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PQR228

VERSION CREATED ON / VERSION / STATUS
06 May 2015 / 1.1 / Approved

EXTERNAL REFERENCE

Report

ITER HARD CORE COMPONENTS - SUMMARY REPORT

This report makes a summary of the Hard Core Components of ITER. For the detailed lists reference is made to the applicable detailed documentation.

Approval Process			
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Document Security: Internal Use *RO: Ghirelli Nicolas*			
Read Access	**LG: SMS Members, LG: Stress Test Task Force Members, LG: stress test group A, LG: PBS contributor to Group-A, LG: Viewers from DAs and IO, AD: ITER, project administrator, RO**		

Change Log			
ITER HARD CORE COMPONENTS - SUMMARY REPORT (PQR228)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v0.0	In Work	31 Mar 2015	
v1.0	Revision Required	01 Apr 2015	First issue.
v1.1	Approved	06 May 2015	Reviewers comments to version 1.0 have been included

1 SCOPE

This report makes a summary of the Hard Core Components of ITER. For the detailed lists reference is made to the applicable detailed documentation.

Contents

2 Abbreviations

ACB	Auxiliary Cold Box
ASN	Autorité de sûreté nucléaire
CVB	Cold Valve Box
CVC	Cryogenic Viscous Compressor
CVCS	Chemical and Volume Control System
DNB	Diagnostic Neutral Beam
DS	Detritiation System
DTR	Drain Tanks Room
EPNS	ITER IO EPNSEnvironmental Protection & Nuclear Safety Division
FDU	Fast Discharge Units
GIS	Gas Injection System
HCC	Hard Core Component
HNB	Heating Neutral Beam
HV	High Voltage
IBED	Integrated loop of Blanket, ELM-VS, and Divertor (PHTS)
ISS	Isotope Separation System
LOOP	Loss Of Offsite Power
LPC	Lower Pipe Chase
NBI	Neutral Beam Injector
PCR	Project Change Request
PHTS	Primary Heat Transfer System
PIC	Protection Important Component
SIC	Safety Important Component
SR (component)	Safety-Related Component
TCVB	Thermal Shield Cold Valve Box
TKM	Tokamak
UPS	Ultimate Power Supply
VV	Vacuum Vessel
VVPSS	Vacuum Vessel Pressure Suppression System

For other abbreviations used in this report refer to Ref. [1].

3 Introduction

According to Ref. [2], Hard Core Components (HCCs) are defined as those components important for the safety of the plant (e. g. PIC components) which are needed in extreme scenarios to prevent cliff edge effects, defined as [3]:

- Dose to population above 10 mSv
- Contamination of the ground water
- High radiation field which avoids long term human intervention on the site

In Ref. [2] 12 scenarios with potential to lead to cliff edge effects were identified. Further evaluation (Ref. [4]) clarified that, out of the 12 scenarios described in Ref. [2], only 2 can lead to cliff edge effects unless HCCs are implemented to limit the consequences. These accidents are briefly described in the next paragraphs.

3.1 Generalized accident in Tokamak building

The first accident which has actually the potential to lead to cliff edge effects is a 'Generalized accident situation in the Tokamak building due to an extreme earthquake (i. e. SL-3)' leading to (Ref. [2] and [4]):

1. Cryogenic circuits break in cryostat and gallery
2. Fracture of vacuum penetrations in the vacuum vessel
3. Multiple cooling system fractures in the vacuum vessel, the port cells and the vault
4. Cryostat failure (loss of vacuum)
5. Failure of the Vacuum Vessel pressure Suppression System (VVPSS)
6. Rupture of the fuelling line
7. Failure of the Detritiation System (DS)

It is assumed that this accident occurs during mode 0 operations (Ref. [2]). According to Ref. [4], if HCCs are not employed the dose at 2.5 km is 130 mSv, clearly a cliff edge effect. During this scenario, two quasi-independent zones are identified—the first one being the gallery, the second one being the Port Cells + the NBI Cell + the VVPSS suppression tank room + the vault. While a small amount of radioactivity is expected in the first zone, the bulk of radioactivity will be contained in the second zone. Furthermore, only in the first zone (i. e. the gallery) the pressure is expected to reach a peak value above the design pressure, leading to a degraded confinement of the gallery.
In Ref. [2] the HCCs identified by ITER IO for this accident are the following:

1. The discharge line of the Vacuum Vessel pressure Suppression System, which shall retain its confinement capabilities.
2. The building volume comprising the NBI cell, the Port Cells and the vault, and the VVPSS suppression tank room, which shall retain their confinement capabilities.
3. The gallery, even with a degraded confinement.

Furthermore, IRSN in Ref. [4] invites to evaluate the possibility to qualify as HCCs also:

1. The VVPSS suppression tank itself (and not only the suppression tank room) and, more in general, all the equipment downstream the VVPSS discharge line.
2. The isolation valves of the fuelling line.

ITER IO in Ref. [5] takes the following engagements:

1. Justify, before June 2015, the efficacy of the equipment downstream to the VVPSS discharge line to prevent cliff edge effects.
2. Justify, within one year, the efficacy of the galleries to prevent cliff edge effects.
3. Consider the fuelling line isolation valves as HCCs.
4. Etc. For details refer to [5].

In Ref. [6] some additional and more precise requests are made by ASN to ITER IO.
In summary, static confinement (supported by penetrations and isolation valves + VVPSS) is required for this accidental scenario.

3.2 Generalized fire in Tritium building

The second accident which has actually the potential to lead to cliff edge effects is a 'Generalized fire in tritium building'. It is assumed that this accident can occur during mode 0, 1 and 2 operations (Ref. [2]). If no HCCs are employed this accident can lead to a dose of 60 mSv at 2.5 km, clearly a cliff edge effect [4]. To prevent cliff edge effects the following HCCs are identified by ITER IO in Ref. [2]:

1. Fire sectorization of tritium facility process rooms.

2. Static confinement of tritium process rooms and facility (civil works and doors) as well as their penetrations and isolation devices.
3. Fire extinguishing system in tritium facility rooms (including water reserves).

The air mixing system of the Isotope Separation System (ISS) is added by ITER IO in Ref. [4].
In summary, static confinement, supported by fire extinction + air mixing in ISS, is required in this accidental scenario.

4 Strategy and implementation

4.1 Clarifications from EPNS

Some questions have been asked to EPNS to better understand the framework of the stress test for the ITER facility. Replies from EPNS are reported in Ref. [10], [11] and [12]. The most important points are hereafter summarized:

1. Attention is given only to the scenarios in the Tokamak and Tritium buildings. With respect to the source term within the other buildings, as of 2012 no cliff edge effect was found for other buildings. In particular two scenarios (namely scenarios 6 and 7) in Ref. [2] concerned the Hot Cell and the Radwaste buildings. Both scenarios have been clarified not causing a cliff edge effect according to Ref. [4]. Nevertheless by oral communication with EPNS it is clear that, because of the very large source term contained in these two buildings, they cannot be neglected in the stress test assessment. Anyway presently there is no scenario associated to these buildings. Furthermore the design of these two buildings is still at conceptual level. For these reasons the detailed identification of HC systems and components is difficult at this stage. It has been agreed informally with EPNS that the situation for these two buildings will be clarified later.

2. In case of collapse of SC2 non-nuclear buildings no cliff edge effect is envisaged (Ref. [11]).
    a. Nevertheless some non-nuclear buildings which could in principle aggress HCC building are identified (see section 5.22)

The following paragraphs describe the logic followed to identify the HCCs.

4.2 Scenario in Tokamak building

For the accident scenario in the Tokamak building the following strategy is proposed:

- All the penetrations[1] from the external into the building (no matter where) are HCCs: this is done to protect the external environment and the last confinement barrier. The penetrations must be isolable and the isolation means preferably fail safe.
    - Where (if any) a penetration cannot be equipped with isolation valves or it cannot be qualified as HCC, this is identified and justification provided.
- All the penetrations from zone 1 (defined as the gallery) to zone 2 (defined as NBI Cell + Port Cell + VVPSS + vault) are HCCs. This is done to protect the gallery (which has a worse performance in terms of design pressure and leak-tightness than zone 2) from being contaminated by a significant amount of radioactive material, i. e. to confine the radioactive material in zone 2, which has higher design pressure and higher leak-tightness performance. The penetrations must be isolable and the isolation means preferably fail safe.

[1] Here and in the following 'penetration' is a discontinuity in the wall. As such of course doors, cable trays, etc. and similar equipment are 'penetrations'.

- Where (if any) a penetration cannot be equipped with isolation valves or it cannot be qualified as HCC, this is identified and justification provided.
- For a pipeline going from zone 1 to zone 2 which is classified HCC, i. e. does not break in this scenario, HCC qualified isolation valves can be avoided since the pipe will keep its confinement capability and will avoid spreading of radioactive material from zone 2 to zone 1.
- It has to be noted that according to Ref. [4], the gallery is the only part of the building in which design pressure is expected to be exceeded, hence degrading its confinement performance. If PCR-628 is going to be implemented this could have a beneficial effect to protect the gallery from over-pressure by releasing cryogenic helium in the vault and then outside (Figure 1[2]). If this is the case, in principle, this second set of HCCs (penetration from zone 1 to zone 2) could be limited since the gallery will keep a better confinement performance. However it has to be noted that in case of concomitant gallery (because of cryogenic helium) and vault (because of water/steam from the cooling water system) pressurization the relief panel between the gallery and the vault could not open.
  It is proposed that EPNS performs an analysis integrating PCR-628 and checking if this second set of HCCs can be limited / eliminated.

- The penetrations within zone 2 (e. g. from port cell to vault) are not considered HCCs.
- Fire sectorization is not preserved: fire is not mentioned in scenario 11 in Ref. [2]. Furthermore, it is expected that it can be deterministically excluded because of the amount of helium and water which are released during scenario 11.

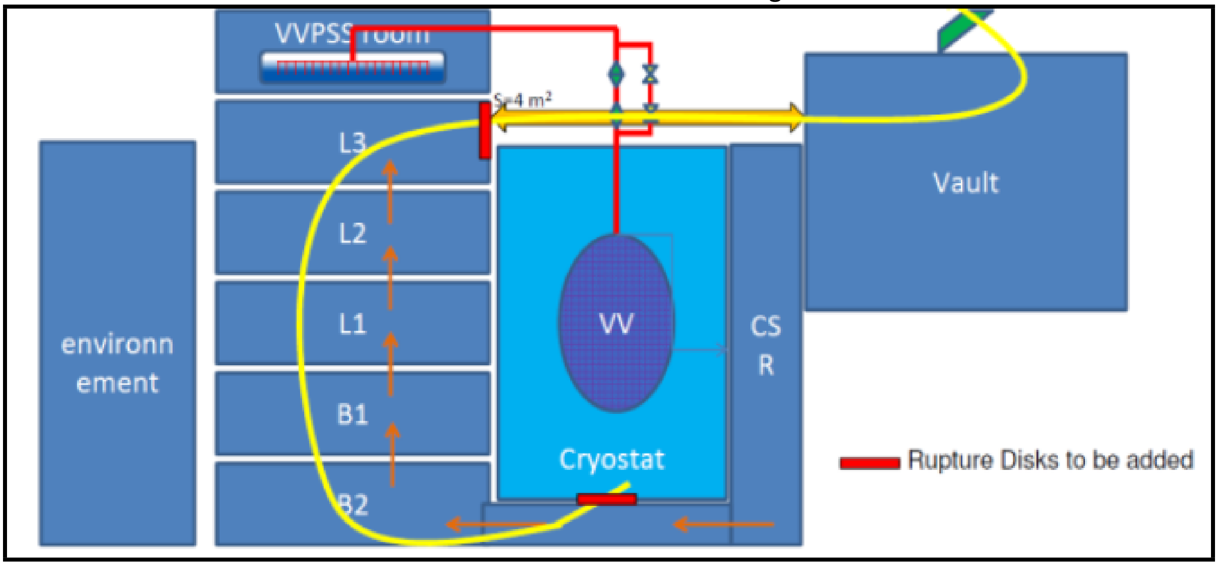

Figure 1 – PCR-628 (from Ref. [13])

4.3 Scenario in Tritium building

For the accident scenario in the Tritium Plant building the following strategy is proposed:

- The building fire extinguishing system is HCC.
- The ISS air mixing system is HCC.

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[2] It has to be noted that the PCR is still under study and the figure (from Ref. [13]) is only indicative. Details on the pressure relief device from gallery to vault will be defined during the PCR study and, potentially, implementation phase. According to a comment by EPNS to version 1 of this report, this pressure relief device shall be a re-closing device instead of a simple rupture disk.

