FANC

FEDERAL AGENCY FOR NUCLEAR CONTROL

# ENSREG TOPICAL PEER REVIEW II

## FIRE PROTECTION

Belgian National Assessment Report

October 2023

## Contents

# 0. Preamble / Foreword

## 0.1. Context

In 2014, the European Union (EU) Council adopted directive 2014/87/EURATOM [1] amending the 2009 Nuclear Safety Directive (NSD) to incorporate lessons learned following the accident at the Fukushima Daiichi nuclear power plant in 2011. Recognising the importance of peer review in delivering continuous improvement to nuclear safety, the revised Nuclear Safety Directive introduces a European system of topical peer review, which commenced in 2017 and will be repeated every six years thereafter. The purpose is to provide a mechanism for EU Member States to examine topics of importance to nuclear safety, to exchange experience and to identify opportunities to strengthen nuclear safety.

The first topical peer review took place from 2017 to 2018 and its topic was ageing management. In November 2020, at its 41st Plenary Meeting, ENSREG[1] decided that the topic of the second Topical Peer Review (TPR II) would be "Fire Protection". This topical peer review on fire protection will:

- Enable participating countries to review their provisions for fire protection to identify strengths and weaknesses;
- Undertake a European peer review to share operating experience and identify findings: common issues or challenges at EU-level, good practices, areas of good performance and areas for improvement;
- Provide an open and transparent framework for participating countries to develop appropriate follow-up measures to address areas for improvement.

## 0.2. Scope

### 0.2.1. Topic

Fire is a risk that is relevant for most if not all nuclear installations. Combustible materials may be present in many locations in the installation and a fire may be capable of affecting multiple structures, systems and components important to safety. Fire can also affect signaling and power supply of multiple systems and is hence potentially capable to cause common cause failures. In addition, a fire could involve radioactive materials and thus lead to their release and dispersion. Fire may also be caused by or result in other hazards or events.

For these reasons, fire protection, broadly including fire safety analysis, fire prevention, active and passive fire protection, is a relevant topic that needs to be considered for every nuclear installation.

### 0.2.2. Installations

It was decided by ENSREG that TPR II should consider all installations under the NSD [1] for the selection of installations to be covered in the National Assessment Reports (NAR):

- nuclear power plants (NPPs),
- research reactors (RRs)[2]
- spent fuel storage facilities,

[1] EU topical peer reviews | ENSREG

[2] In line with the scope of the SRL for existing research reactors published in 2020, all research reactors independent of their type and thermal power with the exception of the critical, sub-critical assemblies, homogeneous zero-power reactors and accelerator driven systems are covered by the term "research reactor"

- enrichment plants,
- nuclear fuel fabrication plants,
- reprocessing plants,
- storage facilities for radioactive waste that are on the same site and are directly related to the types of nuclear installations listed above.

TPR II should cover installations under construction, under operation and under decommissioning. More precisely, the scope should include all nuclear installations that on 30th June 2022:

- are operating or in an outage or shutdown (temporarily or permanently),
- are defueled or in the process of being decommissioned,
- are under safe enclosure, excepting those from which all non-fixed radioactivity had been removed.

## 0.3. Process and TPR II phases

The following phases are carried out sequentially and in accordance with the EU Directive:

- Preparation (2020-2022);
- National self-assessment (2022-2023);
- Peer review (2023-2024);
- Follow-up (2025-).

### 0.3.1. Preparation

During the preparation phase, amongst others, the topic of TPR II was selected and the "Terms of Reference for the Topical Peer Review Process on Fire Protection" [2] as well as the "Fire Protection Technical Specification for the National Assessment Reports" (NAR) [3] were drafted and approved.

The Terms of Reference for the TPR on Fire Protection [2] developed and issued by ENSREG, describes the overarching process in particular the preparation phase, self-assessment, peer review and follow-up. For each phase, a timing is provided as well as a description of deliverables, roles and responsibilities.

On request of ENSREG, the WENRA Ad-hoc TPR II Working Group drafted the Technical Specification for the National Assessment Reports for TPR II [3]. This Technical Specification defines the structure and contents of the National Assessment Reports (NARs) to facilitate an effective peer review and form the basis of the Licensees Assessment Reports. The reference framework defined in the Technical Specification are the relevant WENRA Safety Reference Levels for respectively Nuclear Power Plants [4], Research Reactors [5], waste and spent fuel storage [6] and decommissioning [7].

In addition, as described in the Terms of Reference, during the preparation phase also a selection of the installations to be reported on in the National Assessment Reports, was made by the national competent authorities of each country. That selection had to be based on criteria related to the presence of potential significant radiological risks in case of fire, the representativeness for the various types of installations and technologies in the country, and similarities with other installations regarding the fire-safety concept. In particular, the selection had to include at least one facility of each category addressed by the NSD. The list of installations selected by the Belgian regulatory body together with the rationale for the selection were subsequently reviewed by the team leaders within the TPR Board, set-up in 2020 to supervise the topical peer review process, and reported to ENSREG.

### 0.3.2. Self-assessment

During the self-assessment phase, the Belgian licensees of the selected TPR II installations were each asked to draft and submit an assessment report consistent with the TPR II Technical Specification. The licensee assessment reports were subsequently reviewed by the regulatory body (FANC and Bel V, see §1.2.1.1 for details). The licensee assessment reports and the review by the regulatory body are summarized in this National Assessment Report, which concludes the self-assessment phase.

### 0.3.3. Peer review

During the peer review phase, the National Assessment Reports will be examined by experts from other countries to share operating experience and to identify good practices, common issues and potential follow-up actions.

### 0.3.4. Follow up

Both the national review and the peer review will lead to an action plan, the progress of which will be followed-up in the TPR II final phase.

# 1. General Information

## 1.1. Nuclear installations identification

### 1.1.1. Qualifying nuclear installations

The following areas in Belgium are of relevance for TPR II as they host sites with nuclear installations that in the scope of the European directive NSD 2009 [1]:

- Site of Doel which hosts 4 nuclear power plants (KCD 1 to 4) and 2 installations for the temporary storage of spent nuclear fuel (SCG and SF2 KCD) that are all operated by the licensee Electrabel.
- Site of Tihange which hosts 3 NPPs (CNT 1 to 3) and 2 installations for the temporary storage of spent nuclear fuel (DE and SF2 CNT) that are all operated by the licensee Electrabel.
- Area of Mol-Dessel[3] with a site in Mol hosting a research centre with 4 research reactors (RRs) (BR1 to 3 and VENUS/Guinevere) operated by the licensee SCK CEN and a site in Dessel for centralized waste storage that hosts 1 installation for the temporary storage of spent nuclear fuel operated by the licensee Belgoprocess.

More details on these sites and installations will be provided in the section 1.1.3.

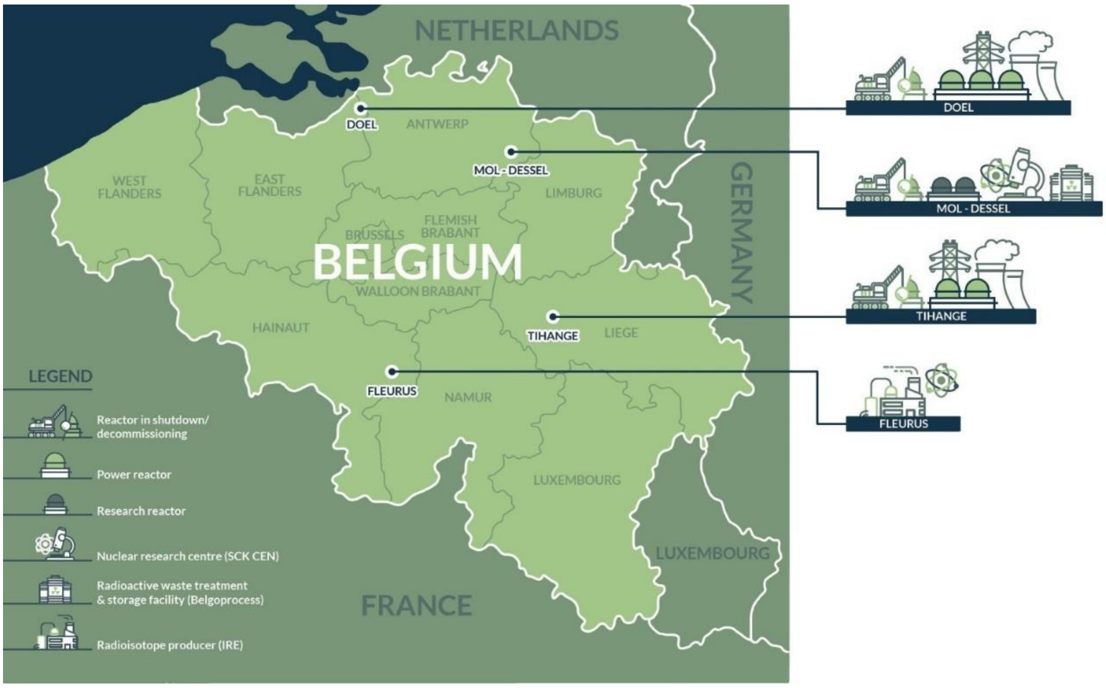


*Figure 1. Nuclear sites in Belgium. Site located in Doel, Mol-Dessel and Tihange host installations that fall under the scope of the Nuclear Safety Directive and are treated in this National Assessment Report.*

[3] In the Mol-Dessel area, two nuclear fuel production facilities, Belgonucleaire and Franco-Belge de Fabrication de Combustibles, were dismantled and released from regulatory control in 2019 and 2022 respectively.

