Revision	Approved by	Number of Pages
000	[signature]	20
Approval Date	26/10-17	

General Nuclear System Ltd.

UK HPR1000 GDA Project

Document Reference:	HPR/GDA/PSR/0019

Preliminary Safety Report

Chapter 19

Internal Hazards

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19.1 List of Abbreviations and Acronyms

BRX	Reactor Building
FCG Unit 3	Fangchenggang Nuclear Power Plant Unit 3
GDA	Generic Design Assessment
HPR1000 (FCG3)	Hua-long Pressurized Reactor under Construction at Fangchenggang Nuclear Power Plant Unit 3
HVAC	Heating, Ventilation and Air Conditioning System
ONR	Office for Nuclear Regulation
PSA	Probabilistic Safety Assessment
SAPs	Safety Assessment Principles
SSCs	Structures, Systems and Components
TEG	Gaseous Waste Treatment System [GWTS]
UK	United Kingdom of Great Britain and Northern Ireland
UK HPR1000	The UK version of the Hua-long Pressurized Reactor
WENRA	Western European Nuclear Regulators Association

System codes (XXX) and system abbreviations (YYY) are provided for completeness in the format (XXX [YYY]), e.g. Gaseous Waste Treatment System (TEG [GWTS]).

19.2 Introduction

This chapter supports the following high level objective: the design and intended construction and operation of the UK HPR1000 will protect the workers and the public by providing multiple levels of defence to fulfil the fundamental safety functions.

This chapter will demonstrate the following: a design basis internal hazard event will not prevent the delivery of the fundamental safety functions.

Internal hazards are events originating within the nuclear licensed site boundary which have the potential to cause adverse conditions for equipment necessary for fulfilling the three fundamental safety functions defined in Chapter 4 of the PSR:

a) Control of reactivity;

b) Removal of heat from the reactor and from the fuel store;

c) Confinement of radioactive material, shielding against radiation and control of planned radioactive releases, as well as limitation of accidental radioactive releases.

This chapter is structured as follows:

a) Sub-chapter 19.3 explains the identification process for internal hazards in the FCG Unit 3 and the general proposal for UK HPR1000 identification;

b) Sub-chapter 19.4 defines the safety philosophy to be adopted for assessing internal hazards in the UK HPR1000;

c) Sub-chapter 19.5 outlines the methodology to be adopted for assessing internal hazards in the UK HPR1000;

d) Sub-chapter 19.6 presents the design principles for protection against internal hazards, based on the FCG Unit 3, and demonstrates the tolerance of the unit to the hazards;

e) Sub-chapter 19.7 presents the overall conclusion.

19.3 Identification of Internal Hazards

19.3.1 Single Internal Hazard

Internal hazards identification of the FCG Unit 3 was based on the following regulations and standards, and is shown in T-19.3-1:

a) NNSA, Safety Regulations for Design of Nuclear Power Plants, HAF 102, 2004, Reference [1];

b) NNSA, Safety Assessment and Verification for Nuclear Power Plants, HAD 102-17, 2006, Reference [2];

c) IAEA, Safety Requirements: Safety of Nuclear Power Plant: Design, No.SSR-2/1, Revision 01, 2016, Reference [3];

d) IAEA, Safety Guide: Protection against Internal Hazards other than Fires and Explosions in the Design of Nuclear Power Plants, NS-G-1.11, 2004, Reference [4];

e) IAEA, Safety Guide: Protection against Internal Fires and Explosions in the Design of Nuclear Power Plants Safety Guide, NS-G-1.7, 2004, Reference [5].

The following guidance will be considered for the UK HPR1000 GDA to ensure that the UK context will be incorporated in the identification process:

a) ONR, Safety Assessment Principles for Nuclear Facilities, SAPs, 2014, Reference [6];

b) ONR, Nuclear Safety Technical Assessment Guide for Internal Hazards, NS-TAST-GD-014, Revision 4, 2016, Reference [7];

c) WENRA, Safety Reference Levels for Existing Reactors, September 2014, Reference [8].