- All the penetrations from the external into the building (no matter where) are HCCs: this is done to protect the external environment and the last confinement barrier. The penetrations must be isolable and avoid fire propagation and the isolation means preferably fail safe.
  - Where (if any) a penetration cannot be equipped with isolation valves or it cannot be qualified as HCC, this is identified and justification provided.
- All the penetrations from each process room to another process room and to the corridors are HCCs: this is done to prevent fire from spreading from one process room to another or to the corridor. The penetrations must be isolable and avoid fire propagation and the isolation means preferably fail safe.
  - Where (if any) a penetration cannot be equipped with isolation valves or it cannot be qualified as HCC, this is identified and justification provided.
- The fire sectorization within the corridor is not preserved. This is consistent with Ref. [2] where fire sectorization is identified as HCC only for the process rooms.

4.4 Requirements and design verification of HCCs

For the HCCs whose function is to maintain static confinement, since no detailed analyses were available, for the time being the same leak tightness requirements as per design basis are maintained. In the logic of the stress test it is proposed to relax these requirements by means of an iterative process up to the point at which a cliff edge effect is got. This would simplify the qualification and design verification of HCCs. Therefore it is suggested that EPNS performs a verification on the possibility to relax the leak tightness requirements.

For the HCCs whose function is to maintain fire segregation (fire dampers and/or isolation valves and/or small pipes), the requirements are the same as per design basis.

For the fire extinguishing system in the tritium building and the ISS air mixing system the requirements are the same as per design basis.

For the ultimate power supply system the requirement is to feed the HCCs which needs electrical power to reach and/or maintain their safe state and to avoid or limit at the maximum extent the time during which these components are not fed (time to start the ultimate diesel generator for the fire extinguishing system in the tritium building and the ISS air mixing system). Furthermore electrical power supply to the Back-up Control Room shall also be assured.

All the HCCs will be verified against SL-3 and according to the methodology developed within the framework of group B activity.

Finally it is assumed that redundancy is not required in a hard core scenario.

4.5 Monitoring of plant parameters from the Backup Control Room

The need of monitoring of some few and essential parameters from the Backup Control Room (BCR) needs to be assessed. Even if most of the HCCs are fail safe[3] and mobile vehicles for site monitoring

[3] Particular attention is given to some systems like for example CHWS-H1, SIC compressed air, DS, etc. because of their functions in design basis events. For CHWS-H1 the strategy is to qualify the piping against SL3 and to use passives check valves for the piping crossing the building boundary to the external and between DTR and Gallery. In case of flow in the system the check valves are open and allow cooling SIC clients. In case of loss of flow (because of any break or pump failure) the check valves passively close keeping static confinement. For DS it has been confirmed that all the valves are already designed as fail close for design basis. A particular case is for the valves for SB-DS which are normally closed during operation, are opened in case of need and anyway designed as fail closed. For design basis these isolation valves are SIC and are supplied by SIC-CA to open the valves in an event where detritiation is needed. Due to the SIC classification, there are redundant valves in parallel in SB-DS so that if one fails (closed) there is a backup in parallel. The only valves which are going to be fail open in the logic of the stress test are the valves for vault over-pressure relief and for the ISS overpressure relief in case of deflagration. Because of their functions these valves cannot be fail closed. The strategy is to have fail open devices and allow reclosing of these devices by local compressed air bottle. In this way we do

are considered as HCCs, nevertheless it could be important to have the possibility to monitor some plant parameters (status of active HCC included) directly from the BCR to allow operators to take decisions and to properly manage the accident. The number of the monitored parameters shall be limited to the ones really essential and most representing the overall plant conditions. Such parameters can be defined as results of detailed analyses to be performed at a later stage.[4]

4.6 Existing / new Hard Core Components

According to Ref. [6], <<*an 'existing' component is a component specified as part of the safety case (nuclear safety demonstration) detailed in the preliminary safety report that was submitted as part of the licensing process. Any other SSC is to be considered as a 'new' SSC*>>. Afterwards if has been clarified that comparison to determine if a component is 'new' or 'existing' has to be done with respect to Ref. [2]. Such a clarification was provided when all the detailed lists of HCCs were already developed. In light of this and since all the functions required in scenario 11 and 12 (confinement, isolation, fire extinguishing, air mixing in ISS) are already in the design basis configuration, it is expected that practically all the HCCs, except the ultimate hard core power generation and distribution, are already in the baseline and hence to be considered as 'existing'. This applies no matter what is declared in the detailed lists of HCCs (which are going to be updated at a later stage to reflect the fact that comparison to comparison to determine if a component is 'new' or 'existing' has to be done with respect to Ref. [2].

5 Detailed list of Hard Core Components

As stated above, the scope of this report is to provide the detailed list of HCCs for the ITER facility, as required in Ref. [7]. Through Ref. [7] and [10] it has been clarified that the starting point is Table 1 of Ref. [8]. The strategy summarized in chapter 4 is applied. In order to make sure that nothing is potentially forgotten, a thorough investigation among all the PBSs has been performed. It has to be noted that some HCCs are presently not PIC (see below and the detailed lists for details). Hereafter a summary is provided and reference is made to the corresponding documentation (detailed lists). Most of the referenced detailed lists have been compiled in a form of an Excel spreadsheet.

Columns A to L identify the HCCs:

- Starting from the identification of the function to be assured in a hard core scenario, provide the identification of the system(s) and then component(s) needed to fulfil that function.
- It is also stated if the component is 'new' or 'existing'. No matter what has been declared in the detailed lists, what reported in paragraph 4.6 applies.
- If, in order to accomplish the function, supporting systems are needed, they are also identified.
- Component tag, reference P&ID and location are also identified if available.

A	B	C	D	E	F	G	H	I	J	K	L
Functional reference	HCC needed to fulfill the function										
Function	System	Component		Existing component?	Needed supporting systems				Component tag	Ref. P&ID	Location

Columns M to AC provide further details on the component:

not need to qualify as HCC the whole SIC-CA, whose HCCs isolations valves can be fail safe closed.

[4] It has to be noted that monitoring of plant parameters is not strictly needed to prevent cliff edge effect. It is a suggestion to help operator taking decision. The power supply will be designed to allow also monitoring of few important plant parameters to be selected at a later stage.

- Column M and N provide the initial state and the state to be reached in order to fulfil the function (i. e. the requirement, see also section 4.4.).
- Column O, P and G provide respectively the seismic classification (it is clear that these components shall withstand SL-3), wheatear it is needed for the component to be re-operated once it has been triggered (for practically all the components once the function is triggered no more change is needed) and weather if confinement after the earthquake is needed.
- Columns R to AC have been thought to provide the 'design' conditions for the components needed in stress test scenario. It is noted that these columns must NOT be looked at. In fact the conditions against which these components will be designed will come from group A activity: anyway it has to be noted that the only environmental conditions available at the moment are the ones for design basis events.
  The only exception is for the required power (i. e. column Z), which is clearly stated.
- Columns AD to AE provide aggressors identification. For the cases in which these columns are void this is because for PIC components the aggressors are (or should be) already identified for design basis events. Hence the same aggressors apply for hard core scenario.

M	N	O	P	Q	R	S	T	U	V	W	X
				Environmental conditions in which function has to be assured (component design)							
Initial state	State to be reached (i. e. safe state)	Seismic classification	Operability after earthquake	Confinement after earthquake	ΔP [kPa]	Tmin [degC]	Tmax [degC]	Humidity [%]	Radiation level [mSv/hr]	Magnietic field [mT]	Mission time [hr]

Y	Z	AA	AB	AC	AD	AE
					Potential aggressors (1)	
Fire protection	Required power [kW]	Required flow rate [kg/s]	Other requirements	Notes	Aggressors	Aggressors qualification (2)

5.1 PBS 11 - Magnet

Referring to the actual status of the design (PCR-662 not implemented), the Hard Core Components for PBS -11 have been identified as those components participating to the "confinement function" between the zone 1 and the zone 2:

- penetration between the gallery (zone 1) and the Upper Pipe Chase (zone 2):
  - water barrier between the Gallery (zone 1) and the Upper Pipe Chaise (zone 2)
  - s-Bend Box and Cold Terminal Box
- penetration between the Upper Pipe Chase (zone 2) and the Cryostat pit (zone 1):
  - bio-shield bellow
  - feedthrough.

The schematic picture of the above components is shown in Figure 2.

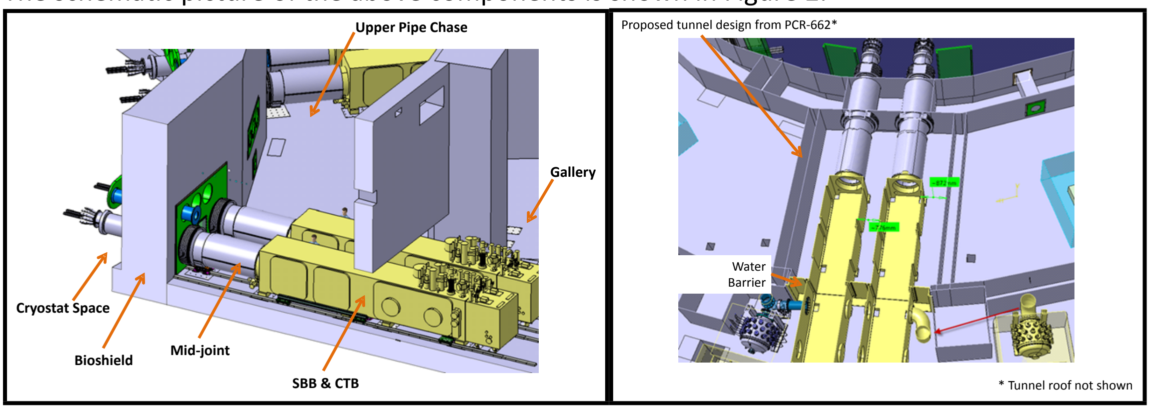

Figure 2 – Magnet Feeder (current status, PCR-662 not implemented yet)

The details can be found at https://user.iter.org/?uid=QEV2BP.
Moreover, it has been investigated if the Magnetic Coils can aggress essential components in case of failure and no additional HCC has been identified.
As far as the Vacuum Vessel integrity is concerned, a specific study has been carried out to verify the outcomes in case of Fast Discharge Unit failure, as described in Ref. [18]. The FDU failure has been selected as "*it envelops hypothetical events in the magnet system that could release some or all of the magnetic energy and potentially challenge the integrity of confinement barriers*". The conclusion of this study based on the Ref. [14], shows that the FDU failure will not lead to a cliff edge effect because the radioactive release will be lower than 10 mSv. Consequently, the Fast Discharge Function will not be considered as a Hard Core Component. Furthermore, it is proposed to activate the FDU as soon as an earthquake above SL-1 is registered to further protect the plant.

5.2 PBS 15 - Vacuum Vessel and In Vessel Coils

The VV does not appear as HCC in any of the input document provided to the Task Force. By communication with EPNS this has been accepted by ASN. Nevertheless an investigation was performed. The VV is a generally thick and robust structure for which the electromagnetic load is by far the design driving one. Few weak points anyway are identified but according to the Preliminary Safety Report (Ref. [14]), Vol. II, chapter 4.2: damage to VV and cryostat resulting in large holes ($1m^2$), the consequences of release in the environment are 3.03 mSv at 200m and 0.136 mSv at 2.5km; i.e. within the requirement of 10mSv. Even if the scenario in a hard core situation is not exactly the same as the one described in chapter 2.6 of [1], it is considered that sufficient margin exists. Details are given in Hard Core Components for PBS-15-VV (PASDT2 v1.0) (current).
In conclusion it is proposed that the VV is not declared as HCC but that verification / margin assessment to an earthquake beyond design basis of the weak points should be performed. In fact these weak points could put in direct contact the VV atmosphere and the gallery atmosphere (with some tritium entering the gallery and/or some cryogenic helium ingress in the VV). By keeping the VV atmosphere confined this could be avoided with beneficial impact on the accident scenario. Furthermore by keeping the VV atmosphere confined, this would potentially reduce drastically the numbers of other HCCs (VV+VVPSS+fueling lines isolation would remain). Hence it is proposed to EPNS to leave this point open and to perform more detailed analysis: PBS 15, when the detailed methodology and especially the load combination for the scenario 11 will be available, could analyse if it is possible to consider the VV as HCC and EPNS could perform a safety analysis in this new scenario to check if the number of other HCCs can be limited.
In any case the VV shall not aggress other HCCs or initiate another accidental scenario.
For the in vessel coils no HCC has been identified. In fact the in-vessel coils are completely within the vacuum vessel. Details are given in Hard Core Components in PBS-15-IV (PKP2WG v1.0) (current).

5.3 PBS 16 and PBS 17 - First Wall Blanket and Divertor

No HCC has been identified for first wall blanket and divertor. In fact they are completely within the vacuum vessel. Details can be found in Hard Core Components in PBS-16 and PBS-17 (P4AL9R v1.0) (current).