#### 1.1.2. National selection of installation for TPR II and justification

The following installations, all located in the area of Mol-Dessel, were excluded from TPR II:

- The installation for centralized waste storage of Belgoprocess in Dessel, that is used for the temporary dry storage of spent fuel because of the very limited quantities of the BR3 SNF, which represents no significant radiological risk in the context of TPR II.
- The BR3 research reactor as this installation is in an advanced state of decommissioning with all fuel and major source terms removed; only some activated concrete is left, which represents no significant radiological risk in the context of TPR II.
- The VENUS/Guinevere research reactor because this is a zero-power assembly.

Waste storage facilities at any of the sites considered, were also excluded because of the low radiological risk. They are also subject to requirements and regulations that are the same as for other installations on site that pose a higher risk and which are considered explicitly in this report.

The following installations were finally selected and this selection was confirmed by ENSREG TPR II board:

*Table 1: Candidate and represented nuclear installations*

| Candidate | Type | Site location | Status | Represented installations |
|---|---|---|---|---|
| CNT3 | NPP | Tihange | operation | All other operating NPPs (CNT1 and 2<br>KCD 1,2 and 4)<br>DE Tihange (wet SNF storage) |
| KCD3 | NPP | Doel | decommissioning | (and CNT2 which went into decommissioning in February 2023) |
| BR2 | RR | Mol | operation | BR1 |
| SCG | SFSF | Doel | operation | Doel SF2, Tihange SF2 |

In addition, it is noted that:

- Site specific differences between Doel and Tihange will be highlighted when they are not treated for resp. CNT3 or KCD3.
- Differences between the represented NPPs and the candidate NPPs will be highlighted when relevant. This is specifically the case for KCD1/KCD2.
- The DE building for the wet storage of spent fuel was operated under the license of CNT3 until the end of May 2022 when it was moved under a separate license in anticipation of the decommissioning of CNT3[4]). A project has been initiated to arrange for the technical separation of both installations. In the current state however, no relevant changes have been made organisationally or structurally and for all practical purposes of this TPR II, the current situation is the same as before the administrative change. Therefore the DE installation is considered to be represented by CNT3 and will only be specifically treated when relevant as part of the section on NPPs.
- The BR1 is considered to be represented by the BR2. However, the BR1 does feature a graphite matrix which is subject to specific fire risks and measures. These are discussed separately in appendix 1 of this report.

- Both SF2 facilities are under construction and not all details related to fire protection are already available. SCG is therefore considered to be the more useful candidate installation. Differences between SCG and the SF2 spent fuel storage facilities at Doel and Tihange will be highlighted when relevant as part of the reporting on SCG.
- CNT2 was definitely shut down in February 2023 after the time of the TPR II selection (i.e. 30 June 2022), so in its current state, CNT2 should be considered to be represented by KCD3.

### 1.1.3. Key parameters per installation

#### *1.1.3.1. NPP in operation: CNT3*

The Doel and Tihange NPPs are all PWR types and are operated by Electrabel, a member of the ENGIE group. Table 2 and Table 3 show the main characteristics of the 7 Belgian NPPs.

*Table 2 : Main characteristics of the units located at the Doel Site*

| Licensee | Units | Type | Thermal power (MWth) | Date of first criticality | Scheduled shutdown | Designer |
|---|---|---|---|---|---|---|
| ENGIE Electrabel | Doel 1 /KCD1 | PWR (2 loops) | 1 312 | 1974 | 2025 | Westinghouse |
| ENGIE Electrabel | Doel 2 /KCD2 | PWR (2 loops) | 1 312 | 1975 | 2025 | Westinghouse |
| **ENGIE Electrabel** | **Doel 3 /KCD3** | **PWR (3 loops)** | **3 064** | **1982** | **Permanent shutdown in 2022** | **Framatome** |
| ENGIE Electrabel | Doel 4 /KCD4 | PWR (3 loops) | 3 000 | 1985 | n.a.[4] | Westinghouse |

*Table 3: Main characteristics of the units located at the Tihange Site*

| Licensee | Units | Type | Thermal power (MWth) | Date of first criticality | Scheduled shutdown | Designer |
|---|---|---|---|---|---|---|
| ENGIE Electrabel | Tihange 1 /CNT1 | PWR (3 loops) | 2 873 | 1975 | 2025 | Framatome / Westinghouse |
| ENGIE Electrabel | Tihange 2 /CNT2 | PWR (3 loops) | 3 054 | 1982 | Permanent shutdown in 2023 | Framatome |
| **ENGIE Electrabel** | **Tihange 3 /CNT3** | **PWR (3 loops)** | **2 988** | **1985** | **n.a.[4]** | **Westinghouse** |

[4] An agreement between the government and the licensee on 29 June 2023 confirmed that, in principle, the operation of KCD4 and CNT3 will continue beyond 2025 (expected to continue until 2036 but this has not been formally confirmed).

#### *1.1.3.2. Nuclear reactor after shutdown: KCD3*

KCD3 was shut down in 2022 and has entered a post-operational phase (POP) in which it will remain for several years until a dismantling licensee has been granted (based on the current planning, this is not foreseen before 2026). In the current post-operational phase the regulatory framework that applies to KCD3 is the same as for an operating NPP.

In the post-operation phase several activities are carried out to reduce the nuclear and radiological risks where possible and to prepare for dismantling. This phase is divided in the following sub-phases:

- POP-1: unloading of SNF from the reactor for temporary storage in the spent fuel pools. This phase has been completed.
- POP-2: chemical decontamination of the reactor cooling system. This phase has been completed.
- POP-3: removal of SNF and waste from the spent fuel pools. Beginning of the reduction of the nuclear island[5]. This phase has started and lasts for an estimated 4 to 5 years.
- POP-4: Preparation for dismantling: cleaning of spent fuel pools, removal of filters and resins, removal of waste, etc. . This phase lasts for about 4 months.
- POP-5: preparing storage areas and awaiting dismantling authorization.

This report will mostly focus on the POP-3 phase as this is the longest and because the state of the installation is less similar to the operational state than the POP-1 and POP-2 phases which have been completed already. In addition, POP-3 also represents a higher radiological risk than the POP-4 and POP-5 phases (although obviously already significantly reduced when compared to the operational period).

Due to the similarities between CNT3 and KCD3 in the applicable regulatory framework and their approach for fire protection this NAR will present and discuss both KCD3 and CNT3 in the sections dedicated to NPPs and not in a separate section on “facilities under decommissioning” to avoid unnecessary duplication.

#### *1.1.3.3. Research reactors*

Four research reactors and assemblies at the Mol site are present at the Belgian Nuclear Research Centre SCK CEN that is located in the Belgian municipality of Mol:

*Table 4: Main characteristics of Belgian research reactors (more details are provided below)*

| Licensee | Units | Type | Thermal power (MWth) | Date of first criticality | (Scheduled) shutdown |
|---|---|---|---|---|---|
| SCK CEN | BR1 | Graphite moderated | 1 (4) | 1956 | n.a. |
| **SCK CEN** | **BR2** | **Material test reactor** | **< 125** | **1961** | **n.a.** |
| SCK CEN | BR3 | prototype PWR | n.a. (11) | 1962 | 1987 |
| SCK CEN | VENUS/ Guinevere | zero-power assembly | ≈0 | 1964 | n.a. |

[5] During the post-operational phase the risks will be reduced in function of progress. As a consequence, more and more systems will no longer have a safety function. The ensemble of SSCs that still has a safety function is called the nuclear island.

The **BR2 reactor** is a heterogeneous thermal high flux material test reactor, designed in 1957 for SCK CEN by Nuclear Development Corporation of America. It was built on the SCK CEN site and operation of the reactor started in January 1963. In 2016 the Beryllium matrix was replaced and the installation was refurbished; simultaneously the latest periodic safety review (PSR) was concluded. The next PSR is due for 2026.

The reactor is cooled and moderated by pressurised light water in a compact core of highly enriched uranium positioned in and reflected by a beryllium matrix. The maximum cooling capacity is 125 MWth, and the primary loop operates at 12 bar pressure and at temperatures below 50°C. Heat is evacuated via the secondary loop to cooling towers.

The fuel is made up of highly enriched uranium (HEU), in the form of aluminide dispersed in plates. Under international agreements, SCK CEN is committed to develop and validate a suitable low enriched uranium (LEU) fuel to be used as standard fuel for the BR2 reactor. To this end, a LEU fuel qualification program is underway and is currently in its final phase with the irradiation of 3 prototype LEU elements using silicide dispersion.

The reactor vessel is located in an open pool. This allows for additional irradiation facilities in the pool, in the vicinity of the reactor vessel. Pool side facilities for silicon doping and isotope production are available. The reactor pool serves as biological shielding for the reactor and irradiated materials, as well as an alternative ultimate heat sink in shutdown conditions. Spent fuel is stored in a channel-type pool outside the main containment building which is an integral part of the installation and hence of this TPR II assessment.

The residual heat of the reactor can be evacuated to the pool by natural convection immediately after shutdown. The valves facilitating this cooling mode in case of loss of flow and/or loss of pressure, are driven by a hydraulic battery located inside the reactor building, without the need for an external power source.

The reactor is housed in a cylindrical steel containment building which offers ample floor space for various experimental equipment. The containment building is kept in under-pressure by a dynamic ventilation system but can be sealed and is resistant to 1 bar overpressure. Two control rooms are present: one in the reactor building mostly focused on the core and activities in and around the core including experiments, and a second in the machine hall that oversees the cooling circuits.

**BR1** is a research reactor with natural uranium metal as fuel, graphite as moderator, and is cooled by forced circulation of air, which is released through a chimney after passing through the reactor. The BR1 is comparable to the ORNL X-10 (USA) and BEPO (Harwell, UK) reactors. The reactor is air cooled and went critical for the first time in 1956; its design thermal power is 4 MWth. However, since the start of operation of the BR2, the power level of 4 MWth was no longer needed, and since 1965 BR1 is operated at a maximum thermal power of 1 MWth, using only the auxiliary ventilation system. The core is composed of a pile of graphite blocks. The fuel is metallic natural uranium with an aluminium cladding.
The BR1 reactor is mainly used for calibration of instrumentation, neutron activation purposes, production of tracers and training of nuclear engineers.