In addition, a review of the experience feedback from previous GDA projects and UK relevant good practices will be undertaken.

A comprehensive and systematic approach will be used to identify the credible internal hazards in the UK HPR1000 and then a complete internal hazards list considered during GDA process will be given.

19.3.2 Combined Hazards

19.3.2.1 Overview

Combined hazards are defined as a combination of hazards (both internal and external). Combined hazards are required to be considered as part of the hazard assessment to ensure that safety measures implemented for single hazards remain adequate for the effects of combined hazards. This is because the effects of the individual hazard (that constitutes the combined hazards) have the potential to be superimposed with each other’s and as a result, exceeding the limit of the available safety measures.

Combined hazards can be divided into three categories as follows:

a) Consequential hazards

Consequential hazards are defined as the occurrence of a secondary hazard event directly caused by a primary hazard event (e.g. a dropped load hitting a pipe below resulting in a flooding event).

b) Correlated hazards

If a common initiator causing unacceptable consequences of multiple failures of Structures, Systems and Components (SSCs), then the correlated internal hazards might arise. The initiator for consequential internal hazards is local while for correlated internal hazards the root cause is experienced globally in general.

c) Independent hazards

Independent hazards are defined as the simultaneous occurrence of two hazard events which have no causal relationship between them.

19.3.2.2 Methodology

19.3.2.2.1 Consequential Hazards

Each individual internal hazard will be assessed to find out the root causes leading to initiation of other internal hazards. This is to determine whether an internal hazard could be the initiator of other internal hazards. The following methodology for the UK HPR1000 will be adopted, which will ensure a comprehensive and accurate outcome from consequential hazards. The methodology is based on the following steps:

a) Step 1 – Preliminary Assessment

The Preliminary Assessment involves screening of consequential hazards based on the general characteristics/properties of each credible hazards and good engineering judgments. The results of step 1 are shown in T-19.3-2.

T-19.3-2 Assessment of Consequential Internal Hazards

Primary hazards \ Secondary hazards	Internal fire	Internal explosion	Internal flooding	High energy pipe failures	Internal missile	Dropped load
Internal fire	√	√	√	√	√	√
Internal explosion	√	√	√	√	√	√
Internal flooding	√	×	×	×	×	×
High energy pipe failures	√	√	√	√	√	√
Internal missile	√	√	√	√	√	√
Dropped load	√	√	√	√	√	×

Note: At this stage of the GDA, no claim is made on barriers, so it is a very conservative approach to identify consequential hazards. The Table T-19.3-2 may be adjusted according to future Specific Safety Features that will be applied to the design.

b) Step 2 - Detailed Assessment

This assessment involves identification of consequential internal hazards that can be excluded from assessment based on specific plant arrangements, layout and hazard analysis strategy in the UK HPR1000 from the list derived in Step 1. For example, internal explosions are prevented within the safety related buildings, or else the necessary protection measures should be taken to ensure the nonoccurrence. On this basis it is not possible for an explosion to be initiator for consequential internal hazards. The consequential internal hazards shown in T-19.3-2 will be simplified after the step 2.

19.3.2.2.2 Correlated Hazards

In the case of correlated internal hazards, these are likely to be mainly associated with failures of pipes, vessels and tanks containing fluids, such that depending on the fluid type could result in flooding, fire or explosion and depending on the type of containment system could result in missiles, high energy pipe failure. The consequence of correlated internal hazards will be bounded by each individual internal hazard protection measures.

External hazards can be the cause of correlated internal hazards. Each external hazard has been assessed to confirm whether it can be the potential cause of internal hazards.

As all the equipment whose failure could lead to unacceptable consequences are located in the safety-classified buildings that protected from the effects of the external hazards except earthquake, then earthquake is considered as the only common cause of correlated internal hazards.

It is conservatively assumed that all non-seismic equipment fails in the earthquake.