5.4 PBS 18 - Fuelling and Wall Conditioning

For Fuelling and Wall Conditioning System, isolation valves between Vacuum Vessel and Gas Injection System Gas Valve Box, VV and Pellet Injection System, and Disruption Mitigation System and GIS are considered as the HCC. They are all fail close valves to confine tritium inventory in the VV and GIS manifold during the extreme accident scenarios.
In addition, Penetrations of Gas Distribution System Manifold which penetrate fire barriers are also considered as the HCC.
Details can be found in Hard Core Components for PBS 18 (QXBLR9 v1.2) (current)

5.5 PBS 22 - Machine Assembly & Tooling

Most of the tools and equipment from PBS-22 will be removed before plant operation; however, some of them like rails will remain installed and are in close proximity of penetration/guard pipes.
It can be concluded that no Hard Core Components are identified in PBS-22.
PBS-22 equipment shall not be aggressors against SIC and Hard Core Components.
In particular these components are:

- Permanent ladders,
- Permanent platforms,
- Rails for cryostat top lid manipulator,
- Rails for cryostat cylinder tool transporter.

Details and pictures which show the potential aggressors and their location can be found in ITER_D_QXZ6EP - Hard Core Components in PBS-22.

5.6 PBS 23 - Maintenance & Remote Handling System

It is recalled that the PBS-23 equipment in the TKM building is used only in Mode 1 or Mode 2. Scenario 11 is supposed to occur only during mode 0 [2]. For scenario 12 it is supposed to occur during mode 0, 1 and 2 [2] but no PBS-23 equipment is present in Tritium building. It should be noted that PBS-23 equipment (remote handling cask in particular) shall not aggress other HCCs in TKM and hot cell building.
By taking a wider approach if the extreme earthquake occurs while the cask is in the TKM building, since it shall not aggress other HCCs and since it will be within the second confinement no cliff edge effect is expected if the remote handling cask is not considered as HCC. The same applies if the cask is within the Hot Cell building. A particular situation is the one in which the cask is transferred from TKM building to the Hot Cell building through the 'bridges' between the two buildings. In particular it is proposed that EPNS could analyse weather the drop of the cask could lead to a cliff edge effect. Following the analysis the possibility to qualify either the bridges or the cask as HCCs should be further discussed.
Details can be found in Hard Core Components in PBS-23 (QZ2LP9 v2.1).

5.7 PBS 24 - Cryostat and VVPSS

5.7.1 Cryostat

The cryostat does not perform a confinement function in design basis events. In the terms of the stress test the cryostat does not appear as HCC in any of the input document provided to the Task Force. By communication with EPNS this has been accepted by ASN. During the exercise to identify HCC several "weak" points in the cryostat vacuum boundary (essentially some SIC bellows), which if breached due to the initiating event (scenario 11 – earthquake) while there is a loss of confinement of the VV (i.e. tritium contamination in the port cell) could lead to a release of tritium in the gallery (by putting in direct communication zone 1 and zone 2 or also the VV atmosphere directly with the cryostat boundary[5]) and leading possibly to a cliff edge effect. These "weak" points are listed inCryostat penetrations between zones 1 and 2 - possible HCC (QX3U6X v1.0) (current).
The possibility to structurally analyse the behaviour of these "weak" components under the conditions of the stress test should not be precluded from this exercise.

5.7.2 VVPSS

For the VVPSS, basically the whole system is qualified as HCC. It is important to note that it is proposed to qualify the bleed valves only for confinement, i. e. they could not open in an extreme scenario (SL-3). Rupture Disks, passive device, will open. This is done in order to avoid the

[5] Considering PCR 628 the cryostat then is connected to the gallery

qualification of 4 active components (the 4 bleed valves) to operate, plus all the instrumentation and control system necessary to open them (it has to be noted that fail open bleed valves cannot be employed). It has to be noted that most part of the steam (about 80-90 %) when bleed valves and rupture disks are open goes through the rupture disks. Hence if the bleed valves do not open a considerable impact is not expected. Details can be found in Hard Core Components for PBS-24 VVPSS (PJK22L v1.0) (current).

5.8 PBS 26 Cooling Water System

In the frame of the Stress Test PBS-26 is investigated only in building 11 and 14 hence several configurations are possible. For scenario 11 main following confinement zones have been investigated:

- Drain Tank room (DTR),
- Gallery, (including CSR)
- Lower Pipe Chase (LPC),
- NB Cell,
- HV Deck,
- Port Cells (PC),
- Vault,
- Tokamak building boundaries with Bldgs 74 and 14,
- External boundaries.

For scenario 12 main following fire sectors have been investigated:

- Process Rooms,
- Corridors,
- Technical galleries (TG),
- Fire Airlocks (noted F),
- Tritium building boundaries with Bldg 11,
- External boundaries.

The strategy of PBS-26 to address the Stress Test is broken down to the functions of Cooling Water sub systems / PBS levels 2 or 3. For some particular cases, such as penetrations shared with two subsystems, it is the GBS or the functional reference of the opening that is the identifying parameter.
Details can be found below and in Hard Core Components in PBS-26 (QZ3KZY v2.3) (current).

5.8.1 UPC penetrations

The penetration is localised in the upper pipe chase toward the machine through the bio-shield. In this penetration IBED PHTS and VV PHTS piping are surrounded by a guard and welded closure plates at both ends allow the segregation of volumes. In this configuration, it is proposed to qualify the piping against SL3 as well as the closure plates (located in the UPC and at the chimney level). The portion of pipe to be qualified will be within the guard and up to the next anchor point. The guard is considered as an aggressor.

5.8.2 CCWS-1, CCWS-2A, CCWS-2B, CHWS-H2

The strategy for these systems when crossing confinement or fire sectorization boundaries is to qualify against SL3 the portion of pipe crossing the penetration and adding at least an isolation valve designed to close in case of any failure (fail close valve) as close as possible to the penetration to maintain the fire or confinement boundary.

5.8.3 CHWS-H1

Due to his particular role in normal operation as well as in accidental situation, CHWS-H1 shall have a limited number of valves: this is the reason why it has been proposed to qualify the piping against SL3 and to use passives check valves for the piping crossing the building boundary to the external and between DTR and Gallery. In case of flow in the system the check valves are open and allow cooling SIC clients. In case of loss of flow (because of any break or pump failure) the check valve passively close keeping static confinement.
Isolation valves will be implemented if full redundancy on VV decay heat removal for Investment Protection will be implemented.

5.8.4 CVCS

In order to maintain the coolant quality, hydrogen is injected in the IBED-PHTS and NBI-PHTS CVCS. A hydrogen line routed from the external gas cylinder storage shared with PBS-32 penetrates the Tritium building at Level 3. It is proposed to use the isolation valves (fail close valves) and to qualify the piping for the portion crossing the penetrations. Guard has to be considered as an aggressor. A concept for CVCS isolation is reported in Figure 3.

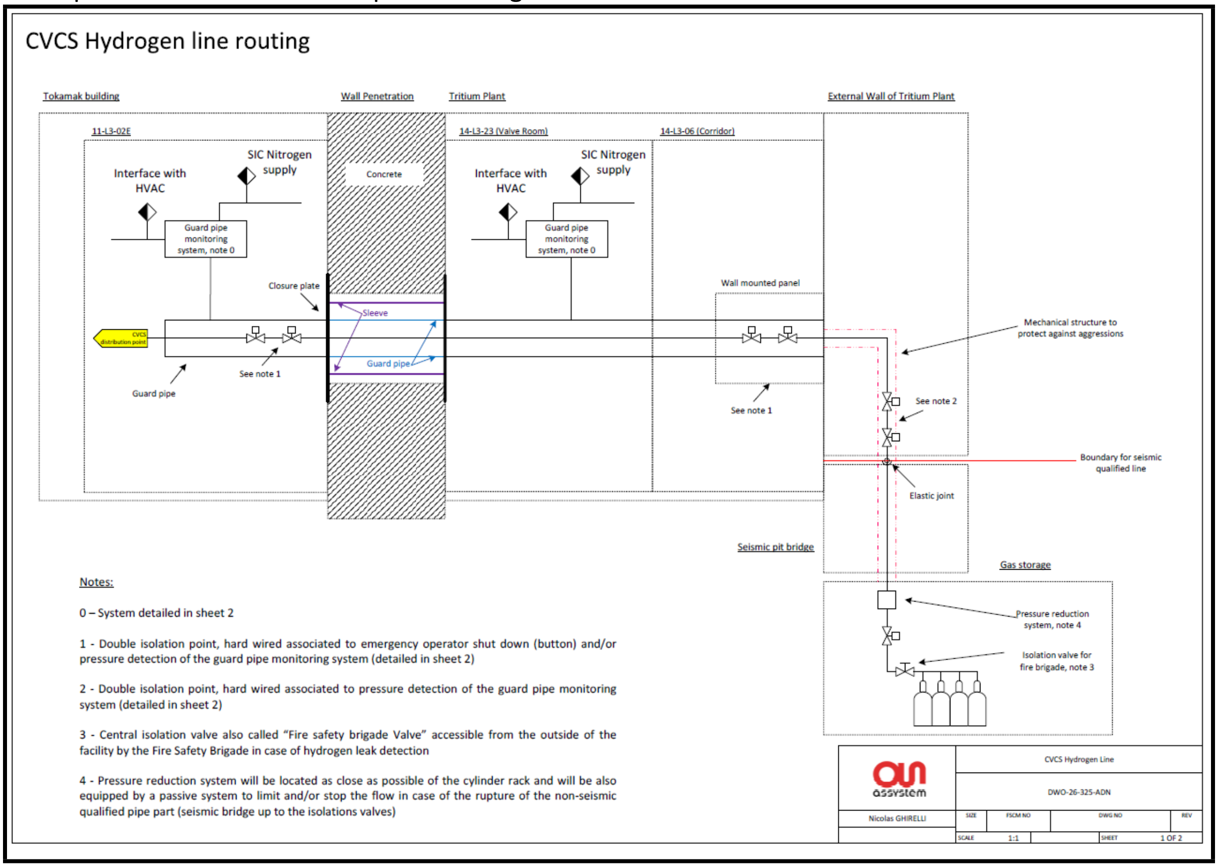

Figure 3 – Concept of CVCS isolation

5.8.5 Draining pipe(s)

It is proposed to use isolation valves and to qualify against SL3 the portion of pipe crossing the penetration to the isolation valve (fail close). In the particular case of the draining line from the Sampling Station located in the Tritium Building, the pipe is protected with a guard pipe: in this case it is proposed to qualify also the closure plate to avoid any by-pass. The guard has to be considered as an aggressor.

5.8.6 NBI PHTS

For NBI PHTS it is proposed to qualify the portion of pipe against SL3 crossing the penetration from Vault to HV Deck up to the isolation valve (fail close).

5.8.7 IBED Equatorial at B2M

Equatorial port piping lines at B2M are routed from the Vault to the machine using guards. The guards are keeping segregated the Bio-shield pit and the vault: this is the reason why it is proposed to qualify both piping and closure plate against SL3. The portion of pipe to be qualified will be within the guard and up to the next anchor point. The guard has to be considered as an aggressor.

5.8.8 VV PHTS

Main Vacuum Vessel PHTS equipment is segregated in the DTR from the rest of the plant, supply and return pipes are crossing from the DTR to the LPC by using the B2M tunnel. A pipe rupture in this tunnel would cause major local increase of pressure: this is the reason why it is proposed to qualify VV PHTS piping in the tunnel as well as all the piping in the tunnel. Tunnel is considered as an aggressor.

5.8.9 Sampling

An important number of sampling lines is foreseen to be routed from the vault and DTR to the Sampling station. It is proposed to qualify the piping crossing the penetration against SL3, the valve (fail close) and the closure plate. The portion of pipe to be qualified will be within the guard and up to the next anchor point.

5.8.10 IBED Equatorial, VV safety drainage and VV PHTS at B2M

Equatorial port piping lines at B2M, VV safety drainage and VV PHTS are routed from the Vault to the machine using guards. The guards are keeping segregated the Bio-shield pit and the vault this is the reason why it is proposed to qualify both piping and closure plates against SL3. Guards are considered as aggressors. The portion of pipe to be qualified will be within the guard and up to the next anchor point.

5.9 PBS 27 – Thermal Shield

In the frame of the scenario 11, no essential function is required to the Thermal Shield. In fact, the only possible function, related to penetration between zone 1 (galleries) and zone 2 (Vault, VVPSS Port Cells and NBI cell) has been investigated. Since the Thermal Shield is completely located inside the zone 1, as shown in the Figure 4, it is in the cryodistribution area and in the cryostat pit, which belong to the zone 1, no penetration between zone 1 and zone 2 has been identified.