Both BR1 and BR2 research reactors have storage spaces for (spent) fuel that are an integral part of the installation and which are not considered as a separate installation under spent fuel storage facilities.

As indicated, aspects specific to BR1, in particular those related to the graphite matrix and associated fire risk and measures, will be examined separately in this national report in appendix 1.

**BR3** was a PWR prototype research reactor. It was shut down in 1987 and is currently in the final stages of dismantling: all fuel and significant sources of radioactivity having been removed from the installation. What currently remains in the installation is a very limited amount of activated concrete and radioactive waste. Consequently, the BR3 is not considered in TPR II.

**VENUS/Guinevere** is a zero-power assembly which is currently operated in a subcritical source drive configuration to study the neutronics of lead cooled fast reactor systems. The VENUS installation is out of scope of TPR II.

#### *1.1.3.4. Spent fuel storage facilities*

Both NPP sites host four facilities dedicated to the temporary storage of spent nuclear fuel:

*Table 5. Main characteristics of spent fuel storage facilities*

| Licensee | Name | Type | Site | Start of operartion |
|---|---|---|---|---|
| **ENGIE Electrabel** | **SCG** | **Dry – dual purpose casks** | **Doel** | **1994** |
| ENGIE Electrabel | SF2 | Dry – dual purpose casks | Doel | Expected 2025 |
| ENGIE Electrabel | SF2 | Dry – dual purpose casks | Tihange | Expected 2024 |
| ENGIE Electrabel | DE | Wet | Tihange | 1997 |

The construction of the **SCG** spent fuel (dry) storage facility on site in Doel started in 1994, and the first container from Doel 3 was stored in the building in November 1995. The building is designed for intermediate storage of spent fuel. In a first phase, a storage area was provided for a total of 53 nuclear fuel containers (56 places, 3 of which must be kept free to allow permutations of containers); in a second phase, the building was extended with an additional storage area for 112 nuclear fuel containers.

Spent nuclear fuel stored in SCG is loaded into dual purpose casks at the NPPs. Since the fuel elements in the different NPPs are of different lengths, different types of casks are required for each type. These casks ensure most safety functions, including the protection against fire. The storage building itself contributes to heat removal through natural ventilation, the reduction of radiation levels and protection against external hazards.

The **SF2** installations at the sites of Doel and Tihange are conceptually similar to the SCG building and both are under construction. Operation is currently expected to start in 2024 for SF2 Tihange and in 2025 for SF2 Doel.

In Tihange, spent nuclear fuel is currently stored in the **DE** building in pools. When SF2 Tihange is operational, part of the spent fuel will be transferred from the DE building.

All spent fuel storage facilities are considered to remain operational for many decades; during this period these facilities are subject to 10 yearly periodic safety reviews.

As already explained, an installation for centralized waste storage of Belgoprocess in Dessel is used for the temporary storage of spent fuel from the BR3. This installation is not considered further in this TPR II due to its very low radiological risk.

#### 1.1.4. Approach to development of the NAR for the national selection

In order to meet the requirements of the TPR II Technical Specification, the Belgian Federal Agency for Nuclear Control, FANC, involved the relevant licensees in the process of drawing up the National Assessment Report.

In Belgium, licensees have the prime responsibility for nuclear safety. FANC therefore asked licensees to perform a self-assessment of their fire protection program on the basis of the specifications of the Topical Peer Review process. More specifically, licensees were asked to provide a Licensee Assessment Report following the structure and contents recommended in the specifications for the NAR [3].

In the framework of the TPR II process, FANC has requested Bel V, its subsidiary, to assess the specific reports provided by the licensees, and to verify that the information provided by the licensees is adequate. This includes an assessment of the appropriateness of the proposed action plan to address potential areas of improvement.

On the basis of the self-assessment and the reports prepared by the licensees and the Bel V assessments, FANC issued this National Assessment Report.

### 1.2. National regulatory framework

#### 1.2.1. National regulatory requirements and standards

##### *1.2.1.1. Belgian national regulatory framework for nuclear safety and radiation protection*

***Oversight***

The Belgian law of 15 April 1994 [8] created FANC as a public regulatory body in charge of enforcing the application of this law and its associated Royal Decrees. This law also allows FANC to create and call upon legal entities to assist the FANC in the execution of its missions.

FANC created Bel V in September 2007 as a FANC subsidiary, which is mandated to perform regulatory missions that may be legally delegated by FANC, a.o. on-site routine inspections or the review and assessment of safety files provided by licensees. Together FANC and Bel V form the regulatory body and both carry out inspections which are either reactive (e.g. following a notification) or planned based on a multi-annual and annual inspection program.
Bel V carries out systematic and thematic inspections. Systematic inspections are performance-oriented and focus on the practical implementation of regulatory requirements in the installations; within the scope of this NAR, this includes inspections on the management of fire loads (housekeeping), maintenance of equipment, respect of procedures such as the hot-work permit, and verification of the execution of modifications that could have any impact on the fire safety. Thematic inspections are process-oriented and entail an in-depth review of a specific topic, such as the general fire protection strategy to the development or the dedicated

procedures related to fire safety. A graded approach is applied to the frequency of these thematic inspections: for NPPs every 24 months and for the research reactors every 36 months.

Each licensee of a "Class I"[6] nuclear installation is required to have an independent "health physics department" (HPD) in its organization. This department is part of an internal service for prevention and protection at work (ISPPW) and its head reports directly to the director general. The HPD employs Radiation Protection Officers (RPO), and recognized Health Physics Experts who corresponds to a RPE (Radiation Protection Experts) as defined in the European Directive 2013/59/EURATOM.
The ISPPW/HPD is in charge of supervising the activities and organizing measures under the licensee's responsibility to ensure the protection of the population, the workers and the environment against the hazards of ionizing radiations. The Belgian legislation assigns specific tasks to the HPD which includes tasks relevant for TPR II. For example, the HPD is responsible for the assessment of risk analyses and their subsequent approval. The regulatory body oversees the adequate functioning of the HPD.
Licensees are required to notify the regulatory body of events on the basis of pre-defined declaration criteria. Such events are for instance the non-respect of operating limits and conditions, unavailability of safety systems or the presence of external emergency services on-site. In reaction to such notifications, the regulatory body may carry out a reactive inspection or require specific measures. Depending on the event, also an incident analysis has to be provided by the licensee, which feeds the operating experience feedback process and allows for the identification of potential recurring patterns and tendencies.

A comprehensive overview of the Belgian regulatory framework and oversight is provided in the national report for the Convention on Nuclear Safety [46].

### *WENRA Safety Reference levels*

Within the Belgian national regulatory framework for nuclear safety and radiation protection, the Royal Decree of 30/11/2011 with Safety Requirements for Nuclear Installations (SRNI-2011) [9] transposes the WENRA Safety Reference Levels, including those related to fire prevention and protection. This Royal Decree consists of several sections: the generic section of SRNI-2011 applies to all Class I facilities, which includes nuclear power plants, research reactors and spent fuel storage facilities. Specific chapters of SRNI-2011 for NPPs and for installations for the storage of radioactive waste and spent fuel apply only to those specific types of installations.

SRNI-2011 is amended and modified as needed when WENRA Safety Reference Levels are issued or modified, such as the WENRA 2020 SRLs for NPPs [4] (ongoing). In July 2023, a new chapter of SRNI-2011 was introduced specifically for research reactors which transposes the WENRA Safety Reference Levels for research reactors [5] and which becomes in force in July 2024.

The implementation of WENRA Safety Reference Levels in the national regulatory frameworks is subject to a self-assessment and peer review within the context of the dedicated WENRA working groups.

Regulatory requirements include requirements related to (near-)incident reporting and analysis, experience feedback gathering and exchange, testing and maintenance, as well as periodic safety reviews.

[6] Class I installations as defined in the Belgian regulatory framework includes all installations that fall under the NSD [1].

### *Fire protection*

Article 17 of SRNI-2011 applicable to all Class I installations states, amongst others, the requirements related to defence in depth as related to fire safety:

*"**Article 17 Protection against internal fires***

***17.1 Internal fire protection strategy***
*An up-to-date fire protection strategy shall be developed and be subject to a training program, for each location where a fire can affect components important to safety, or where radioactive materials are present.*

***17.2. Design basis principles***
*The structures, systems and components important to nuclear safety shall be designed and installed so as to mitigate the probability and effects of fires.*
*The structures, systems and components important to nuclear safety shall be housed in buildings with an appropriate fire resistance and which are subdivided into compartments, as justified by the fire hazard analysis.*

*Buildings housing equipment important to nuclear safety shall be subdivided into compartments which shall separate the calorific loads of the equipment and isolate the redundant systems from one another. When a compartment-based approach is not possible, protection shall be ensured through a combination of active and passive protection means, which shall be justified by the fire hazard analysis.*

*Concerning the buildings containing radioactive materials which may be released in the event of fire, appropriate measures shall be taken at the design stage in aim of mitigating these possible releases. Safe access and evacuation routes shall be provided for the emergency response and operating personnel.*

***17.3. Fire hazard analysis***
*A deterministic fire hazard analysis shall be carried out for each installation in order to show that:*

- *The fire protection objectives have been achieved according to the above-mentioned principles.*
- *The fire protection systems have been designed in an appropriate manner.*
- *All the necessary administrative provisions have been identified correctly.*

*The fire hazard analysis shall be updated throughout the service life of the installation.*

*The deterministic fire hazard analysis shall cover the following scenarios as a minimum:*

- *for the operational conditions and normal shutdown conditions of the facility, fire outbreak and propagation to all the locations where combustible materials are stored temporarily or permanently.*
- *the consideration of credible combinations of a fire and other initiating events.*