19.3.2.2.3 Independent Hazards

According to the engineer judgement and feedback of previous GDA projects, two independent hazards occurring at the same time would be below the cut-off frequency for explicit assessment within the design. One of the hazards, the internal fire, occurs more frequently than others. The risk of internal fire has been considered within the Probabilistic Safety Assessment (PSA) and the assessment shows that the total risk of fire is acceptable. Based on this, the situation that two independent internal hazards occur simultaneously has been considered incredible. Therefore, there is no need to assess the combinations of independent internal hazards.

19.3.2.3 External-Internal Combined Hazards

It is credible that external hazards could give rise to internal hazards. The types of external hazards relevant to the HPR1000 (FCG3) are defined and described in chapter 18. Further consideration of external-internal combined hazards will be presented in future GDA steps.

T-19.3-1 Identification of Internal Hazards

ID	Type	HAF 102-2004	HAD 102-17	SSR-2/1	NS-G-1.7/NS-G-1.11	HPR1000 (FCG3)	Justification
1	Fire	√	√	√	√	√	Identified as an internal hazard
2	Internal explosion	√	√	√	√	√	Identified as an internal hazard
3	Internal flooding	√	√	√	√	√	Identified as an internal hazard
4	Internal missile	√	√	√	√	√	Identified as an internal hazard
5	Pipe whip	√	√	√	√	√	The effects of pipe whip are considered under high energy pipe failures
6	Jet impact	√	√	√	√	√	The effects of Jet impact are considered under high energy pipe failures
7	Release of fluid	√	---	√	---	---	Internal flooding for water: included in internal flooding
							Fire or internal explosion for oil or flammable liquid: included in fire and internal explosion

ID	Type	HAF 102-2004	HAD 102-17	SSR-2/1	NS-G-1.7/NS-G-1.11	HPR1000 (FCG3)	Justification
8	Collapse of structures and falling objects	---	---	√	√	---	Major structures are covered by the civil structure design (with a low risk of collapse) Falling objects which are non-seismic are covered by the safety evaluation on single failure caused by earthquakes
9	Pipe failure	---	---	---	√	√	Included in high energy pipe failures Included in internal flooding
10	Tanks, pumps and valve failures	---	---	---	---	√	Included in high energy pipe failures, internal missiles, and internal flooding
11	Dropped load	---	√	---	√	√	Identified as an internal hazard
12	Water spray	---	---	---	---	√	Included in internal flooding

19.4 Safety Philosophy

A design basis internal hazard event will not prevent the delivery of the fundamental safety functions. This objective is further explained by the following:

Generally, the effects of a design basis hazard event will be limited to one division.

It should be noted that any exceptions to segregation of hazard, item(s) from different division(s) located in a same hazard influenced scope, will be clearly identified with corresponding arguments developed after Step 2 of the GDA. Examples for areas where exceptions to segregation may possibly exist are in the Main Control Room (safety important signals coming together) and in the Reactor Building (BRX) (e.g. pipes from the three safeguard buildings no longer in separate compartments).

Division is defined as a train of safety systems that is sufficient to deliver the required fundamental safety function.

In the specific case of fire, the design will holistically accommodate both nuclear and conventional fire safety, although where necessary a nuclear safety requirement will take precedent. Further details on the approach for incorporating conventional fire safety in the design are presented in Chapter 25.

19.5 Methodology

19.5.1 Generic Methodology

The generic internal hazard assessment methodology to be used for assessing all types of internal hazards in the UK HPR1000 is shown in the following steps:

a) Identification of internal hazard source

The location and source for internal hazards are identified and captured on a ‘room by room’ basis through generation of multiple ‘living’ databases, one for each hazard. For example, the combustible loading will be quantified (MJ) together with a listing of the main contributing materials, and energized systems (pipes, vessels etc.) and water sources will be recorded.

b) Identification of safety related SSCs

Safety related SSCs along with its safety class and divisions (i.e. trains) are identified and captured.