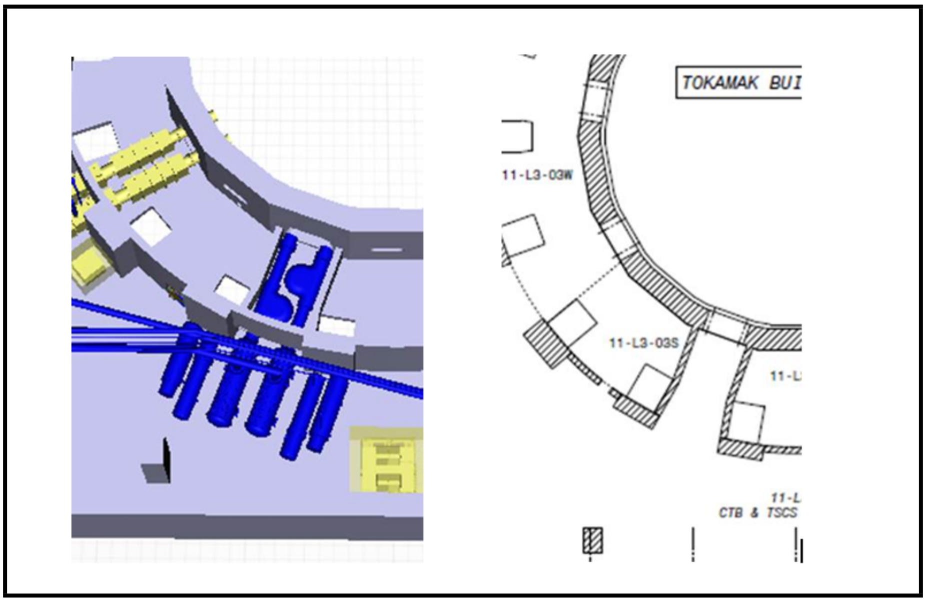

Figure 4 – Thermal Shield location inside the Tokamak Building

Finally, no HCC is identified for PBS-27. Details can be found in Hard Core Components for PBS 27 (ITER_D_QF6AR7 v1.0).

5.10 PBS 31 – Vacuum

The detailed list of PBS 31 HCCs is provided in the document PBS 31 detailed list of HCC (QEZ4MS v2.0) (current). The identification of penetrations which PBS 31 pipe work systems pass through are also detailed in the document.

In consideration of the PBS 31 HCC the following assumptions have been made.

- PBS 31 Pipework systems comprise of pipework (pipe, pipe fittings etc.) and valves.
- In the event of pipework system failure only pipework systems that are connected to a significant source of tritium have the possibility, on the event of breakage, to lead to a release of tritium.
- Only the confinement function of the HC pipework system has to be maintained.

With consideration of the above only PBS 31 pipework directly connectable to the ITER main VV or Cryogenic Viscous Compressor (CVC) could lead to cliff edge effect in the case of failure (i.e. loss of confinement). The HCC pipework will maintain confinement after the event hence the operation of an isolation valve in the system does not need to be considered as hard core, only that the valve must maintain confinement after the event (section 4.2).

For what SVS penetrations from zone 1 to zone 2 is considered they have not been considered HCCs for the moment. The reason is basically that SVS is normally connected to low tritiated zones and, moreover, qualifying SVS as HCC would cause a major impact to the design of this system: in fact we are talking of about 126 vacuum and gas lines (DN150 & DN25) and several thousand 6 mm pneumatic lines which would need to be equipped with isolation valves (technologically impossible at the moment) or which would have to be sized against SL3. It has to be noted that even for design basis it was considered a major challenge adding isolation valves on vacuum system as reported in Ref. [19]: hence these isolation valves are not present in SVS design.

If, following analysis by EPNS, it is absolutely necessary to take into account also the SVS to prevent cliff edge effect this will be re-considered.

The current design of PBS 31 vacuum system is such that in the case of loss of services (for e.g. cryogens) leading to a warm up of the Cryogenic Viscous Flow Compressor (CVC) within the roughing system, leading to regeneration of the CVC, sub atmospheric conditions are maintained in the system by allowing the gas to expand back into the line running between the tritium building and the tokamak. Hence isolation valves with a safety closure function within the tritium plant or in the galleries close to the tritium plant are not included in these lines.

In addition, there is no high vacuum valve currently available which can perform a safety closure function after the considered events.

5.11 PBS 32 - Tritium Plant

The general strategy for identifying HCCs in the Tritium Plant is described in chapter 4. The specific application of this strategy for PBS 32/64 equipment in the Tritium Plant building is presented in this section. Based on Table 1 of Ref. [8], there are two primary hard core functions that apply to PBS 32 equipment: tritium confinement and fire sectorization. There are several instances where penetration of equipment (i.e., pipes) across fire sectors/confinement barriers requires the equipment to be classified as HCCs. This equipment is grouped into nine categories; these categories and the strategy for the tritium confinement and fire sectorization approach are summarized in Table 1 and shown in Figure 5. Each penetration has been identified and the detailed list is documented in ITER_D_QCMWQ2 - Hard Core Components for PBS 32 and PBS 64. A more detailed explanation of the methodology used for identification of HCCs for PBS 32 and PBS 64 is described in ITER_D_Q83WR4 - Post-Fukushima Stress Test Hard Core Components for PBS 32 and PBS 64. Additional HCC equipment associated with PBS 64 and located outside of the Tritium Plant Building is explained in section 5.23.

Table 1 Summary of approach to tritium confinement and fire sectorization for PBS 32/64 equipment.

Type	Pipe Type	Pipe Size	Example	Side 1	Side 2	Valve has HCC confinement fcn?	Valve has HCC fire damper fcn?	Fire sectorization approach
a	Single	Large	In-leakage system for accelerated room detritiation	Process room	Corridor	Yes	Yes	Credit pipe/valve as fire break Valve must serve as fire damper since short distance between inlet and outlet
b	Single	Large	DS M2 manifold (room air to DS) ISS refrigerant line	Process room	Corridor	Yes	No	Credit pipe/valve as fire break Valve does not serve fire damper function since pipe is sufficiently long that gases cool before reaching another fire load
c	Single	Large	TC-DS & WDS to Stack (gas) HCF-DS to WDS (liquid) WDS to/from Radwaste	Process room	Corridor/exterior	Yes	No	Same as above
d	Single	Large	DS M1 manifold (process and GB to DS)	Process room	Process room	NA	NA	Credit pipe as fire break
e	Guardpipe with small process tubes within	Small within Large	Pipes from TEP to ISS	Process room	Process room	NA	NA	Porous fire break material fills annular spaces
f	Single	Small	Non-tritium gas supply from Gases Compound	Exterior	Corridor/process room	Yes	No	Small pipe size maintains sectorization
e/f	Guardpipe with small process tubes within	Small within Large	Pipes from SDS to Fuelling	Process room	Process room	Yes	No	Porous fire break material fills annular spaces
g	Single	Small	Pressure reference for confinement pressure cascade	Exterior	Corridor	NA	NA	Small pipe size maintains sectorization
h	Single	Small	REMS sampling lines in the corridor	Process room	Corridor/process room	NA	NA	Small pipe size maintains sectorization
-	Single	Small	Non-tritium gas supply, low-tritium process lines	Process room	Process room	NA	NA	Small pipe size maintains sectorization

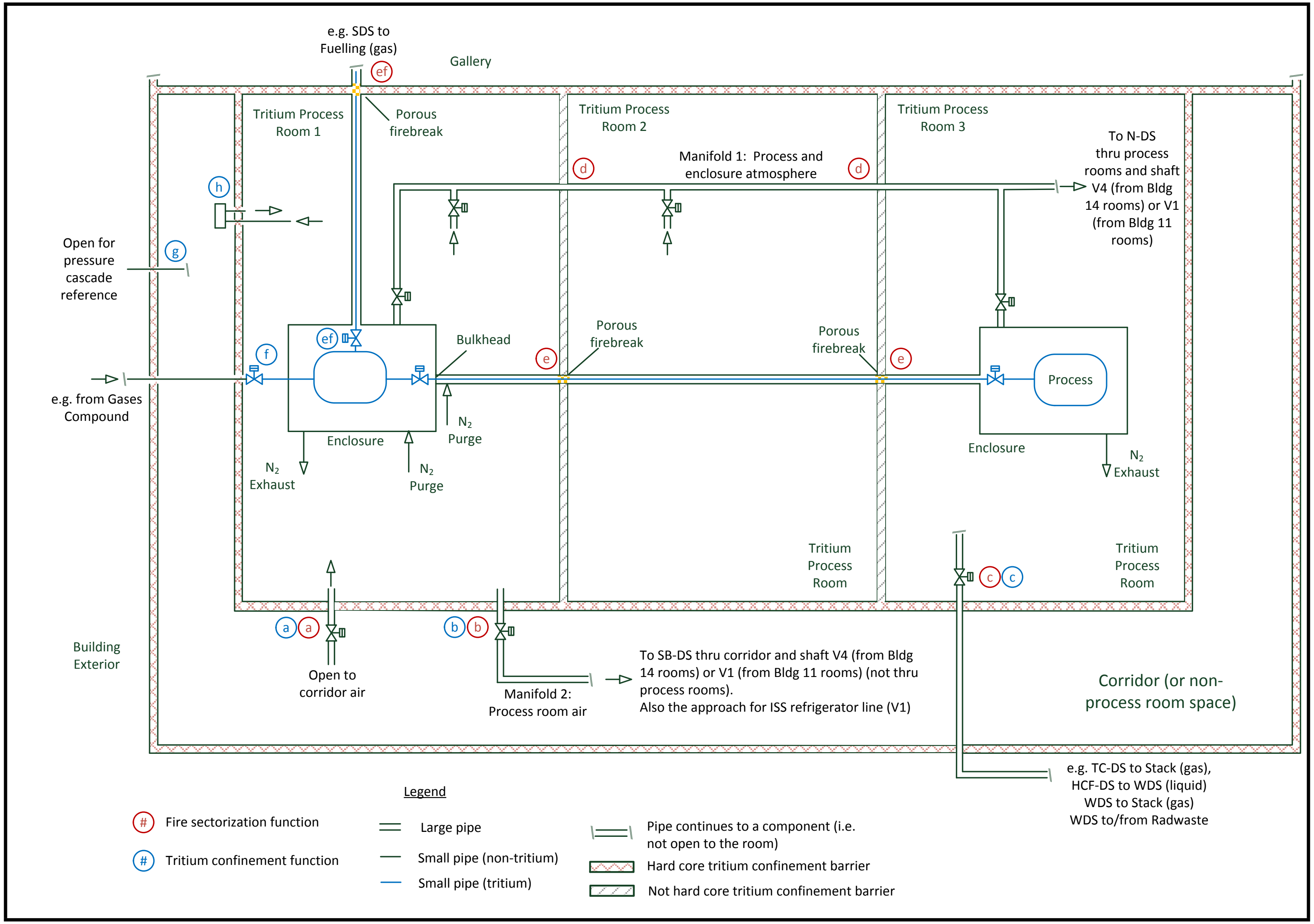

Figure 5 – HCC approach to tritium confinement and fire sectorization for PBS 32/64 equipment

5.12 PBS 34 – Cryogenic System

The essential function performed by PBS 34 in the frame of the Stress Test is the confinement function. Therefore, all the penetrations at the 2° confinement (B11) and at the penetration between the zone 1 (i.e. galleries) and zone 2 (i.e. NBI cells, port cells, vault and VVPSS) are identified as HCCs.

Moreover four options have been proposed in Ref. [20] (still to be approved by the time this report is prepared) for what the Tanks located in Area 53 is concerned: whatever option is selected it is clear that area 53 cannot aggress or induce aggression on HCCs.

The analysis for the HCCs identification has been based in the current status of the design and on the available PFD (all reference given at the https://user.iter.org/?uid=QF6DKY). The update of the HCCs list shall be performed when the Cryodistribution design will be fixed.

Among all the identified HCCs, only the vacuum barrier at the 2° Confinement Penetration and the Quench Line are classified PIC. All the other components are not PIC.

More details on the approach applied and on the outcomes of the analysis are given at the https://user.iter.org/?uid=QF6DKY.