*The fire hazard analysis shall demonstrate how the possible consequences of a fire and of the operation of the fire extinguishing equipment have been taken into account.*

***17.4. Fire protection systems***
*Each compartment shall be equipped with appropriate fire detection and alarm systems. The fire detection system shall report the alarm to the personnel in the control room with audible and visual signals. It shall be capable of indicating the accurate location (inside the compartment or the fire area) of the event. The fire detection and alarm systems shall be backed up by uninterruptible power supplies so that they can maintain their functionality if the normal power supply is lost. They shall be equipped with electric cables with appropriate fire resistance.*

*Stationary and/or mobile, manual and/or automatic fire extinguishing systems shall be installed. They shall be designed and installed such that their operation in the event of real fire, as well as their spurious* *operation, inadvertent start-up or failure does not prevent the structures, systems and components from completing their safety functions.*

*The ventilation systems shall be designed so that the compartmenting function can achieve its segregation purpose in the event of fire.*

*The components of the ventilation systems belonging to a fire compartment (connection ducts, fan batteries, filters), which are located outside this compartment, shall have the same fire resistance as the compartment itself or it shall be possible to isolate them by means of fire dampers having appropriate fire resistance.*

*In compliance with the risk assessment, measures shall be taken to ensure that the release of corrosive smoke due to a fire does not prevent the structures, systems and components important to nuclear safety from completing their safety functions.*

***17.5. Administrative inspections and maintenance***
*Procedures shall be available in aim of ensuring that the quantity of combustible materials (calorific load) and the numbers of sources of ignition are controlled and restricted in areas containing equipment important to nuclear safety and in adjacent areas where such equipment may be exposed to a fire risk.*

*Inspection, maintenance and testing procedures shall be prepared and implemented in order to guarantee the effectiveness of the fire protection measures during the entire service life of the installation. They shall verify the integrity of the barriers and the availability of the devices installed for detecting and extinguishing the fires and mitigating their effects.*

***17.6. Firefighting organisation***
*When the fire fighting capacity relies on external personnel, there shall be an appropriate coordination between the personnel of the installation and the external emergency response group in order to make sure that the group is well-informed of the risks in the facility. In such cases, firefighting exercises shall be organised at least once a year with the external personnel.*

*The organisation of the fire protection department employing personnel from the site, who are required to take part in the firefighting activities, the staffing level, the equipment and the training of the personnel shall be documented, and the adequacy of this organisation shall be confirmed by a person who is skilled in the relevant field."*

Article 32 of SRNI-2011 applicable only to NPPs additionally requires that:

*"**Article 32. Protection against internal fires***

***32.1. Design basis principles***
*The reactor shutdown, residual heat removal, radioactive material confinement and power plant monitoring capacities shall be maintained during and after fire occurrences.*

***32.2. Fire hazard analysis***
*A probabilistic fire hazard analysis, supplementing the deterministic approach, shall be carried out. In the level 1 probabilistic safety assessment, fire hazards shall be analysed in aim of assessing the protection measures and identifying the risks caused by the fires.*

***32.3. Fire protection systems***
*The fire hydrant distribution system, involving fire hydrants positioned outside the buildings, the internal fire security columns as well as the fire hoses with their connections and fittings, shall appropriately cover all of the safety-related areas for the power plant. This coverage shall be justified by the fire hazard analysis."*

#### *1.2.1.2. Other national regulations*

In addition to the regulatory framework for nuclear safety and radiation protection, the following national regulations relevant in relation to fire protection, also applies to nuclear installations:

- General regulations of 8/9/2019 for the electrical installations [10];
- Royal Decree of 07/07/1994 establishing basic fire and explosion prevention standards with which buildings must comply [11];
- Royal Decree of 28/03/2014 on fire prevention at work [12];
- Royal Decree of 21/04/2016 on explosive environments [13];
- CODEX code related to the well-being at work, in particular Book III, Titles 3 and 4 related to fire prevention and explosion hazard on the workplace [14] and which includes the Royal Decree of 28/03/2014.

#### *1.2.1.3. European legislation and Belgian standards and guides*

Relevant European and Belgian standards and guides are:

- NBN S21-100-1/2 Belgian standard for the fire detection and alarm system [15];
- NBN 713-020 Belgian standard on Firefighting - Fire performance of building materials and products - Fire resistance of building materials [16] which was superseded by NBN EN 13501 [17] part 2;
- NBN EN 13501-1/2 European standard on fire classification of construction elements [17];
- EN 54: European guide for the detection and alarm system [18];
- IEEE 383: Standard for Qualifying Electric Cables and Splices for Nuclear Facilities [19].

For historical reasons, some fire protection systems have been established using non-national standards such as the NFPA standards for fixed fire protection systems. Currently and wherever possible, use is made of the Belgian or European standard, in this case:

- NBN EN 12845: European standard for Fixed firefighting systems - Automatic sprinkler systems [20];
- NBN EN 14972: European standard for Fixed firefighting systems - Water mist systems [21];
- NBN EN 15004: European standard for Fixed firefighting systems - Gas extinguishing systems [22].

In addition, the European legislation of relevance to TPR II are:

- Council directive “on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres” of 23 March 1994 [24]
- Council directive “on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres” of 15 December 1999 [25]
- Regulation (EU) No 305/2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC, 9 March 2011 [26]

#### 1.2.2. Implementation/Application of international standards and guidance

Licensees have provided extensive lists of the international standards and guidelines that are or were used. These include IAEA Safety Requirements and Guides, US NRC regulatory guides and standard review plans, Eurocodes, ASME codes, NUREG reports, EPRI reports and other sources. An extensive list was provided by the licensees and the selection of the most relevant references is provided in the section on page 106.

# 2. Fire Safety Analyses

Article 17.3 of SRNI-2011, see section 1.2.1.1, requires that a deterministic fire safety analysis (named Fire Hazard Analysis, FHA) is performed for all Class I facilities, including NPPs, research reactors and spent fuel storage facilities. These fire safety analyses have to be kept up to date during the entire lifetime of the installation. In addition, article 32.2 of SRNI-2011[7], see section 1.2.1.1, also requires - specifically for NPPs - to carry out a fire Probabilistic Safety Analysis of level 1 (Fire PSA).

## 2.1. Nuclear power plants

### 2.1.1. Types and scope of the fire safety analyses

#### *2.1.1.1. Fire Hazard Analysis*

CNT3 and KCD3:

The objective of the FHA study is to assess the potential safety consequences of fire events through the capability to perform the following safety functions (FHA objectives) for all operational states:

1. Safe Shutdown Capacities (Cool down, Criticality, Reactor Coolant System (RCS) integrity and pressure control);
2. Residual Heat Removal;
3. Confinement;
4. Mitigation of Internal Accidents in the Long Term.

Equipment associated with these safety functions and the associated support equipment are considered as “FHA equipment” and are included in the scope of the FHA studies. These studies cover all the buildings containing FHA equipment and buildings located near a building containing FHA equipment as well as the transformer yards.

In the framework of the FHA study, an adequacy check of the fire protection means was performed in accordance with the standards and codes applicable at the time of the study.

The FHA studies were finalized in 2017 for all units in operation, and are periodically updated at least in the framework of the Periodic Safety Review required in SRNI-2011 art. 14. The first FHA results were provided to the regulatory body by end 2015 and updated was provided in 2017.

CNT3:

The FHA for CNT3 was finished in 2017. An update in the framework of Long-Term Operation (>2025) is ongoing.

DE:

For the DE building, a FHA study has also been performed to evaluate the impact of a fire starting in the DE building on surrounding buildings, in particular the adjacent solid waste storage building.
This includes the adequacy check of fire protection means inside the DE building, as well as inspection of the fire barriers and fire loads inside the building.

[7] Note that other articles in SNRI-2011 provide requirements related to the (general) Probabilistic Safety Analysis.

KCD3:

The FHA for KCD3 as a reactor in operation was finished in 2017.

In the current post operational state, with all fuel elements removed from the reactor building, some of the FHA objectives are not relevant anymore. Therefore, the FHA studies have been updated in the framework of the Periodic Safety Review for the post operational phase with an emphasis on the residual heat removal and the confinement function of the spent fuel pools.

Specific decommissioning activities during the post operational phase of KCD3, e.g. the CSD activities in POP-2, have been addressed in dedicated fire risk analyses. These rely on the existing (deterministic) FHA studies and evaluate the impact of the modifications in the plant, such as the introduction of additional fire loads or the (temporary) modifications to the compartmentalization, on the conclusion of the analyses and the available safety margins.

Wherever necessary, additional calculations, using the fire containment approach (FCA, see section 2.1.2.1), or justification by crediting existing fire protection measures have been used to demonstrate the acceptability of the situation. When such justification is not feasible, additional fire protection measures are introduced.

KCD1/KCD2:

The study has been performed in the framework of the Long Term Operation (LTO) project (>2015) and an update is foreseen for the upcoming POP starting in 2025. The safety objectives for that study were identical to those for KCD4 and CNT3.

Based on the experience gained from the FHA for the other units and the specificities of the design of the KCD1/KCD2 twin units, the methodology relies on the identification of two mutually independent success paths capable to bring the reactors in a safe state in case of a postulated single internal fire event. The second-level emergency systems are credited as one of these success paths.

#### *2.1.1.2. Fire Probabilistic Safety Analysis*

CNT3 and KCD3:

The objectives of the Fire PSA Level 1 (core/fuel damage) studies for CNT3 and KCD3 are to complement the deterministic Fire Hazard Analysis and to estimate quantitatively the contribution to the global risk of the Fire Hazards and consist of:

- Mapping the probabilistic risk of internal fire hazards – i.e. determine the Core/Fuel Damage Frequency (CDF/FDF) due to internal fire events – for all Plant Operating States;
- Performing a systematic ranking of fire areas to identify the major contributors to the risk of core/fuel damage;
- Identifying possible improvements to increase the nuclear safety level related to internal fire hazards.