c) Quantification of load (hazard specific)

The characteristics of the internal hazard design basis events are quantified based on specified parameters if necessary. For example, a fire event is quantified in terms of the temperature-time profile on the hazard barriers, or a pipe whip event is quantified in terms of force. In addition, the initiating event frequency for each internal hazard type will be estimated.

d) Identification of unmitigated consequences

The unmitigated consequences are identified. For most cases, the initial assumption for the unmitigated consequences is loss of all SSCs within a hazard influenced scope. More detailed assessment of unmitigated consequences will only be carried out when necessary.

e) Identification of safety measure

Based on the identified unmitigated consequences according to the outcomes of hazard analysis, suitable and sufficient safety measures (including ‘defence in depth’ safety measures) are identified for an internal hazard event to ensure the mitigated consequences are acceptable. These measures can be adding hazard barriers, changing layout design (if possible), adding restraints, etc.

f) Assessment of an internal hazard (hazard specific)

The effects of an internal hazard on the safety measures (e.g. hazard barriers) are assessed with the aim to ensure that the safety measures will not fail under the internal hazard events. The hazard barriers are designed based on conservative calculation approach for each internal hazard (or credible combination) and a suitable safety margin is applied.

g) Production of a hazard schedule

The internal hazard sequence progression and the associated safety measures are captured via the production of a hazard schedule. This provides a summary of the assessments of all internal hazard events to give the links between hazard identification, safety measures, and where appropriate the bounding Design Basis Accidents defined in the Fault Schedule (Chapter 12).

19.5.2 Steps 3) and 6) of Hazard Specific Methodology

19.5.2.1 Internal Fire

A fire hazard analysis will be carried out in each fire compartment to confirm that the objective defined in sub-chapter 19.4 can be achieved. The analysis will include:

a) Appropriate fire modelling to establish temperature-time profiles for design basis fires established on a conservative approach;

b) Determination of the fire resistance requirements for the hazard barriers, with a suitable safety margin to allow for uncertainties.

19.5.2.2 Internal Flooding/Spray

Internal flooding and spray can occur due to leakage from any pipework containing any fluid. The flooding assessment will provide a conservative assessment of the quantity of water that can be released from a breach of a water containment system (pipe or tank) and the extent of its spread, with assumptions on potential blockages causing a dam. This will establish flood levels and static pressure to the hazard barriers and provide a basis for defining the requirements for the hazard barriers against flooding, including location of any doors or penetrations through the barriers. Appropriate safety margin will be assumed for both flood levels and static pressure. In addition, the damage potential to SSCs from water immersion will be assessed. The spray assessment will include identifying the spray area, evaluating affected SSCs and taking protection measures. The spray assessment can be carried out with the internal flooding assessment.

19.5.2.3 High Energy Pipe Failures

The piping systems are divided into two types according to temperature and pressure of the fluid inside, (1) high energy piping system and (2) medium energy piping system. Failures of both types of piping are considered. Overpressure, water immersion, pipe whip and jet impacts are possible consequences of high energy piping failure. Water immersion impact is assessed in internal flooding/spray hazard presented in sub-chapter 19.5.2.2.

Overpressure may challenge the integrity and function of SSCs. Overpressure analysis includes analysing environmental conditions, identifying the overpressure area and take protection measures.

High energy pipe failures safety analysis will be carried out for each high energy pipe failure location to demonstrate that the consequences of the hazard will not affect the ability to fulfil the fundamental safety functions. The assessment includes analysing the failure possibility of a system, identifying the impacted area by the pipe whip and jet impact, evaluating affected SSCs and finally qualifying the hazard barriers which are relied upon to protect other division of SSCs.