5.12.1 2° CONFINEMENT PENETRATION

These penetrations (see conceptual configuration at Figure 6) shall assure the continuity of the 2° confinement and shall include:

- the extra-flange for confinement sleeve (in the scope of PBS 34) which is welded to both the vacuum jacket (in the scope of PBS 34) and the confinement sleeve (in the scope of the PBS 62, together with the wall of the building)
- the vacuum jacket, from the weld to the extra-flange to the weld to the vacuum barrier (see green part of vacuum jacket at Figure 6); since the extra-flange is not designed to withstand the seismic loads and the loads due to the failure of the no-HCC vacuum jacket in case of earthquake, the external support of the cryolines (support connecting the cryolines to the civil structure close to the penetration, in the scope of the PBS 34) is identified HCC, as well as the anchor plate (in the scope of PBS 62) and the seismic decoupling system located inside the cryobridge for coping with differential displacements between the Tokamak building and the cryobridge
- the vacuum barrier
- the process pipes, from the vacuum barrier up to the first valve
- the valves, where possible; if isolation valves are already foreseen in the design for confinement purposes, they shall be considered HCC; if not, the first valve installed on the process pipe (even if located inside the ACBs or the TCVB) shall be considered HCC, together with the safety relief panel (up to the safety valve) and the purge line (up to the manual isolation valve) installed "before" this first valve (see conceptual configuration shown at Figure 7); if no isolation valve is foreseen on the pipe (i.e. quench line, relief header and 6-100 K line) and if the addition of new valves is not feasible because of specific safety or technical constraints, a suitable justification shall be given; therefore, the quantity and dimensions of the process pipes are specified in order to allow the evaluation of the dose at 2.5 km.

The general idea behind the approach proposed above is to extend the 2° confinement function from the penetration up to the first valve, as shown at Figure 6, which, for cryolines, is located inside the Auxiliary Cold Boxes or inside the Thermal Shield Cold Valve Box.

Moreover, the aggressors, identified as those components that can affect the HCC in case of failure, are identified:

- Vacuum Jacket, from the vacuum barrier weld up to the Cold Box
- Cold Box where the first valve is located

Concerning the Cold Boxes, since they act as the support of the valves included in the HCC list, a suitable design criterion shall be identified for them and verified (within group B framework).

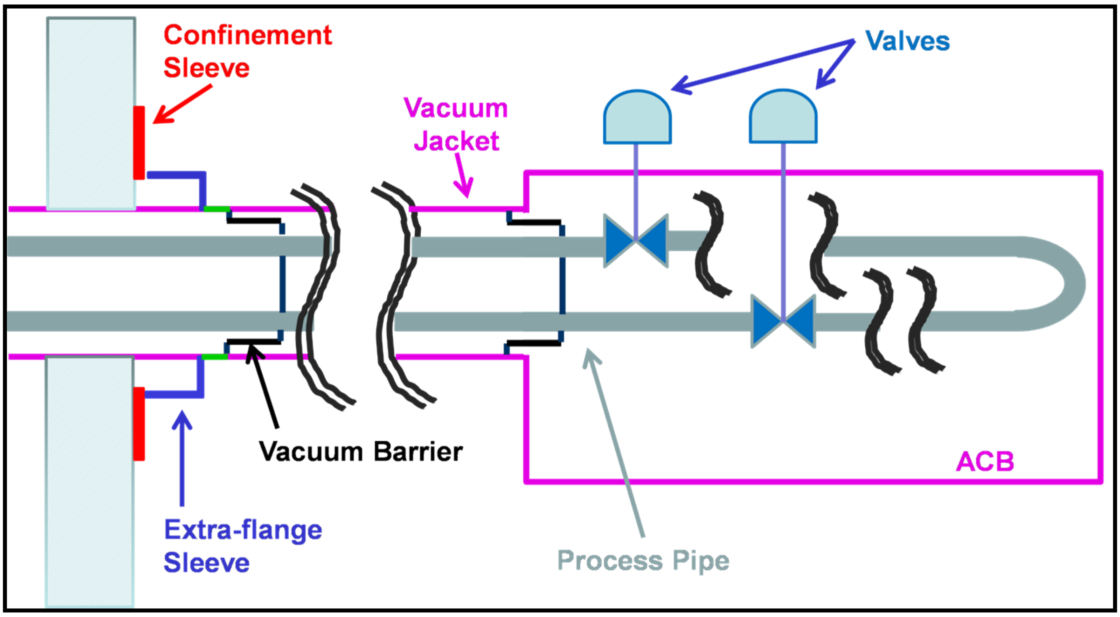

Figure 6 – Conceptual Configuration of Cryolines at 2° Confinement Penetration

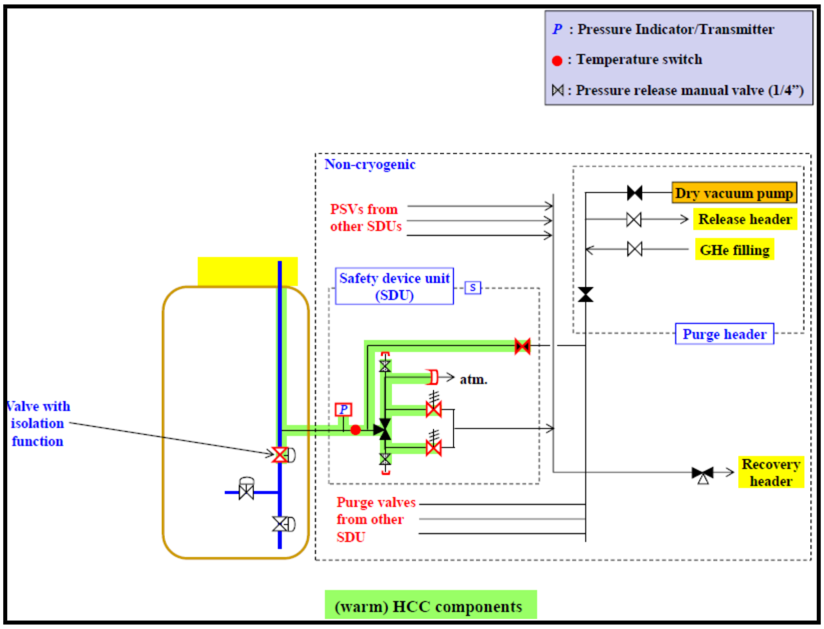

Figure 7 – Conceptual Configuration of Cryodistribution Boxes with safety relief panel and purge line

With the aim to guarantee the 2°confinement, the penetration shall be a fixed point (since the Sleeve could not act as a fixed point, the first support of the cryolines, close to the penetration, shall be verified to guarantee the confinement continuity) and the seismic decoupling system shall withstand the differential displacement between the Tokamak Building and the Cryobridge.
It is highlighted that no isolation valves are installed on the Cryolines and on the Quench Line, in the proximity of the 2° confinement penetration, for the following safety or technical constraints:

- Cryolines technical constraints:

  - installation of isolation valves
    - by two additional Valve Boxes: considering the current diameter of the cryolines manifolds (about 1 m), the installation of new additional valve boxes is a very big challenge in terms of layout and space availability inside B11; furthermore, since the most critical issue of the approach proposed above is related to the seismic qualification of the valves, this solution, with two new boxes, does not offer any advantages compared to the concept of "extension of the 2° confinement" up to the first valves, proposed above
    - directly on the process pipes, which requires the installation of bellows on the process pipe to absorb thermal displacement: this solution will lead to less reliable and less safe design.
  - installation of check valves: the addition of check valves could cope with the isolation issue only where Helium flows from the external environment to inside B11; in fact, no "weighted" check valves can be installed on the other direction because the corresponding pressure loss will not be compliant with the cryogenic system design; nevertheless, due to the identification of valves in cryodistribution boxes for the isolation of the process pipes, there is no need to add check valves on Cryolines.
- Quench Line, Relief Headed and 6-100 K safety and technical constraints:
  - no isolation devices shall be put on the quench line, relief header and 6-100 K because it has to guarantee safe blow down of the He inventory away from the Magnetic Coils, in case of Quench / Fast Discharge
  - the installation of "weighted" check valve, in case of need, shall be carefully addressed because (only if it is demonstrate that dose release will exceed 10 mSv at 2.5 km), due to the flow inventory and to the flow speed, and finally due to the impulsive force transmitted to the disc in case of quench, this equipment could decrease the reliability of the line during normal operation.

5.12.2 PENETRATION ZONE 1 / ZONE 2

The penetrations from the zone 1, Galleries, to zone 2, i.e. Port Cell, Vault and VVPSS, shall be identified as HCC in order to minimize the release of radioactive material from the more highly contaminated zone 2 to the galleries. These penetrations shall include:

- the extra-flange for confinement sleeve (in the scope of PBS 34) which will be welded to both vacuum jacket (in the scope of PBS 34) and confinement sleeve (in the scope of the PBS 62, together with the walls of the building)
- the vacuum jacket, from the weld to the extra-flange to the weld to the vacuum barrier, if the vacuum barrier is foreseen (see green part of vacuum jacket at Figure 6; since the extra-flange is not designed to withstand the seismic loads and the loads due to the failure of the no-HCC vacuum jacket in case of earthquake, the external support of the cryolines (in the scope of the PBS 34) is identified HCC, as well as the anchor plate (in the scope of PBS 62)
- the vacuum barrier, if foreseen.

In the case of penetration between zone 1 and zone 2, since

- no valve is foreseen on process pipes from zone 1 to zone 2 and
- no vacuum barrier is foresee between B2 level and B2M Level

it is proposed to evaluate the impact in terms of dose release in case of breakage of cryolines, taking into account that the second confinement function is kept, except for quench line, 6-100 K Line and relief header (see safety and technical constraints already given above).

Therefore, the process pipe and vacuum jacket diameters are detailed in order to allow the assessment of dose at 2.5 km.

5.12.3 CONCLUSION

Among all the identified HCC, only the vacuum barrier at the 2° Confinement Penetration and the Quench Line are classified PIC. All the others are not PIC.
It is highlighted that

- concerning 2° confinement, the process pipes of Quench Line, Relief Header and Upper 6-100 K Line cannot be isolated in case of scenario 11 due to specific safety and technical constraints specified above
- concerning penetrations between zone 1 and zone 2,
  - the process pipes between galleries and port cells cannot be isolated because of the technical constraints specified above
  - both the vacuum jacket and the process pipes between galleries and vault cannot be isolated because of the technical constraints specified above

In this frame, the diameters of process pipes and of vacuum jacket are indicated at the Table 2 with the aim to assess the dose release at 2.5 km in case of cryolines breakage.

Table 2 – Dimension of not isolable process pipes and vacuum jacket

2° Confinement Penetration	1 Quench Line	34.2S.QU	process pipe	DN 300
	1 Upper Level 6-100 K	34.2S.OU	process pipe	DN 150
	1 Relief Header	34.2S.R0	process pipe	DN 150
Penetration Zone 1 & Zone 2	1 Lower Level 6-100 K	34.2S.OL	process pipe	DN 100
	1 Relief Header	34.2S.R0	process pipe	DN 100
	1 Half Ring North Cryoline	34.2C.HN	vacuum jacket	DN600
	1 Half Ring South Cryoline	34.2C.HS	vacuum jacket	DN600

It has to be noted that the total un-isolated area for the second confinement according to the table above is about 0.11 m^2. As explained above it is extremely difficult to add isolation valves on these lines. Hence it is proposed that EPNS checks by detailed safety analyses if these valves are absolutely needed to prevent cliff edge effect. If this is the case the design will be modified to avoid cliff edge effect.

5.13 PBS 41 - Coil Power Supply and Distribution

Among all components of coil power supply and distribution (PBS 41), only Fast Discharge Units (FDUs) for TF coils are classified as PIC components. It has been examined whether the FDUs shall be HCCs and the outcome is that they do not need to be classified as HCC. Details can be found in ref. [18].

Within the PBS41 components, there are busbars crossing the secondary confinement barriers (wall between B11 and B74 at B11, B2 and L3 and the ceiling of L3). Those segments of the busbars and their associated supports are clarified as HCCs in order to support the confinement function under extreme scenario. It is requested that the portion of the busbars penetrating the just mentioned confinement barriers will maintain their structure stability and support this safety function. The detailed information can be found in document (IDM_D_JE43GH).

5.14 PBS 43 - Steady State Electrical Power Supply Networks

For scenarios 11 and 12 it has been proposed to be considered as Hard Core Components the electrical components that feed the rest of HCCs which require power to reach and/or maintain the safe state[6]. The need of power supply stablishes the criteria to select the appropriate **Ultimate Emergency Power Supply (UEPS) components**. The power supply must keep the functional requirements in order to provide reliable electrical supply to the active HCCs in case of a SL3 event.
The reason of this UEPS is to allow the active HCC to manage the transition into a safe state during or after one of the previous two scenarios.

Depending on the location of the mechanical HCCs to be feed, and also on the voltage level and voltage type of consumers (AC, DC, 400 V, 230 V. 110 V…), several Ultimate components have been proposed.

- **Ultimate Generator**: To provide electrical power to interruptible 400 Vac and 230 Vac loads.
- **Ultimate Fuel Transfer System**: To provide a certain level of autonomy to the Ultimate Generators.
- **Ultimate UPS**: To provide electrical power to uninterruptible 400 Vac and 230 Vac loads.
- **Ultimate DC charger and batteries**: To provide electrical power to uninterruptible 110 Vdc and 48 Vd.
- **Ultimate Distribution Boards**: To distribute the energy between the loads. In all rages of voltages and types AC-DC.