At the end of 2015, the first Fire PSA L1 study results were transmitted to the regulatory body. Following this review, a second iteration of these Fire PSA L1 study had to be performed by the licensee to reduce excessive conservativeness in the approach and prioritize the identification and implementation of fire safety improvements by the end of 2017.

Fire PSA Level 2 (integrity of the reactor containment and atmospheric release) studies are currently ongoing for CNT3 (reactor).

A Fire PSA Level 1 study has been carried out for the spent fuel pools for KCD3 and CNT3. For KCD3, this study was done before the definitive shutdown.

DE:

The reduced thermal load and huge water reserve in the DE installation result in available grace times that justified screening out PSA analyses.

KCD1/KCD2:

The PSA model of KCD1/KCD2 is represented by a single-reactor PSA model for KCD1 and there is no specific PSA model for KCD2. Thus, the Fire PSA model for KCD1/KCD2 is based on the PSA model of KCD1, and a qualitative analysis has been made on the cross-unit events (i.e. the events affecting both units at the same time) and the impact on the results for the twin units.

There is only a Level 1 Fire PSA developed for KCD1/KCD2. The level 2 Fire PSA has not been developed.

### 2.1.2. Key assumptions and methodologies

CNT3 and KCD3:

The methodologies of the deterministic and probabilistic fire safety analysis and the related main assumptions are summarized below.

#### *2.1.2.1. Deterministic Fire Hazard Analysis (FHA)*[8]

CNT3 and KCD3:

The FHA has been developed as a comprehensive study to evaluate the potential safety consequences of any fire. The study assigns a status to each location, i.e. per room or per building, that reflects whether a fire starting there has the potential to lead to unacceptable safety consequences.

As requested by SNRI-2011 art. 17.3, the study considers all operating modes and credible combinations of a fire and other postulated events that are independent of the fire. To assess the possible safety consequences of those combinations, the study is performed based on enveloping scenarios:

- The plant is operating at hot full power and has to be driven to cold shutdown with a Loss Of Offsite Power (LOOP). This scenario covers all operating modes;
- The plant is in the long term accident management phase of a Large Break Loss of Coolant Accident (LBLOCA), core cooling is ensured by ECCS recirculation. This scenario covers the design base accidents;
- The plant is in cold shutdown after a design-base earthquake, i.e. the Safe Shutdown Earthquake (SSE).

It is worth noting that the latter combination of fire and SSE does not cover seismically-induced fires (SIF). A specific methodology addressing SIF is currently being developed in the framework of the implementation of the WENRA-2014 SRLs.

[8] The steps, particularly the order of the steps, described in this section maybe confusing and represent the way the licensee carried out the FHA. For comments by the RB, see section §2.1.7.1.

The FHA is based on IAEA SRS No. 8 [28] and consists of the following approaches:

**Fire Containment Approach (FCA)**
The FCA is used to assess the capability of fire barriers to withstand the fire and is an iterative calculation that consists of the following steps:

- Identification and characterization of all the fire loads inside all the rooms within the scope (e.g. heat release rate, heat of combustion, physical dimensions, etc.);
- Fire growth calculation inside the selected burning space with the assumption that all the combustible materials present inside the burning space are ignited at the onset of the fire;
- Evaluation of the fire resistance of the boundaries of the considered zone;
- If a failure of the fire barrier is predicted, extension of the burning space up to the next fire barriers is assumed.

Numerical characterization of all separation walls is based on the normalized curve ISO 834. As a conservative assumption, all the safety equipment located inside the impacted room is supposed to be lost when the first ignition occurs.

**Fire Influence Approach (FIA)**
The FIA is a more accurate and less conservative approach than the FCA and uses state-of-the-art fire modelling techniques (zone modelling, computational fluid dynamics, etc.) to evaluate the consequence of a fire on the targets (FHA equipment) inside the same compartment.
It is much more computationally and time intensive, and therefore it is applied only in specific cases, in particular scenarios involving a fire starting in large and/or complex volumes. It has been systematically used for the following buildings or equipment:

- the reactor building;
- the annular space;
- the turbine building;
- the outdoor transformers.

The FIA is also used to demonstrate that the safety objectives are met for the rooms where the FCA, the System Analysis and the Classification (see below) are not sufficient to demonstrate that those safety objectives are met.

The FIA consists on the following steps:

1. define the fire modelling objectives (identify the targets, i.e. FHA equipment located in the considered space);
2. describe the fire scenarios (ignition sources and fire loads);
3. select and evaluate the fire models (e.g. the Fire Dynamics Tools developed by the US NRC, Magic developed by EDF, Fire Dynamics Simulator developed by NIST, etc.);
4. calculate the fire-generated conditions and evaluate the consequences on the considered targets.

The “**System Analysis**” has been performed to address the importance of the loss of different safety equipment located in an area impacted by a postulated fire. As such the FHA safety objectives (see section 2.1.1) are screened by the system analysis and the potential impact of the affected equipment is evaluated. If the loss of the equipment does not result in the loss of the associated function (because of available redundancy, or non-critical failure) the potential safety issue is not raised, the FHA objectives are met, and no further analysis is needed.

The **adequacy check** of fire detection and fire suppression means has been performed for all the buildings in the scope of the FHA. The goal of the adequacy check is to evaluate if the fire detection and protection are suitable with regards to the fire risk:

- The rules from the Belgian standard NBN S21-100 [15] have been used for the evaluation of the adequacy of fire detection;
- The adequacy check of the automatic fire protection system has been performed by using the applicable (usually NFPA) standards;
- The adequacy study of the manual fire protection means has been done by using the NFPA standards and the good practices from the industry.

Based on the outcome of these analyses and checks, the consequences are classified. In case of a **classification** as potentially leading to unacceptable safety consequences, this has been addressed either by a more detailed analysis or through hardware (or procedural) modifications aimed to resolve weaknesses.

KCD1/KCD2:

Because of the specificities and limitations of the design of KCD1/KCD2, the FHA methodology developed for the other units could not be directly applied. This is, among others, the consequence of the limited physical separation between the redundant "1st level safety trains" (particularly in the auxiliary electrical building) as well as the poor fire compartmentalization in some other parts of the plants (e.g.: the auxiliary nuclear building). Therefore, the following modifications were introduced to the general FHA methodology:

- the system analysis of FHA is based on the concept of two mutually independent "success paths". One is based on the equipment controlled from the main control room, the other one on the equipment controlled by the emergency control room. The objective is to demonstrate that at least one of the two success paths remains available in case of a single internal fire.
- a new risk assessment methodology has been developed in addition to the previous FCA and FIA: the Fire Risk Analysis (FRA). The FRA is a risk-informed analysis of the defence in depth principle applied to fire protection. It is based on [32] and [45].

##### *2.1.2.2. Fire Probabilistic Safety Assessment (Fire PSA)*

CNT3 and KCD3:

The Fire PSA L1 study is mainly based on two NUREG guidelines: NUREG/CR-6850 [29] and NUREG/1921 [30], and the general approach is the following:

1. Qualitative screening of fire areas based on which all possible fire scenarios are identified for the different fire areas;
2. Quantitative screening of fire areas: the consequences of all possible fire scenarios are quantified in terms of Fire CDF, based on bounding assumptions, and are subsequently screened;
3. Detailed fire modelling of risk by significant fire areas: Fire scenarios of all screened-in fire areas are fine-tuned in terms of Fire CDF, based on representative assumptions, taking into account the time dependency of fire propagation and fire protection systems;

4. Final Fire CDF quantification of fire scenarios: the final Fire CDF is obtained by adding up the Fire CDF of all fire areas;
5. Sensitivity and uncertainty analysis: the level of confidence in the final Fire CDF is supported by sensitivity and uncertainty analyses performed on various assumptions considered in the modelling.

The supporting tasks include:

- Cable and circuit failure analysis: Evaluation of fire-induced short circuits in component I&C and power cables to identify all possible component failure modes that can be caused by the fire;
- Human reliability analysis: Assessment of the reliability of all operator actions that need to be executed to eliminate the fire and to mitigate its consequences for safety.

For the associated spent fuel pools, the development of SFP PSA L1 is based on the same NUREG guidelines as for the reactor Fire PSA L1 (i.e. also NUREG/CR-6850 and NUREG/1921).

The development of Fire PSA Level 2 studies for CNT3 (reactor) is currently underway.

<u>KCD1/KCD2</u>

For all locations, except for the turbine hall and the auxiliary electrical building, the NUREG guidelines as applied for KCD3 and CNT3 were used for the Fire PSA study on KCD1/KCD2. A specific analysis has been made to evaluate the applicability of the recommendations identified at KCD1 to KCD2, based on a single-unit PSA model.

For the turbine hall and the electrical auxiliary building a dedicated approach was applied, based on fire decision trees and elements of [29] in an effort to limit the dependency on information that was difficult to obtain within the remaining operating time of the units. The primary distinctions are the absence of detailed circuit failure mode analyses and human reliability analysis. Moreover, the analysis was limited to full power operation.

The goals of these studies were to identify the main scenarios, to determine their consequences and to define the recommendations.

#### 2.1.3. Fire phenomena analyses: overview of models, data, and consequences

<u>CNT3 and KCD3</u>:

To perform the fire safety analysis, an extensive data collection program was started. The information needed for each room includes the following:

- Geometry of rooms and openings;
- fire loads type and characteristics;
- fire protection characteristics:
  - compartmentalization,
  - automatic fire detection,
  - automatic fire suppression,
  - manual fire suppression;
- localization of safety related equipment;
- ventilation flowrates.

The required input data has been collected from available plant documentation and/or via dedicated walkdowns using a data collection and mapping tool.