19.5.2.4 Dropped Loads

If dropped load occurs, it may lead to mechanical damage to the equipment or structures located under the lifting area (including the area influenced by the possible tipping over of the dropped load). The safety analysis will demonstrate that the consequences of the dropped loads will not affect the ability to fulfil the fundamental safety functions. The handling devices include:

a) Fuel handling devices are designed and operated to prevent fuel damage. This includes the qualification and integrity of the lifting devices and the use of safe lifting heights and transfer paths;

b) Equipment handling devices must have high-reliability to prevent damage to safety significant SSCs.

19.5.2.5 Internal Missiles

Internal missiles may be generated by failure of component over-speed, failure of high-energy fluid systems or as a consequence of gravitational effects (which will be considered in dropped load effects in sub-chapter 19.5.2.4). The mass of a missile will be considered as well as its velocity, impact area with regard to consequential effects on the target SSCs.

Appropriate missile protection measures are considered in the design according to the internal missile protection design principle described in sub-chapter 19.6. An internal missile safety analysis will be carried out taking into account all safety important SSCs which may be affected by the potential internal missile source. A deterministic or probabilistic approach will be used to demonstrate that either the consequence of internal missile can be ignored because of extremely low probability, or the probability is high but the hazard barriers can accommodate the missile impact with a suitable safety margin.

19.5.2.6 Internal Explosion

The leakage rate of the explosive gas in the room or area will be estimated and the concentration of the gas will be calculated assuming that the gas homogeneously mixes in the atmosphere of the room or area.

The explosion assessment will need to demonstrate that the room or area has adequate protection against the explosion, as based on a combination of local blast walls and the hazard barriers to accommodate the explosion effects with suitable safety margin. The assessment will be performed in accordance with the following principles:

a) The rooms or locations at risk should undergo an analysis of the adequacy of the preventive measures in place;

b) If the risk remains, the consequences of an explosion against the safety functions should be analysed.

19.6 Internal Hazards Safety Measures

This sub-chapter describes the design principles for protection against internal hazards that have already been applied to the FCG Unit 3 to ensure that the objectives defined in sub-chapter 19.4 will be achieved. In GDA Steps 3 and 4, further assessments, based on the above methodology, will be undertaken to confirm the adequacy of the protection design against internal hazards for the UK HPR1000 design.

The following assumption is made for the analysis of the different internal hazards:

- The initial conditions considered are normal operating conditions.

19.6.1 Internal Fire

According to Reference [5], the fire protection design is based on the following objectives:

a) To prevent fires from starting;

b) To detect and extinguish quickly those fires that do start, thus limiting the damage done;

c) To prevent the spread of those fires which have not been extinguished, thus minimizing their effects on SSCs performing essential safety functions.

The principle of 'defence in depth' has been implemented for fire protection design of the FCG Unit 3, including three levels: fire prevention, fire containing and fire control.

a) Fire prevention

Fire prevention is based on a complete set of precautionary measures to prevent the occurrence of fire or decrease the possibility of occurrence. These measures include selection of non-combustible or fire-retardant materials, including fire retardant cables and fire resistant cable trays/conduits, and control of ignition sources, such as electrical equipment designed to applicable standards.

b) Fire containing

Limiting the spread of a fire is achieved by dividing the buildings into fire compartments or fire cells. Redundant SSCs important to safety are located in separate fire compartments as the fire containment approach. In some areas, fire compartments cannot be utilized to separate items important to safety, protection can be provided by locating the items in separate fire cells as the fire influence approach.

In the case of hazard barriers, there may be a need to incorporate penetrations in the barrier structure, such as doors (to provide emergency escape), services or Heating, Ventilation and Air Conditioning System (HVAC). The number of such features will be minimized and their design will be such that the overall hazard requirement will be maintained, i.e. they will not result in a weakness when the hazard barriers are challenged by a design basis fire and the loads generated from other internal hazards.

c) Fire control

Detection and fire-fighting systems are installed to detect and fight the fire and get it under control as quickly as possible. In addition, there are features such as collection bunds for the control of flammable fluids.

The assumptions are expected to be used in the fire hazard analysis are as follows:

a) Fire is normally assumed to occur in any room which contains combustible materials and ignition sources;

b) Coincidental occurrence of two or more fires, from independent causes, affecting rooms in the same or different plant is not taken into consideration.