Could be the case that one or more of the UEPS components will not be needed because of the non-using of one or more type of voltage. This must be decided during the design phase and once the voltage of the instruments is set (see paragraph 4.5).
In the case of the Ultimate Transfer System, the emergency time requirements from the active HCC need to be known. 72 h for autonomy could be considered as a first approach.
Each of these electrical HCCs must be qualified for a SL3 event, in order to meet with the seismic requirements for the two envelope scenarios.

The UEPS system will feed the HCCs loads only when the Emergency Power Supply (EPS) (*) components cannot provide the operability function to these loads in case of an extreme event. In this case, the power supply will be transferred through an automatic transfer device from the EPS components to the UEPS components. The signal that will trigger this transfer switch could be a local signal (for example an under-voltage relay), a remote signal (for example a detection signal for high level earthquake) or the combination of both. As back up, also manual starting is considered.

* The Emergency Power Supply (EPS) System feed all emergency loads, which are important to safety, classified into PIC. Even in the event of LOOP (loss of off-site power), the EPS system shall provide the emergency loads with reliable electricity with sufficient capacity and duration for their due performance. The two trains of EPS serve as a full-capacity independent on-site standby power source, satisfying the single failure criteria. EPS components are classified as SC-1-SF so they must comply with the safety requirements (Single Failure Criterion, Independency, Redundancy) in case of a SL2 event. In normal operation EPS trains A and B are connected with the ITER SSEN network and feed SIC loads. It is proposed that it feeds the HCCs loads in design basis events, as shown in the following figure.

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[6] Of course BCR is going to be fed by HCC power supply. BCR is still at conceptual design stage but, based on operating plants, a required power of about 20-30 kW is expected for the BCR.

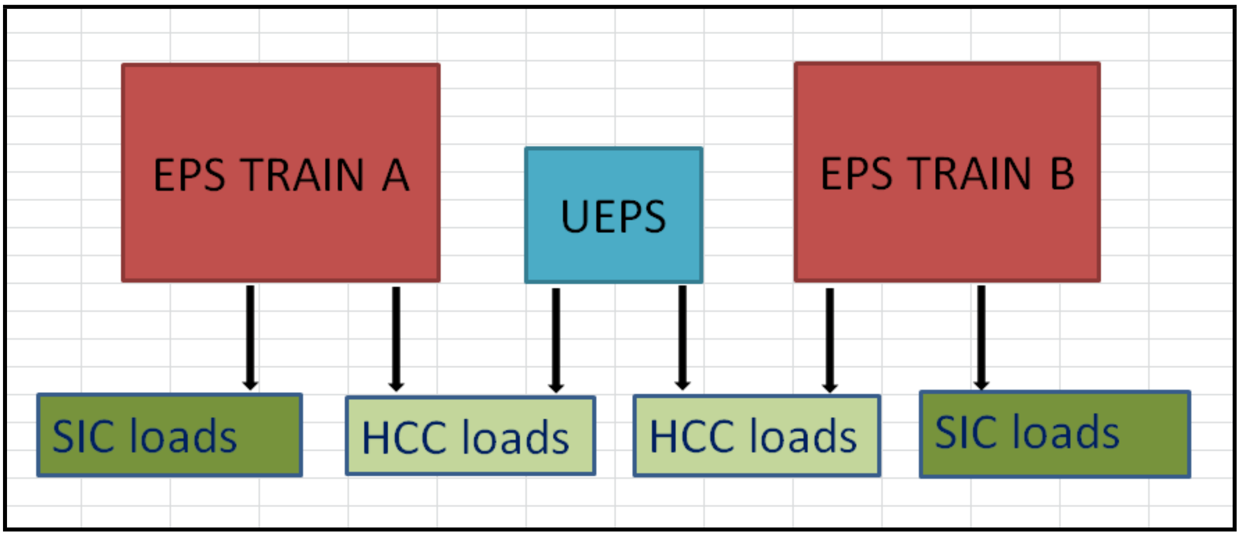

Figure 8 – Scheme for emergency and ultimate emergency power generation and distribution

In this first approach of the Hard Core Components that integrate UEPS, the following rated power is considered:

- **Ultimate Generator**: The main two active HCCs that need to be fed by the ultimate generator are the Fire Protection Pumps (the possibility to feed and operate both of them is envisaged) and the Air Mixing blowers (the possibility to feed both of them is envisaged and the generator is sized to operate the two of them even if redundancy is not required since the electrical load of the fans is very small compared to the pump of the fire extinguishing system and it is not going to affect the generator size considerably). A preliminary 4 MVA LV generator is foreseen.
- **Ultimate Fuel Transfer System**: Preliminary autonomy of 72 h.
- **Ultimate UPS, DC chargers and batteries**: Between 1h and 2 h autonomy is preliminary considered to feed some instrument loads considered as HCC.
  For components, due to the fact that the air mixing blowers (preliminary rated power of 70 kW) shall have uninterrupted operation, we propose two solutions:
    - the UPS will be sized to feed this fan,
    - The fan will work in DC and the fan will be fed by batteries.

The final solution will be selected during the development phase. Anyway uninterrupted operation of the ISS air mixing system will be assured.
Of course all the distribution to get the electrical power where it is needed is classified HCC: cables, trenches, etc.
The detailed list is in Detailed List HCC PBS43-PBS44 (Q5V4VL v4.0).

5.15 PBS 44 - Cable Tray

In order to keep the ultimate power supply between the operability limits of the active HCC, it has been proposed to consider the assembly **cable-trays/conduits-supports** also as a HCC.
In particular, the cable tray boundaries that must comply with the detailed methodology for PBS44 are:

- Cable connection with the electrical energy source. That is one of the Ultimate Emergency Power Supply Components.

- Cable connection with the electrical energy load. That is the active Hard Core Component.

In the case of cable trays inside the Tokamak Complex, it will be considered as HCC the SIC trays whose cables feed active HCC or to have a separated cable trays or conduits for HCCs.
In the case of the cable trays outside the Tokamak Complex (in the case that any UEPS component is outside this complex) it will be considered as HCC the SIC trays whose cables feed active mechanical HCC or to have a separated cable trays or conduits for HCCs.
Special attention in the design and qualification for the cable trays proposed as HCC must be paid to the metallic supports.

Also all electrical penetrations between the Tokamak and Tritium building on one side and the exterior on the other side are considered as HCCs. The same applies for the penetrations between the Tritium Building and the Tokamak Building. Furthermore the penetrations between zone 1 and zone 2 are also considered HCCs, as well as the penetrations from external in the Hot Cell building.

All these penetrations shall keep confinement and, for tritium building, fire sectorization.

The three commercially available solutions for electrical opening sealing are based on:

- **Silicone foam**: which fill completely all the space between cables and cable tray.
- **Multilayer rubber** (multi cable transits), where each individual cable is sealed.
- **Non-continuous wall penetration**: EPA or Electrical Penetration Assembly.

The three options are considered to be qualified as HCC. The selection of each solution is based in the safety requirements considered in the baseline design (Figure 9).

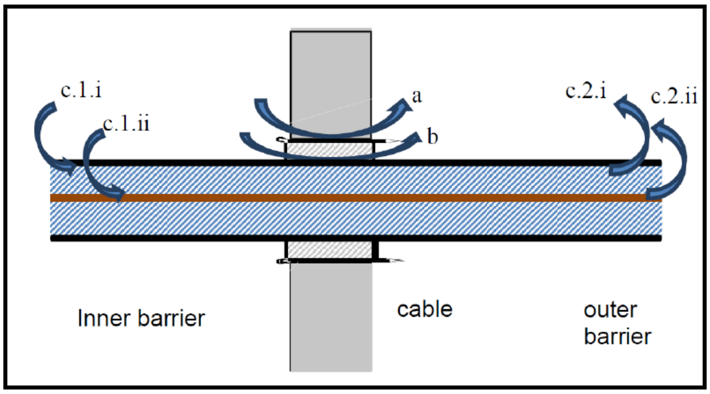

Figure 9 – Sketch of a generic penetration

The detailed list is in Detailed List HCC PBS43-PBS44 (Q5V4VL v4.0).

5.16 PBS 45 - CODAC, PBS 46 - Central Interlock System, PBS 47 - Plasma Control System, PBS 48 - Central Safety System

A preliminary general policy for the I&C systems in their contribution to hard core functions to cope with impact of the post-Fukushima stress tests scenarios is developed in the document ITER_D_QB7TJQ - Preliminary general policy for the I&C systems in their contribution to hard core functions.
According to the proposed policy, when the HC actuators are “failsafe” (do not require an energy source or an I&C command to enter the safe state), then no dedicated HC I&C is required. Those

actuators will go to their safe state in case of failure of the energy source of the existing I&C. It has to be verified that a manual command can bring them to the expected safe position in case the power source and existing I&C survive (at least partially) the accident scenario.
When (or if) Hard Core Instrumentation and Control is required, such HC I&C will be implemented as a dedicated, hardwired, robust control of the actuator, powered directly by the Hard Core Power supply. Direct manual command (e.g. a switch) on the actuator powering cubicle would be the preferred option because it allows to develop a very simple and efficient control of the system and a very high robustness.
In the scope of this proposal, PBS.45 CODAC, PBS.46 CIS (Central Interlock System), PBS.47 PCS (Plasma Control System), PBS.48 CSS (Central Safety System) are not expected to include Hard Core Components.
This impact would be reconsidered in case of identification of "active" Hard Core actuators needing manual commands from the BCR because direct manual command (e.g. a switch) on the actuator powering cubicle wouldn't be suitable.
Furthermore the need to monitor some essential plant parameters will be assessed, according to paragraph 4.5.

5.17 PBS 51 - 54 Heating & Current Drive Systems

5.17.1 PBS 51, 52 and 54

These 3 PBS are using high power radio frequency transmission line systems crossing 2 boundaries:

- The south wall of tokamak building for lines coming from the assembly hall to the galleries at L1 or L2
- The port cell lintels for the port cells used by these systems

The penetrations are qualitatively similar, and the HCCs mainly consist of SIC-2 sections of transmission lines and gas barrier (PBS 51) or fail safe isolation valves (PBS 52 and 54). Some associated cooling circuits crossing the lintels are fitted with fail safe isolation valves.

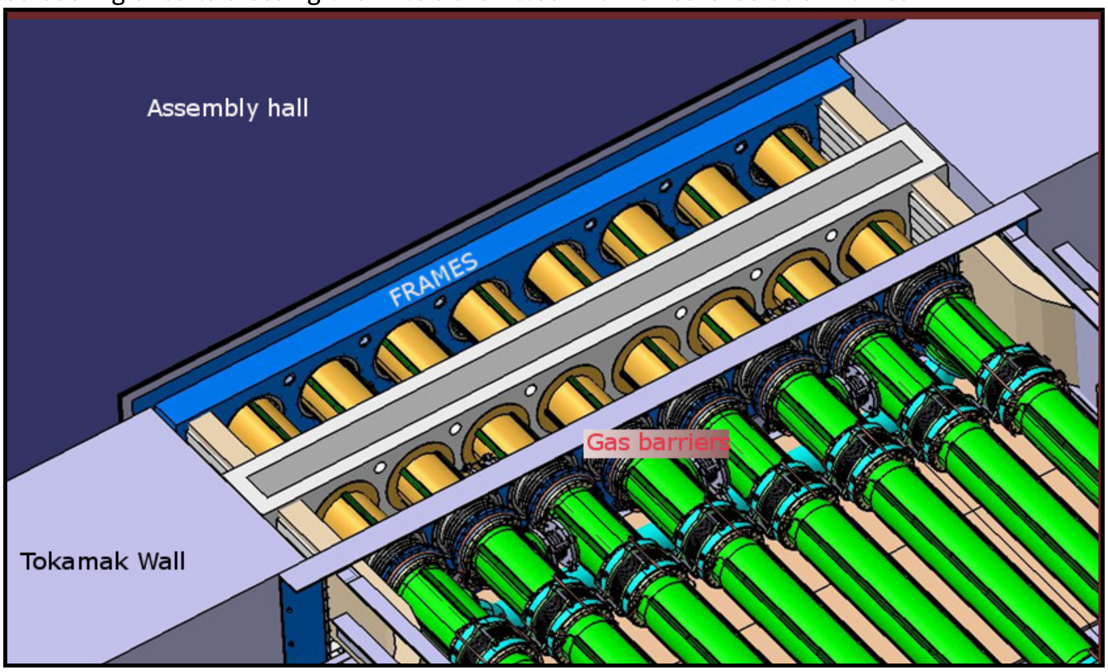

Figure 10 – Typical penetration system through tokamak wall / assembly hall interface: transmission lines (in green) and cable trays (each side) are crossing the wall, gas barriers are fitted on each transmission lines and the gallery side is provided with fire insulation.

