with redundancy Redundant support system is needed	Support of VVPSS during an accident
Management of water level, detection of water temperature deviation from operation range in the tanks	CSU's safety I&C	PIC/SIC-2 with redundancy Redundant support system is needed	Support of VVPSS during an accident

Safety function	Sub-system	Classification	Rationale
Confinement	Rupture Discs	PIC/SIC-1	Divice providing overpressure protection for the vacuum vessel
Confinement	Bleed Valves	PIC/SIC-1	Divice providing overpressure protection for the vacuum vessel
Hydrogen risk reduction	Igniters (in VST and in PST)	PIC/SIC-1	Device providing hydrogen explosion risk reduction by controlled deflagration
Confinement	Safety pressure relief valves in VVPSS downstream of CSU	PIC/SIC-1	Divice providing overpressure protection for the DS
Confinement	Bypass isolation valves (for connetcion of vacuum vesel to CSU, vacuum vessel to LLTs, LLTs to CSU)	PIC/SIC-1	Divice providing support to ensure overpressure protection for the vacuum vessel
Confinement	Wet Recombiner	PIC/SIC-1	Vessel containing radioactive fluids (water, vapour, gas)
Confinement	Scrubber column	PIC/SIC-1	Vessel containing radioactive fluids (water, vapour, gas)
	Passive Autocatalytic Recombiner		Vessel containing radioactive gas

Confinement		PIC/SIC-1	
Hydrogen risk mitigation	Wet Recombiner	PIC/SIC-2 Redundant support system is needed.	Device providing protection of DS by reduction of molecular hydrogen
Detritiation and aerosols trapping	Scrubber column	PIC/SIC-2 Redundant support system is needed.	Device providing complimentary dehumidification of gas to be discharged to DS
Hydrogen risk mitigation	Passive Autocatalytic Recombiner	PIC/SIC-2 Redundant support system is needed.	Device providing protection of DS by reduction of molecular hydrogen
Hydrogen risk mitigation/ Detritiation and aerosols trapping/confinement	VVPSS safety I&C	PIC/SIC-2 Redundant support system is needed.	Monitoring of hydrogen in gas stream downstream of PAR and detection exceeding allowed level
Hydrogen risk mitigation/	VVPSS safety I&C	PIC/SIC-1	Detection of failure of sub-system for air supply to CSU.

Protection of DS	VVPSS safety I&C	PIC/SIC-1	Detection of temperature/humidity of gas to be discharged to DS exceeding the allowed level.

Table B-1 – Summary table of defined requirements for PBS 24 VVPSS

Create the summary table with all needed loads