The fire hazard analyses make use of the following models:

**Fire Containment Approach (FCA):**

- Mainly based on the algebraic models developed by USNRC and documented in NUREG-1805 [31];
- The gas temperature is calculated taking into account all the fire loads present inside a selected burning space and for all the ventilation conditions;
- Propagation through the separation wall is predicted by a 1-D thermal conduction model;
- Fire automatically propagates from the initial room to an adjacent room through openings or separation walls.

**Fire Influence Approach (FIA):**

- Fire growth calculation inside a burning space by assuming the fire ignition on a selected fire load;
- Calculation of gas temperature, fire propagation and time to failure is performed using a specifically selected tool (such as zone models, or CFD codes), depending on the objective and the complexity of the identified scenario.

**Fire Probabilistic Safety Assessment (Fire PSA):**

- The plant is divided in Plant Analysis Units (PAUs) based on FCA calculations performed within the FHA;
- In case of a detailed modelling of the fire is required, a tool has been developed to model the propagation of the fire to the other equipment and cables: depending on the complexity of the scenario, simpler algebraic models or more advanced external tools (such as zone models, or CFD codes) were used.

#### 2.1.4. Main results / dominant events

CNT3:

The FHA identified the following weaknesses:

- Loss of spent fuel pool cooling function (pumps);
- Loss of ventilation of pool area in the post accidental phase.

The adequacy check of the automatic fire detection system has resulted in the installation of additional fire detectors to ensure the compliance with the most recent standards.

The main findings of the Fire PSA L1 are:

- Fire hazard is the dominant risk when compared to the other considered internal hazard (flooding) and the Internal Events (more than 60% of the total Core Damage Frequency);
- The most significant fire scenarios are:
  - A fire on the cables of main transformers, inducing the initiating event of Loss Of Offsite Power (LOOP);
  - The spurious opening of a valve in shutdown mode, leading to an undesired loss of inventory of the primary circuit.

For the associated spent fuel pools, the fire hazard is not the dominant risk when compared to other internal events. The main initiating event is the induced loss of pool cooling pumps.

On the basis of both analysis the main physical areas from which the risk arises and the dominating initiating events are the following:

- Main control room: spurious actuations potentially leading to the Loss of Instrumentation Air or a Small LOCA;
- Switchgear in electrical buildings: Loss of Instrumentation Air or the Loss Of Offsite Power;
- Annular space: the loss of the pumps related to the Residual Heat Removal System.

KCD3:

The general conclusion from the updated FHA performed for the post-operational phase is that the installation is adequately protected against internal fire hazards during decommissioning activities. Nevertheless, a limited number of opportunities for improvement have been identified (see below).

The general conclusion from the Fire SFP PSA L1 is that the risk is low. The main improvement identified from this study is to strengthen the protection of the Pool Loop cooling pumps by improving the automatic fire detection in the compartment.

KCD1/KCD2:

FHA:

- Physical separation of the cables has been improved as a result of the FHA, in the form of cable re-routing or the addition of passive protection (cable wrapping or coating) around existing cables.
- Additional fire protection measures were installed to ensure the functionality of critical FHA-system when a fire occurs. For example, electrical raceways fire barrier system and water mist systems were installed.
- Furthermore, some modifications to the technical specifications and procedures are proposed to ensure both success paths, see under §2.1.2.1, have a sufficient cooling capacity in order to bring the affected reactor in a cold shutdown state.
- Rerouting of critical FHA system cables in the RGB's was proposed.

FPSA:

- In addition to the FHA findings, the Fire PSAs have identified additional rooms where improvement of the fire protection would be beneficial. These include improvement to the active fire protection (extension of the automatic detection or extinguishing systems) or passive protection (compartmentalization, or physical separation of equipment).
- Administrative and procedural modifications in a number of safety significant locations (e.g. limitation or prohibition of hot works).

#### 2.1.5. Periodic review and management of changes: actions and implementation status

CNT3 and KCD3:

In order to keep the FHA studies up-to-date, the evaluation of the impact of plant **modifications** on the outcomes and conclusions of the FHA has been included in the standard modification process. For any modification that has a (negative) impact on the conclusion of the FHA (e.g. by increasing the local fire load), the study will have to be updated for the areas involved in the modification or alternative solutions will have to be determined to remove the impact.

In accordance with IAEA SSG-25 [33] the deterministic and probabilistic studies will have to be revised in the framework of Safety Factors 5/6/7 of the **Periodic Safety Review process**. Given the recent agreement on the operating license extension of the two most recent NPPs (including CNT3) it is expected that such studies will be carried out in the near future.

CNT3 action plan

Based on the results of the FHA and Fire PSA for CNT3, an action plan was developed with a total of 76 actions. The main actions carried out are:

- Improvement of the fire protection (passive or active) of the cables related to the Ventilation of the Annular Space and the spent fuel pool building;
- Improvement of the physical separation between electrical boxes (relocation) or re-routing of cables, e.g. related to the electrical supply of the pool cooling function system pumps;
- Add fire detectors;
- Limitation/interdiction of transient fire loads in the rooms with high potential fire safety issue;
- Addition of portable fire extinguishers;
- Modification of emergency operating procedure, including the management of fire events.

All actions were implemented by December 2020.

KCD3 action plan:

The FHA and Fire PSA performed on the reactor in the operational phase resulted in an action plan covering 136 actions which were implemented by the end of 2020.

The FHA study for post-operational phases POP-3 and beyond has been performed in the framework of the definitive shutdown PSR, and all the following actions were completed within 1 year after the shutdown:

- Install extra cable coating in rooms for ensuring the ventilation for the SFP building and annular space;
- Install fire stops on the cables which pass through the ceiling of the compartment of the SFP cooling pumps and of the compartments for ensuring the ventilation for the fuel building;
- Provide adequate smoke detectors in the compartment of the SFP cooling pumps and the compartments for ensuring the ventilation for the deactivation pools building;
- Assess the seismic behavior of the lifting device above the SFP purification pump.

### 2.1.6. Licensee's experience of fire safety analyses

#### *2.1.6.1. Overview of strengths and weaknesses identified*

<u>CNT3 and KCD3</u>

The methodology applied for FHA and FPSA was similar for CNT3 and KCD3 and the following strengths and weaknesses were identified by the licensee:

**Strengths:**

- Fire PSA:
  - A Fire PSA is developed for each NPP which means that the resulting Core Damage Frequency obtained takes into consideration, as far as practically possible, the design specificities and reflects the reality of each unit, especially in the cable routing;
  - Thanks to the presence of a specific Fire PSA model per unit, when a safety equipment or a fire protection is unavailable, impact on Core Damage Frequency can be evaluated;
  - The value of Core Damage Frequency and the value per PAU permits to clearly identify the main risk point not only in terms of fire frequency, but also in terms of cables present in the rooms (especially the rooms present in the electrical building);
  - The cable routing database, as well as the databases containing information on fire protection provisions, have been consolidated during the data collection phases and walkdowns.
- FHA:
  - A dedicated FHA is performed for each NPP taking into consideration the design specificities of each unit;
  - A dedicated automated tool for the FHA is available which contains the results and the data of all 7 NPPs. This tool allows to have a clear view on fire risk locations and the position of fire protection equipment.
  - In case of plant modification, the FHA tool can be used to easily determine the fire risk based on the actual situation, and allows to assess the adequacy of the fire protection means;

**Weaknesses:**

- Fire PSA:
  - The routing of some cables is not totally known, which resulted in conservative hypotheses being taken in the analyses, and resulting in core damage frequencies that do not reflect the actual fire protection level of the facilities;
  - Due to the time constraints, the number of required iterations per (sub-) tasks was limited. Increasing the number of iterations could have resulted in a less conservative Core Damage Frequency value.

<u>CNT3:</u>

**Strengths:**

- The main conclusion of the IAEA OSART mission in 2007 was that the unit has developed an ambitious program for reducing fire hazards by improving firefighting capability, staff behaviour, training, firefighting equipment and facilities;

- The operation shift team effectively monitors through a screen in the main control room the unavailability of fire detection and protection equipment;
- Other feedback from the IAEA OSART mission in 2007 was the good quality of fire-fighting action sheets which contain the information and instructions for the emergency response teams, including a fire-zoning map stating the location of the main firefighting equipment, specific risks and hazards at the actual location (such as presence of fuel oil, H2, etc.) and response procedures and instructions.

KCD3:

**Strengths** in relation to the post-operational phase**:**

- Operational procedures (e.g. fire load management, fire permits, …) will remain valid during the POP which contributes significantly to the reduction of fire hazards;
- A specific FHA study was developed for POP;
- A risk analysis on Lithium-Ion batteries (electrical cars and electrical bicycles) has been made as well as on all charging points. Analysis showed that electrical bicycles cannot be allowed inside the buildings.

KCD1/KCD2:

**Strengths:**

- The introduced FRA method requires the assessor to perform systematic on-site visit (not pure tabletop assessment), which resulted in a more realistic depiction of the plant state, and less potential fire safety issues that would otherwise be later dismissed based on refined analysis ;
- A seismically qualified fire detection system in parallel of the existing one has been installed to detect fire that could endanger specific 2$^{nd}$ success path cables;
- Active automatic protection systems including a seismic gas total flooding fire suppression system in the shutdown pumps basement room and passive fire protection systems such as Electrical Raceways Fire Barriers systems have been installed to protect FHA cables. Moreover fire retardant coating on cables has been added to limit fire growth.

##### *2.1.6.2. Lessons learned from events, reviews, fire safety related missions, etc.*

Via the operating experience process, internal and external events reports are shared for information with KCD3 and CNT3. Not all events require a specific action or response. If so, a formal action is defined and carried out.

CNT3 and KCD3

- It is necessary to maintain an up-to-date FHA database. This was not the case in the past and led to additional efforts to collect the data necessary for the fire risk analyses. Existing procedures have been updated, new ones created, in order to ensure that the data is kept up to date;
- Participation in international conferences and exchanges shows that having a Fire PSA model specific to each unit is an added value.