Details for these three PBSs can be found in Detailed List HCC PBS51 (QUSSLH v1.2) (current), Detailed List HCC PBS52 (QUUCYP v2.0) (current) and Detailed List HCC PBS54 (QXX7TH v1.1) (current)

5.17.2 PBS 53

The identified HCCs of the NB system are related to the penetrations of the HV transmission lines from the Power supplies located in Area 30 when they penetrate the North wall at L3 of the building 11. They then go through the L3 floor into the NB cell. The penetrations must be leak tight between the transmission lines and the concrete and this is achieved with dedicated flanges. They must also be leak tight within the transmission lines themselves and this is achieved by bulkheads made of epoxy.
There is also a pipe penetration in the north wall and it is used for the transfer of SF6 gas from the section of the transmission lines situated within B11 to the SF6 handling plant in Area 31. The SF6 transfer pipe will be equipped with a fail-safe normally closed isolation valve installed in B11 L3 HV deck room. Since the valve is a fail-safe normally closed valve, it will not require any power to fulfil the isolation.
Furthermore the penetrations for bushing including lines for D2/H2, water cooling and circulating air are also considered as HCCs.

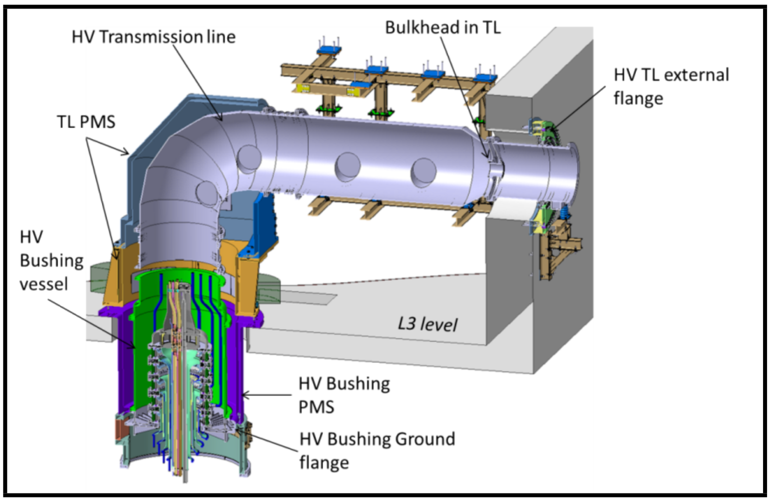

Figure 11 – A cross section view of the HNB HV transmission line from the B11 L3 north wall to the HV Bushing in NB cell. At the penetration at the north wall the leak tightness is achieved external to the transmission line with the external flange and internally with a bulkhead. The leak tightness between L3 and NB cell in L1 is achieved with HV Bushing PMS and the HV Bushing vessel.

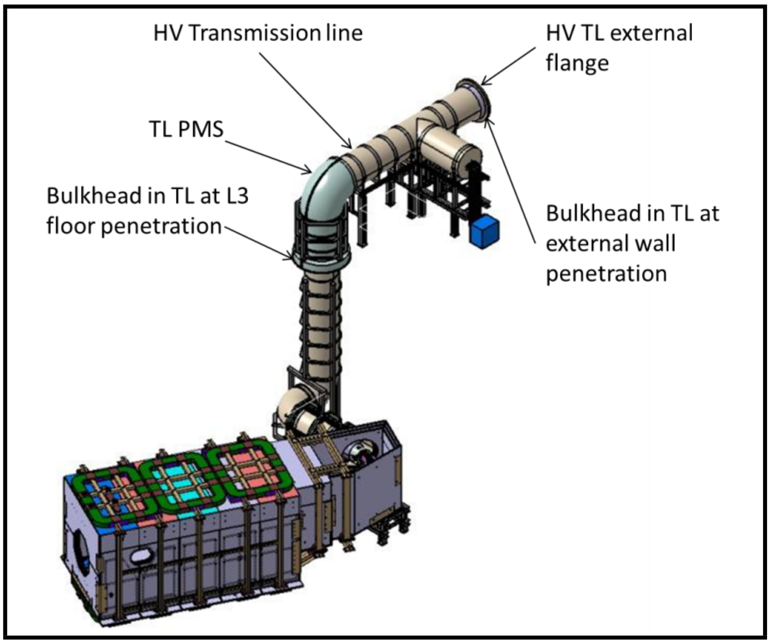

Figure 12 – A view of the HV transmission line of the DNB. The leak tightness at the north wall is achieved like the HV transmission line of the HNB by an external flange and an internal bulkhead. The penetration of the HV transmission line going from L3 to NB cell is achieved with a leak tight floor penetration and internally with a bulkhead.

Details can be found in [Detailed List HCC PBS53 (QXV7AH v1.1) (current)]

5.18 PBS 55 – Diagnostics

Analysis of PBS 55 from the perspective of applicable scenario has led to detection of several HCCs. Most of them are associated with the penetrations of diagnostics transmission lines and pipes through the port cell door lintels at B1, L1, L2 and L3 levels and, the same levels, through the boundaries between the tokamak building and adjacent buildings where diagnostic enclosures are located:

- Port Cell-Gallery in B1, L1, L2 and L3
- Gallery-Diagnostic Building in B1, L1, L2 and L3
- Gallery-Assembly Building in L1 and L2
- Tokamak Building-Tritium Building in L3

Hard Core components mainly consist of isolation valves and secondary (SIC-2) window assemblies. For cases when isolation valves cannot be placed, the entire pipeline shall be considered as a HCC. Details can be found in [Detailed list of HCC PBS 55 (QF6DC5 v1.0) (current).]

5.19 PBS 56 – Test Blanket Modules

PBS 56 is located in the Port Cells 02, 16 and 18 at the level 1 of the Tokamak building and has piping crossing galleries, TCWS Vault, Tokamak building boundaries, Tritium building boundaries and tritium plant process rooms.

The strategy proposed by the PBS 56 is to qualify the lines against SL3 except CCWS-1 piping (large pipe diameter ~ DN200) for which the strategy proposed by PBS-26 will be applied i.e. to implement isolation valves and to qualify the pipe from the valve to the penetration.

The list of HCC for the PBS 56 can be found in [Hard Core Components in PBS-56 (QZ3R6L v2.0) (current)].

5.20 PBS 57 - In Vessel Viewing Systems

PBS-57 components are located in the machine (Vacuum Vessel), port cells and galleries, cables and penetrations are under PBS-44 responsibility.
It can be concluded that no Hard Core Components are identified in PBS-57.

Details can be found in [Hard Core Components in PBS-57 (QZ9ARE v1.0) (current)].

5.21 58 - Port Plug Test Facility

Analysis of PBS 58 from the perspective of applicable scenario has led to detection of no HCCs. Required protection will be provided by the Hot Cell building envelope, where the Port Plug test facility will be located. Only fire considered for this building. Pressure relief and pressure resistance of door installed on the confinement barrier of the PPTF door will be provided, but not identified as HCC.

5.22 PBS 61 - 63 - Site and Buildings - PBS 70 - Site Outside Platform

5.22.1 Buildings HCCs

According the strategy defined in section 4, the attention is given to the scenarios in the Tokamak and Tritium Buildings. On that basis, and with respect to the identified HCCs, the following structural parts of the PBSs 61-63 and 70 shall be identified as HCC:

Tokamak building PBS 62.11:

- Galleries levels B2, B1, L1, L2, L3, L4 and L5
- NB Cell L1 and L2
- Port Cells B1, L1 and L2
- VVPSS room L5
- Vault area

This include the concrete structural elements forming the above areas, the doors, the embedded plates supporting penetrations identified as HCCs and the refilling of the penetrations located inside those concrete structural elements. Static confinement has to be assured as well as the possibility to protect the various areas of the building from over-pressurization.

Tritium building PBS 62.14:

- Process rooms (SDS, WDS, ISS, VPS, …) levels B2, B1, L1, L2, L3 and L5
- External walls of the outer corridors inc. airlocks levels B2, B1, L1, L2, L3 and L5
- Foundation supporting the water tanks located outside

This include the concrete structural elements forming the above areas, the doors, the embedded plates supporting penetrations identified as HCCs and the refilling of the penetrations located inside those concrete structural elements. Static confinement and fire sectorization have to be assured, as well as the possibility to protect the ISS room and the vault areas of the building from over-pressurization.

Hot Cell Facility building PBS 62.21 and Radwaste building PBS 62.23:

Two scenarios (namely scenarios 6 and 7) in Ref. [2] concerned the Hot Cell and the Radwaste buildings. Both scenarios have been clarified not causing a cliff edge effect according to Ref. [4]. Nevertheless by oral communication with EPNS it is clear that, because of the very large source term contained in these two buildings, they cannot be neglected in the stress test assessment. Anyway

presently there is no scenario associated with these buildings. Furthermore the design of these two buildings is still at conceptual level. For these reasons the detailed identification of HC systems and components is difficult at this stage. It has been agreed informally with EPNS that the situation for these two buildings will be clarified later.
For the Hot Cell in table 1 of Ref. [8] the fire dampers are reported as HCCs, even if no scenario is currently retained for this building. Because of this and since the Hot Cell building contains a considerable amount of radioactive material (source term comparable to the one of the Tokamak complex), the following systems/components have been preliminary identified: concrete structural elements forming the fire sectors, the doors, the embedded plates supporting penetrations identified as HCCs and the refilling of the penetrations located inside those concrete structural elements. Static confinement and fire sectorization have to be assured as well as the possibility to protect the various areas of the building from over-pressurization.

Personal Access Control Building PBS 62.24:

- Back-up control room and its power supply

This include the concrete structural elements forming the above area, the doors, the embedded plates supporting penetrations identified as HCC and the refilling of the penetrations located inside those concrete structural elements.

Building/location of ultimate diesel, fuel and batteries and pump houses for Tritium building fire extinguishing system:

- For the ultimate power supply location to be defined: it will be HCC. It has to be noted that when location will be defined, such location cannot be aggressed. Preliminary locations of the pump houses are shown in Figure 13 in paragraph 5.22.3: it can be seen at least one pump house is protected from area 53 and area 31. Anyway it has been clarified by EPNS that the whole amount of water shall be available for delivery to the tritium building in case of stress test scenario. This means no pump house can be aggressed.

5.22.2 Other Buildings

As also mentioned in section 3 and Ref. [11], in case of collapse of SC-2 non-nuclear buildings, no cliff edge effect is envisaged. Nevertheless some non-nuclear buildings which could in principle aggress HCCs are recalled hereafter:

Cryo-bridge PBS 61-C1-PB

- The Cryo-Bridge is considered as an aggressor for the TKM complex (cryolines included).

Assembly Hall PBS 62.13:

- This building could be aggressor to the Tokamak and Tritium buildings considered as HCC

Tokamak Complex retaining walls PBS 62.12:

- This structure could be aggressor to the Tokamak and Tritium buildings considered as HCC

NB Power Supply PBS 63.37:

- This building could be aggressor to the Tokamak and Tritium buildings considered as HCC

Cryogenic Buildings PBS 63.51/52

- The classification of these buildings will depend on the strategy considered for the cryogenic fluid storage tanks. Four options have been proposed in Ref. [20] (still to be approved by the time this report is prepared) for what the Tanks located in Area 53 is concerned. Whatever option is going to be selected it shall anyway be noted that these buildings cannot aggress the TKM complex, the pump houses of the fire extinguishing system for the Tritium building and the location of the Ultimate Emergency Power Supply. Preliminary locations of the pump houses are shown in Figure 13 in paragraph 5.22.3: it can be seen at least one pump house is protected from area 53 (and from area 31). Anyway it has been clarified by EPNS that the whole amount of water shall be available for delivery to the tritium building in case of stress test scenario. This means no pump house can be aggressed.

Area 31

- An explosion could in principle occur in area 31 (Ref. [21]). In the input documentation to the TF this is not identified as a problem for HCCs (namely for TKM and Tritium buildings). Anyway location of some HCCs is still to be defined (namely for the Ultimate Emergency Power Supply): of course explosion of the tanks in area 31 cannot aggress any HCCs. Preliminary locations of the pump houses are shown in Figure 13 in paragraph 5.22.3: it can be seen at least one pump house is protected from area 31 (and area 53). Anyway it has been clarified by EPNS that the whole amount of water shall be available for delivery to the tritium building in case of stress test scenario. This means no pump house can be aggressed.