19.6.2 Internal Flooding/Spray

To ensure the principle of 'defence in depth', various measures have been carried out such as using the appropriate design standards, division design of piping fluid systems and building layout, selection of materials and equipment, quality control during manufacture administrative controls, monitoring systems and drainage design. Generally, the effects on the redundant SSCs that perform the fundamental safety functions are limited to one division (i.e. train) from internal flooding/spray by hazard barriers that are designed to accommodate design basis internal flooding. If not, a detailed functional analysis will be performed to demonstrate that the consequences of the hazard remain acceptable. This analysis may lead to the implementation of additional safety measures or mitigations.

19.6.3 High Energy Pipe Failures

To ensure the principle of 'defence in depth', various measures have been carried out such as using the appropriate design standards, specification of materials and equipment, carrying out strictly quality assurance requirements, quality control inspection during manufacture and operation and maintenance provisions. Meanwhile, as a general requirement, pipe layout design has arranged pipework so as to limit the effects of pipe whip or jet impingement by keeping safety classified SSCs beyond the area of influence (spatial separation) or by provision of internal partitions within a room that serve to protect SSCs from the high energy pipe failures effects. Generally, the effects of high energy pipe failures on the redundant SSCs that perform the fundamental safety functions are limited to one division (i.e. train) by the hazard barriers designed to accommodate a design basis high energy pipe failures impact. If not, a detailed functional analysis will be performed to demonstrate that the consequences of the hazard remain acceptable. This analysis may lead to the implementation of additional safety measures or mitigations. In addition the FCG Unit 3 design provides additional protection such as restraints.

19.6.4 Dropped Load

The principle of 'defence in depth' has been implemented for dropped load protection design, such as equipment design and qualification, operating procedures and load routes. Generally, the effects of dropped load on the redundant SSCs that perform the fundamental safety functions are limited to one division (i.e. train) by the hazard barriers that are designed to accommodate a design basis dropped load. If not, a detailed functional analysis will be performed to demonstrate that the consequences of the hazard remain acceptable. This analysis may lead to the implementation of additional safety measures or mitigations.

19.6.5 Internal Missile

To ensure the principle of 'defence in depth', various measures have been carried out such as using the appropriate design standards, specification of materials and equipment, carrying out strictly quality assurance requirements, quality control inspection during manufacture, operation and maintenance provisions.

In addition, the probability of internally generated missiles is reduced by the consistent application of safety oriented design and engineering principles.

Generally, the effects of internal missile on the redundant SSCs that perform the fundamental safety functions are limited to one division (i.e. train) by the hazard barriers that are designed to accommodate a design basis internal missile. If not, a detailed functional analysis will be performed to demonstrate that the consequences of the hazard remain acceptable. This analysis may lead to the implementation of additional safety measures or mitigations.

19.6.6 Internal Explosion

The principle of ‘defence in depth’ for internal explosion protection design has been implemented, based on three levels: explosion prevention, explosion gas detection and explosion consequences analysis.

a) Explosion prevention

1) Piping, valves and vessels containing high energy fluid or flammable gases are potential initiators for internal explosion. The design of such items is based on appropriate design codes and standards, specification of materials and equipment, testing and quality control inspection during manufacture and operation and maintenance provision. Any removable features are securely fixed in place.

2) Hydrogen and oxygen gas are generated in the plant. The Gaseous Waste Treatment System (TEG [GWTS]) ensures that the hydrogen and oxygen concentrations remain below their respective flammability limits of 4% and 2%. This is achieved by recirculating nitrogen gas through tanks in systems where hydrogen and oxygen may accumulate, e.g. those connected to the reactor coolant circuit (hydrogen is injected into the coolant water to limit radiolytic oxygen). In addition the system includes a recombiner which will remove hydrogen and oxygen.