KCD3:

The current post-operational phase is too short to draw lessons from it that are specific to this phase and additional to those for CNT3.

### 2.1.7. Regulator's assessment and conclusions on fire safety analyses

#### *2.1.7.1. Overview of strengths and weaknesses identified by the regulator*

FHA

During the review of the FHA, the regulatory body has evaluated the study as meeting the requirements of SNRI-2011 art. 17.3. The Defence in Depth principles applied to fire protection have been assessed by systematically evaluating fire scenarios, using conservative assumptions, in all rooms containing, or related to rooms containing, equipment important to safety. In particular:

- The studies have been developed and applied on every Belgian NPP unit, taking into consideration the specific design of each unit;
- Weaknesses of the design with respect to the protection against internal fire events have been identified, and have resulted in hardware modifications.

Nevertheless, the opinion of the regulatory body was that the initial proposed approach suffered from very conservative assumptions, which required numerous adaptations in order to provide a realistic perception of the fire risk associated with the covered NPP units, as well as establishing a practical action plan in order to improve the overall fire safety.

The main challenges encountered in the development of the FHA methodology, and highlighted in the evaluation by the regulatory body, were:

- The use of very conservative assumptions regarding the FCA calculations, led to the identification of an unrealistically high number of rooms with potential safety issues that would require further analysis by System Analysis and/or FIA simulations;
- These conservative assumptions resulted, at least partially, from the initially limited quality of the available data. This required an extensive additional work of data collection, either to complete the existing databases, or to directly provide justification of the absence of identified potential safety issues;
- The System Analysis has been introduced at a rather late stage in order to reduce and limit the results to the rooms containing components important for safety (or scenarios involving a propagation to these rooms) and should have been used earlier as a screening method, which would have reduced the workload;
- The resources needed for the application of the FIA approach, specifically for the justification of rooms not screened out by the FCA step, has been vastly underestimated;
- The initial choice to directly apply the FHA methodology to all units, rather than to develop and refine the study for a single pilot unit has led to a very large consumption of time and resources.

Fire PSA

The regulatory body assessed two successive iterations of the Fire PSA studies for Belgian NPPs. Because of very conservative assumptions and only a partial implementation of the NUREG/CR-6850, the studies performed by the Licensee during the first iteration were only at an intermediate phase and needed to be further developed. Both the licensee and the regulatory body concluded that the results obtained after the iteration 1 were not credible and did not reflect the safety of the studied units, and that the objectives of the project were not fulfilled by this first iteration.
The refinements and new developments during the second iteration allowed the regulatory body to conclude that the delivered Level 1 Fire PSA studies resulted in a significant improvement and that these studies now comply with the related WENRA Safety Reference Levels and the Royal Decree of 30/11/2011.

The regulatory body provided a number of recommendations to be considered by the Licensee, either on a relatively short term (project documentation, or additional justifications), for the development of the related improvement action plan, or in the framework of a future update of the Fire PSA studies. All these recommendations have since been addressed or taken into consideration.

##### *2.1.7.2. Lessons learned from inspection and assessment as part of the regulatory oversight*

The execution of the studies, as well as the implementation of the ensuing safety improvements were followed through periodic meetings with the regulatory body, in the framework of the "WENRA Belgian Action Plan" that was developed by the licensee following the introduction of the WENRA 2008-SRLs in the Belgian Regulatory Framework, i.e. the SNRI-2011.
During the development phases of the studies, the regulatory body provided comments, questions and recommendations on the methodology and the covered scope.
In some circumstances, it was agreed to postpone the analysis of specific scenarios, such as combinations of events, to a later stage. In particular, this was the case for the seismically-induced fires (SIFs) for which no mature and widely accepted methodology was available at the time.

The projects have highlighted the importance of the data collection phase and the impact on the outcome of the assessment: it is common practice to use conservative assumptions when such data are not available. Such assumptions are, for instance:

- Maximising the potential fire load in some spaces;
- Not crediting the fire resistance of barrier elements whose qualification is uncertain;
- Simplifying modeling assumptions such as instantaneous total ignition or immediate propagation of the fire.

The combination of such assumptions has led to over-conservatism and preliminary results that could not be considered representative of the real situation in the NPPs.
The reduction and a posteriori justification of such conservatisms was a labour intensive task and had a significant impact on the workload of the licensee and the safety authority, and also resulted in delayed final results of the studies (e.g. updates of the deterministic studies, or need for a 2nd iteration of the Fire PSA Level 1)

The outcomes of the studies were consolidated in a "FHA/FirePSA" action plan detailing the implementation of the safety improvements in all Belgian NPPs.

During the implementation stage of this action plan, in addition to the periodic meetings, the regulatory body followed the progresses through the plant modification process as well as through inspections. These inspections could be specific inspections by fire experts, focused on the follow-up of the implementation of the fire action plans, or via integration in the scope of the systematic inspections by the unit resident inspectors.

The observations and conclusions arising from the inspections were positive and the regulatory body assessed the implemented safety improvements as appropriate and sufficient.

In a limited number of cases, some proposed safety improvements could not be executed and alternative solutions have been proposed (e.g. replacement of an active fire protection by a passive one). Such modifications were systematically reviewed and discussed by the regulatory body.

For KCD1/KCD2, a number of methodological adaptations (including simplified modeling of the turbine hall and auxiliary electrical building in the Fire PSA framework) were accepted by the regulatory body as temporary measures. The objective of this approach was to identify and implement relevant safety improvements on the short term also given the limited remaining operation time of the twin units.

In 2023 an IAEA OSART mission was carried out at CNT3 which identified a good practice related to the fire hazard analysis: "*The plant had developed an integrated tool to support fire hazard analyses which included assessments for the fire resistance of fire separation barriers, calculations for fire propagation in multi-compartment configurations and an algorithm for taking fire extinguishing systems into account in the calculation of fire growth and propagation.*" *[47].*

##### *2.1.7.3. Conclusions drawn on the adequacy of the licensee's fire safety analyses*

The conclusion of the regulatory body is that the fire risk analyses, both deterministic and probabilistic, meet the regulatory requirements of SNRI-2011 which transposes the WENRA safety reference levels. The studies have been developed using state-of-the-art fire risk assessment methodologies as described in international reference documents such as IAEA Safety Series no8 or NUREG/CR-6850.

## 2.2. Research reactors

### 2.2.1. Types and scope of the fire safety analyses

Article 17.3 of SRNI-2011, see section 1.2.1.1, requires that a deterministic fire hazards analysis (FHA) is performed for research reactors to show that the objectives stated in article 17.2 of SRNI-2011 have been achieved. A probabilistic fire safety analysis is not required for research reactors.

### 2.2.2. Key assumptions and methodologies

The BR2 fire safety analyses which have been carried out have as a starting point a risk inventory of the damage that can be caused to structures, systems and components through a potential fire, taking into account the mission times of the SSC's, the fire resistance and the necessary intervention times. For experiments, see the discussion on page 83.

The fire safety analysis focusses on the SSC's needed to fulfil the fundamental safety functions:

- Criticality control
- Cooling
- Containment/confinement of radioactivity

The design of the BR2 is such that the mission time of active safety components is short in order to bring the facility in a safe shut down state and maintain it over a long period without the need of external power supply or active systems or components. The fire safety analysis demonstrated that the fundamental safety functions can be maintained for all operational states (i.e. normal operation, startup, shutdown). The most critical state at which a fire can occur is during normal operation as all 3 fundamental safety functions are actively controlled.

The mission time for **reactivity control** is very short (drop time of control rods) and the actuation of the reactor stop is transmitted by cabling whose fire resistance, according to the installation standard DIN 4102-12 [23] is greater than 30 minutes minimum. This is considered largely sufficient for automatic and/or manual action. The reactor stop can be initiated from the control room in the reactor building or alternatively, from the control room in the machine hall. Activation of the evacuation signal also automatically initiates the reactor stop. If a fire causes a loss of power to the control rods or the electronic switching logic controlling the reactor scram signal, the reactor will shut down due to the fail-safe design. The reactor (and control rods) is submerged in a large water filled pool which is resistant to fire damage.

In the storage areas, criticality control is ensured by design and/or the presence of absorbing materials. Subcriticality of underwater fuel storage is not affected by fire hazard, while no significant fire load is present in dry storage areas. In the highly unlikely event of a fire in a dry storage area, firefighting interventions using water are prohibited and other means are provided for, although analysis have demonstrated that subcriticality is guaranteed for any water content between 0 and 100% in the storage facility.

For the **cooling function**, the reactor can be cooled by heat transfer to the pool by natural convection immediately after reactor scram. No external power supply is necessary to operate this function, as it is driven by hydraulic batteries in the reactor building. In case of damage to the non-submerged part of the primary cooling loop, the primary isolation valves are automatically closed to prevent any loss of coolant. These automated blocking valves are designed to isolate the primary circuit in the reactor building. The part of the primary circuit located in the process building (i.e. primary pumps, heat exchangers, etc.) is then completely separated from the part located in the reactor building. The signals, actuating this action, are also transmitted via fire resistant cabling, with two independent and separated cabling lines and feeds. The fire resistance of this cabling is again well above the needed mission time, which is less than 1 minute. Given the volume of the reactor pool (870m$^3$), there is no need to supply water or actively cool for several weeks.

The **containment** of the reactor is ensured by the containment building. This building is kept underpressure by active ventilation, but can be isolated by metallic valves in the ventilation lines. This action is performed independently of external power supply (powered by local pneumatic batteries) and the cabling of the actuation signals is redundant, separated and fire resistant.