5.22.3 Buildings Services

Analysis of Site and Buildings from the perspective of two considered scenarios has led to identification of several HCCs in TB04 scope. Numerous existing components have been listed for PBS 62, particularly in the TOKAMAK, Tritium and the Hot Cell Buildings. Based on Table 1 of Ref. [8], the following groups of components have been identified:

- TOKAMAK building (11) isolation valves and doors on the external walls and on the interface with the Diagnostics (72) and Tritium buildings (14),
- TOKAMAK building (11) isolation valves and doors on the interface between the galleries and the connected volume of NBI Cell, Port Cells, VVPSS, Vault,
- Tritium building (14) isolation valves and doors on the external walls and on the interface of process rooms with corridors,
- Tritium building (14) fire dampers and doors on the external walls, between process rooms, on the interface of process rooms with corridors,
- Complete reference pressure line network,
- Relief panes between the vault and the stack,
- Pressure relief device between the ISS room and the vault,
- Hot Cell building (21) fire dampers and doors on the external walls, between confinement areas and on the interface of confinement with common areas,
- Tritium building (14) air mixing system for the ISS rooms, including fans, ductwork, ISS room pressure relief device and required supporting services,
- Tritium building (14) fire protection system, including pumps, sprinkler pipes from pump houses to process rooms, fire protection water tanks and required supporting services. It has to be noted that the design of this system is in progress. Two totally separated trains each one 100% capacity are going to be provided for design basis events. For stress test scenario 12 both trains need to be fully operable. Preliminary locations of the pump houses are

shown in the figure below: it can be seen at least one pump house is protected from area 53 and area 31. Anyway it has been clarified by EPNS that the whole amount of water shall be available for delivery to the tritium building in case of stress test scenario. This means no pump house can be aggressed.

- Connection point and isolation valve for refilling fire protection water tanks from an external source,
- I&C of the Tritium building (14) ISS air mixing system and fire protection system.

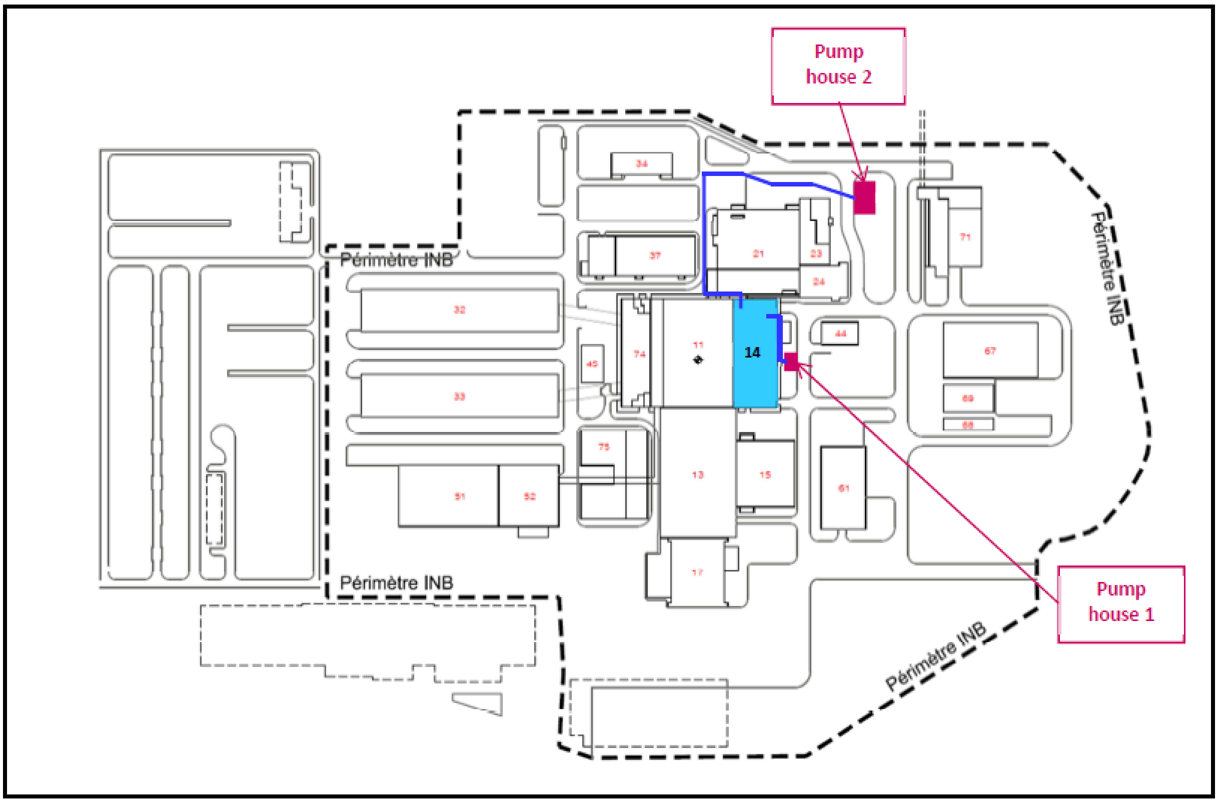

Figure 13 – Preliminary location of the fire extinguishing system pump houses

Active components, like ISS air mixing fans, fire protection pumps and required I&C (if any), will be provided with power from HCC sources. Valves and dampers will be brought to their fail position with no use of external systems.
With exception of isolation valves associated with pressure relief devices between vault - stack and ISS room - vault, all valves are fail-close. This is to permit the corresponding systems to realize their defined functions – relief pressure resulting from an accident within the TOKAMAK building and Tritium building ISS room.
Components have been identified and documented in ITER_D_Q7M5DZ and ITER_D_Q7KU8H for PBS 62.11, PBS 62.14, PBS 62.21 and PBS 65.

5.23 PBS 64 - Radiological & Environmental Monitoring

According to Table 1 of Ref. [8], mobile vehicles including contamination control and monitoring equipment are considered HCCs. Accordingly, there will be at least 2 mobile vehicles associated with this PBS that are considered HCCs. These vehicles are part of the health physics environmental monitoring system. These vehicles will contain measurement and other equipment to monitor the environment; they are expected to be deployed in response to emergencies. PBS 64 equipment located inside the Tritium Plant Building is described in section 5.11. A detailed description of the methodology used for identifying HCCs for PBS 64 (and PBS 32) is found in: ITER_D_Q83WR4 - Post-

Fukushima Stress Test Hard Core Components for PBS 32 and PBS 64. The list of HCCs is found in: ITER_D_QCMWQ2 - Hard Core Components for PBS 32 and PBS 64.

5.24 PBS 65 - Liquid & Gas Distribution

Penetrations and isolation valves of the PBS 65 systems, on the interface of confinement barriers identified for PBS 61-63 within the TOKAMAK and Tritium building, will be considered HCC.

With exception of isolation valves installed on the fire protection water lines all valves will be fail-close. This is to permit the systems to realize its defined function – supply water to Tritium building fire protection system.
Components of PBS 65, located within the TOKAMAK Complex, have been identified and documented in ITER_D_Q7M5DZ and ITER_D_Q7KU8H. See also paragraph 5.22.3.

5.25 PBS 66 - Radwaste treatment systems

PBS 66 equipment and piping are located in the TKM building and have interfaces with Tritium building and Hot Cell building. Inside the Tokamak building, PBS-66 is present in DTR, LPC and Gallery. The strategy proposed is to qualify the piping against SL3 from the penetration up to the isolation valve and the isolation valve (fail safe).
Details can be found in Hard Core Components in PBS-66 (QZ322F v1.0) (current)

5.26 PBS 69 - Access Control & Security Systems

PBS-69 is in charge to analyse and protect the IO-Facility against threats. Hence it can be concluded that no Hard Core Components are identified in PBS-69.
Details can be found in Hard Core Components in PBS-69 (QZ88QD v1.0) (current)

6 CONCLUSIONS

Hard Core Components have been identified in this report (and supporting detailed lists). The main points to be noted are the following ones:

1. The last confinement barrier of the Tokamak building is generally protected. Few penetrations for cryogenic lines are currently not isolable. The total area is about less than 1 m^2 (i. e. 0.11 m^2 as per paragraph 5.12.3). In the case in which the control valves located in the ACB (presently not-PIC) are not considered as HCCs the total uninsulated area is going to be up to 0.9 m^2.
2. For the HCCs whose function is to maintain static confinement, since no detailed analyses were available, for the time being the same leak tightness requirements as per design basis are maintained. In the logic of the stress test it is proposed to relax these requirements by means of an iterative process up to the point at which a cliff edge effect is got. This would simplify the qualification and design verification of HCCs. Therefore it is suggested that EPNS performs a verification on the possibility to relax the leak tightness requirements. In fact, as an example, if few penetrations from the gallery to external are not isolated (see point 1 above), most of the radioactive material is expected to escape through these not isolated penetrations being not very much affected if the rest of the gallery leaks as per design basis or more.
3. It has to be noted that according to Ref. [4], the gallery is the only part of the building in which design pressure is expected to be exceeded, hence degrading its confinement performance. If PCR-628 is going to be implemented this could have a beneficial effect to

protect the gallery from over-pressure by releasing cryogenic helium in the vault and then outside (Figure 1). If this is the case, in principle, the second set of HCCs (penetration from zone 1 to zone 2) could be limited since the gallery will keep a better confinement performance. However it has to be noted that in case of concomitant gallery (because of cryogenic helium) and vault (because of water/steam from the cooling water system) pressurization the relief panel between the gallery and the vault could not open. It is proposed that EPNS performs an analysis integrating PCR-628 and checking if this second set of HCCs can be limited / eliminated.

4. It is proposed to re-consider the possibility qualify the VV as HCC (see also paragraph 5.2). In fact the VV is a generally thick and robust structure for which the electromagnetic load is by far the design driving one. There are some weak points (bellows) which could be challenged by SL-3. Anyway keeping the VV atmosphere confined, this would potentially reduce drastically the numbers of other HCCs (VV+VVPSS+fueling lines isolation would remain). Hence it is proposed to EPNS to leave this point open and to perform more detailed analysis: PBS 15, when the detailed methodology and especially the load combination for the scenario 11 will be available, could analyse if it is possible to consider the VV as HCC and EPNS could perform a safety analysis in this new scenario to check if the number of other HCCs can be limited. Furthermore it is noted that even if the cryostat does not perform a confinement function in design basis events, during the exercise to identify HCCs several "weak" points (essentially some SIC bellows) in the cryostat vacuum boundary, which if breached due to the initiating event (scenario 11 – earthquake) while there is a loss of confinement of the VV (i.e. tritium contamination in the port cell) could lead to a release of tritium in the gallery (by putting in direct communication zone 1 and zone 2 or also the VV atmosphere directly with the cryostat boundary[7]) and leading possibly to a cliff edge effect. The possibility to structurally analyse the behaviour of these "weak" components under the conditions of the stress test should not be precluded from this exercise (see also paragraph 5.7.1)

7 REFERENCES

[1] ITER Abbreviations (2MU6W5 v1.15) (current)
[2] EVALUATION_COMPLEMENTAIRE_DE_LA_SURETE_ITER ENGLISH (QRVGWD v1.0) (current)
[3] ITER - REX Fukushima (ITER_D_QUD4GT v1.0)
[4] Rapport IRSN N° 2013-00013 (limited diffusion document)
[5] Liste des engagements pris par l'exploitant ITER Organization en vue du GP ECS 2013 (ITER_D_QUEEZG v1.0)
[6] LETTRE ASN CODEP-DRC-2014-024054 du 6 juin 2014 (QXBL9H v1.0) (current)
[7] Term of Reference for the task force on post-Fukushima analysis (QU6NKG v1.0) (current)
[8] IMPACT_OF_STRESS_TEST_REPORT_ON_TECHNICAL BASELINE (QXBE8A v1.0) (current)
[9] Stress Test Task Force Minutes _3rd Feb2015 (QXVPZJ v1.0) (current)
[10] EPNS replies - 01 (QE69TV v1.0) (current)
[11] EPNS replies - 02 (QEFG7U v1.0) (current)
[12] Set 3 of answers from EPNS on questions raised during Group A meetings (QXT6EF v1.0) (current)
[13] PCR-628 - Cryostat Pressure Mitigation
[14] Preliminary Safety Report (RPrS) (3ZR2NC v3.0) (current)
[15] Strategy of the Stress Test Assessment on the Explosion in Area 53 (R3HWS5 v1.2) (current)
[16] Defined requirements for PBS11 (L9ZWYD v 3.0) (current)
[17] DDD 11 ITER_D_2NPLKM v1.9 (uploaded as an attachment to PCR-647)

[7] Considering PCR 628 the cryostat then is connected to the gallery

[18] Clarification on the need to qualify the Fast Discharge Units as Hard Core Component (PJJP2V v1.1)
[19] Penetrations through port cell walls (DXBEAL v1.5) (current)
[20] Strategy of the Stress Test Assessment on the Explosion in Area 53 (R3HWS5 v1.1)
[21] PCR-672 - Area 31 Safety Requirements Revision