3) Hydrogen gas can potentially build up in the emergency battery rooms. To avoid it, adequate ventilation and atmospheric monitoring will ensure that the risk associated with potential build-up of hydrogen gas in the emergency battery room is minimised. The emergency battery room is appropriately ventilated and the atmosphere is monitored.

4) There are restrictions on the use of explosive gases or pressurized containers in the safety classified buildings.

5) Hazardous area classification provides the means to identify areas where there is the potential for explosive gas to be present.

b) Explosion gas detection

In the FCG Unit 3, an online detection system for hydrogen and oxygen is installed in rooms where it has been identified there is an explosion risk and the reliability of the detection system must be ensured.

c) Explosion consequences analysis

Generally, the effects of explosion on the redundant SSCs that perform the fundamental safety functions are limited to one division (i.e. train) by the hazard barriers that are designed to accommodate a design basis internal explosion (pressure blast wave and possibly missile fragments). If not, a detailed functional analysis will be performed to demonstrate that the consequences of the hazard remain acceptable. This analysis may lead to the implementation of additional safety measures or mitigations.

19.7 Conclusion

The protection design and safety analysis for the FCG Unit 3 have shown that the internal hazards do not compromise the fundamental safety functions. This is ensured primarily by incorporating the robust hazard barriers, such that generally only one division of safety systems that deliver the fundamental safety functions will be potentially lost and the redundant systems (i.e. other divisions) will remain fully available. The hazard barriers are designed to accommodate the loads from any individual (or credible combination) design basis hazard. The design is based on conservative calculation approach. This will ensure that any abnormal (beyond design basis) load is unlikely to result in a cliff edge effect. In addition, 'defence in depth' measures that will prevent, detect or restrict the effects of each hazard type have been incorporated in the design.

However, some gaps between HPR1000 (FCG3) and UK requirements, which are UK context related, have been identified, such as:

a) A hazard schedule is required by Safety Assessment Principles (SAPs) and no comprehensive analysis and study is conducted in HPR1000 (FCG3). This has been identified as a gap and will be studied during GDA stage.

b) Hazard cliff-edge effects analysis is required by SAPs but no comprehensive analysis and study on cliff-edge effects of internal and external hazards is performed in HPR1000 (FCG3). This has been identified as a gap and will be studied during GDA stages.

c) This identification of the hazards list of HPR1000 (FCG3) has not taken into consideration of UK requirements (the toxic and corrosive materiel release, vehicular impact and electromagnetic interference, e.g.). This has been identified as a gap and will be studied during GDA stages. A comprehensive and systematic approach will be used to identify the credible internal hazards in the UK HPR1000 and then a complete internal hazards list considered during GDA process will be given.

More gaps may be identified during GDA stages and will be properly and carefully studied and treated. These gaps will be closed through GDA process.

In GDA Steps 3 and 4, further analysis will be performed to confirm that the fundamental safety functions for the UK HPR1000 will be available during design basis internal hazard events.

19.8 References

[1] NNSA, Safety Regulations for Design of Nuclear Power Plants, HAF 102, 2004.

[2] NNSA, Safety Assessment and Verification for Nuclear Power Plants, HAD 102/17, 2006.

[3] IAEA, Safety Requirements: Safety of Nuclear Power Plant: Design, No.SSR-2/1, Revision 01, 2016.

[4] IAEA, Safety Guide: Protection against Internal Hazards other than Fires and Explosions in the Design of Nuclear Power Plants, NS-G-1.11, 2004.

[5] IAEA, Safety Guide: Protection against Internal Fires and Explosions in the Design of Nuclear Power Plants Safety Guide, NS-G-1.7, 2004.

[6] ONR, Safety Assessment Principles for Nuclear Facilities, Revision 0, November 2014.

[7] ONR, Nuclear Safety Technical Assessment Guide, Internal Hazards, NS-TAST-GD-014, Revision 4, September 2016.

[8] WENRA, Safety Reference Levels for Existing Reactors, September 2014.