For all rooms and areas within BR2, a specific fire risk analysis is carried out on a deterministic basis and evaluates the intrinsic – or basic – risk of an area without taking into account specific fire detection or suppression means. The intrinsic risk determination is based on scoring the following criteria:

- Fire load: the fire load of an area or room is evaluated based on the maximum capacity of burnable substances (solid, liquid, gaseous) in that specific area or room.
- Flammability: flammability is scored based on the potential to ignite in case some of the content of the room is in contact with, for instance a glowing object (low potential) or with a flame or spark (high potential).
- Energy: the score for the energy criterion is evaluated higher if heat producing equipment is present, for instance furnaces or if activities like welding, grinding, activities with open flame, etc. are carried out.
- Oxygen: the oxygen concentration is scored higher (or lower) if more (or less) than the normal oxygen content in air is present in the room or area.

Based on the four scores of the evaluated criteria, a basic score is determined by multiplication of the different parameters which is used for the categorization of each room:

- Normal (green) areas do not need further fire prevention or mitigation measures;
- Elevated fire risk (yellow) areas require measures (could be administrative or procedural)
- High fire risk (orange) areas require at least technical means to lower the risk;
- Very high fire risk areas (red) require urgent means to lower the risk.

The basic score is used to determine the amount and type of measures to be implemented to lower the risk to an acceptable level. Aspects to be considered are the use of explosion safety equipment, implementation of (sub)compartments, secured fire detection, maintenance and inspection of equipment, presence of (semi)automatic fire extinguishing systems, presence of administrative means (i.e. a permission to perform works with open flame…). This second evaluation results in a score for the residual risk.

The next step consists in a determination of the radiological risk score of the area based on the radiological content and the identified barriers between a credible fire scenario and the radiological source term. Thick concrete shielding structures, for instance, are expected not to be damaged in case of a fire. Some SSC's can be susceptible to fire and its failure can lead to a certain accident scenario (e.g. motors, pumps). The result of this exercise is discussed in a team of experts and then summarized and drafted in a final report by the head of the internal fire department.

Specific attention is given to other (i.e. global) factors which contribute to the potential fire risk, such as:

- Potential initiators beyond or outside the rooms being evaluated (large storages of technical gases, trees…);
- Construction specific aspects;
- Presence of corrosive agents or materials that can lead to corrosive or intoxicating smoke;
- Evaluation of the working regime (e.g. day/night, operation/shutdown, personnel availability).

#### 2.2.3. Periodic review and management of changes: actions and implementation status

For the BR2 research reactor it was concluded that most areas are in the low fire risk category. Several areas had an elevated fire risk and no areas were in the highest fire risk category. Most of these higher risk areas are mechanical workshops where inflammable products are stored and used. The radiological risk in these areas is insignificant.

The fire safety assessment led to the following recommendations:

- Better control of fire loads, especially in controlled areas
- Improvement of fire compartmentalization
- Improvement of fire detection

Actions were undertaken to carry out these recommendations but have not yet been fully completed:

- Separation between a hall used for testing and commissioning, and rest of building has been accomplished by the installation of a fire door, additional wall and closing of lift doors;
- Fire loads are reduced in workshops (completed for the workshop for nuclear control systems and ongoing for others);
- Fire detection system is being modernized;
- Fire detection is planned to be extended.

The SCK CEN fire safety analyses are reviewed periodically: every 3 years for areas in the highest category and every 5 years for the other categories. Other processes such as modifications and the 10-yearly Periodic Safety Review will also trigger the revision of the fire safety analysis if necessary.

#### 2.2.4. Licensee's experience of fire safety analyses

The fire safety analysis as described here above is the standard within SCK CEN and therefore as well for BR2. It is a rather simple but robust technique which is easily understood by operators and safety personnel.

The results of the analysis are visualized on a building map (red, orange, green) for intervention purposes and can easily be updated when needed.

#### 2.2.5. Regulator's assessment and conclusions on fire safety analyses

##### *2.2.5.1. Overview of strengths and weaknesses identified by the regulator*

For the BR2 facility, due to the specific in-pool design and the significant grace times, the system analysis and the "fire" assessment are decoupled; there are very few sensitive safety-related

SSCs whose damage by a fire would lead to unacceptable consequences. This allows the fire hazard assessment to be focused on the conventional aspects of fire protection, such as management of fire loads and ignition sources, compartmentalization and availability of firefighting equipment.

#### *2.2.5.2. Lessons learned from inspection and assessment as part of the regulatory oversight*

The fire safety of the SCK CEN installations was covered by the scope of the 2016 Periodic Safety Review, and resulted in a number of improvements (e.g. of the fire compartmentalization of the facilities, including the BR2).
As a result, these corresponding actions could be credited in the fire risk analyses performed to meet the regulatory requirements of SNRI-2011, further reducing the final risk level.

The regulatory body has reviewed and approved the fire risk assessment methodology applied to the BR2. The proposed fire risk reduction measures have also been reviewed and evaluated as appropriate by the regulatory body and their implementation is followed through the periodic on-site inspections.

The very different nature of the facilities operated by SCK CEN (research reactors, laboratories, etc. ) and the organizational set-up of responsibilities has led to varying levels of details and some divergences in the way the methodologies are applied. This observation does not result in identifying an increased fire risk in specific facilities, but rather make the systematic review and the comparison of proposed safety improvements more difficult.

#### *2.2.5.3. Conclusions drawn on the adequacy of the licensee's fire safety analyses*

The regulatory body considers that the developed fire safety analyses for the BR2 facility meet the regulatory requirements of SNRI-2011, has allowed the implementation of relevant safety improvements, and provides an adequate overview of the residual risk in the facility.

## 2.3. Fuel Cycle Facilities

Not applicable.

## 2.4. Spent fuel storage facilities

### 2.4.1. Types and scope of the fire safety analyses

Article 17.3 of SRNI-2011, see section 1.2.1.1, requires that a deterministic fire safety analysis (FHA) is performed for spent fuel storage facilities. A probabilistic fire safety analysis is not required for spent fuel storage facilities.

### 2.4.2. Key assumptions and methodologies

A Fire Hazard Analysis was carried out for SCG using the same methodology and methods as for the NPPs, see §2.1.2.

An adequacy check and system analyses have been performed, but given the minimal (or non-existent) fire loads and the absence of fire compartmentalization in the main storage area, it was justified that performing calculations using FCA or FIA has little added value. Due to the similarities with SCG the same conclusion was drawn for SF2.

In the framework of the licensing of the SF2 facility, fire modeling has been used to demonstrate the protection level offered by the spent fuel storage casks against the (external) fire resulting from an aircraft crash. Due to the very low amount of calorific load in this type of facility this fire scenario is considered as envelope for all internal fire events.

### 2.4.3. Main results and licensees experience

For SCG it was concluded that the fire risk is very low because of:

- The current fire protection and detection;
- The resistance to a fire of 600°C for at least 1 hour of the fuel containers;
- The design of the building allowing natural convection which also allows dissipation of part of the heat in case of fire;
- All load-bearing elements have a minimal structural fire resistance of 1 hour;
- Presence of on-site fire brigade.

### 2.4.4. Regulator's assessment and conclusions on fire safety analyses

Dry spent fuel storage facilities have a low risk related to fire events due to the (dual purpose) spent fuel casks that provide a very high level of protection against the conditions resulting from such events.

The resistance of the casks against a large scale kerosene fire (resulting from an aircraft crash) was reviewed by the regulatory body.

See also §2.1.7 for an overview of the regulator´s assessment and conclusion for NPPs.

## 2.5. Waste storage facilities

Not applicable.

## 2.6. Installations under decommissioning

See under §2.1

# 3. Fire protection concept and its implementation

Article 17 of SRNI-2011, see section 1.2.1.1, which applies to all class I installations, provides several requirements of importance to the fire protection concept, in particular: design principles (art. 17.2), fire protection systems (art. 17.4), administrative means (art. 17.5) and the firefighting organisation (art. 17.6).

## 3.1. Fire prevention

### 3.1.1. Nuclear power plants

#### *3.1.1.1. Design considerations and prevention means*

***Design principles***

CNT3 and KCD3

The general design principles for the fire protection are defined in the safety assessment reports of the plants:

"*Structures, systems, and components important to safety shall be designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions.*

*Non-combustible and heat resistant materials shall be used wherever practical throughout the plant, particularly in locations such as the containment and control room. Fire detection and fighting systems of appropriate capacity and capability shall be provided and designed to minimize the adverse effects of fires on structures, systems, and components important to safety. Firefighting systems shall be designed to assure that their rupture or inadvertent operation does not significantly impair the safety capability of these structures, systems, and components*".

The fire protection program is part of the Defense-in-Depth approach derived from RG1.189 [34]:

1. *Prevent any start of fire:*
   This objective is achieved by the fire prevention strategy, including administrative controls (limiting fire load, fire permits, transient fire load management, …) and, wherever possible, the implementation of physical features (e.g. barriers or other physical separation of combustibles from ignition sources) to provide reasonable assurance that fires will not occur or minimized.
2. *Detect rapidly and extinguish of the onset of fire while minimizing damage:*
   The second objective is achieved by appropriate levels of fire protection, including detection systems, automatic and manual fire suppression systems, water supplies, and firefighting emergency response capability (onsite fire brigade).
3. *Design the safety systems in such a way that a fire, which would have started despite the precautions, and which would spread for a long time despite the protection conditions, would not prevent the safety systems of the plant from performing their functions.*
   The third objective is achieved by an appropriate level of fire protection of the plant SSCs important to safety, including those required for the prevention or mitigation of fire-induced releases of radioactive materials. This includes the fire compartmentalization, the physical segregation between significant fire loads

and those SSCs. In addition, plant personnel are adequately trained in emergency response procedures for fire events. Finally, the smoke exhaust systems are provided in the buildings wherein no uncontrolled radioactive release to the outside is possible.

The following general design considerations are used to achieve the objectives of the fire protection program:

**Compartmentalization**

Each plant has been compartmentalized to reduce the risk of fire spreading, as well as the spreading of smoke, corrosive gases and radioactive substances potentially released by a fire event.

Each plant is divided into fire compartments based on the quantities of combustible materials present, so as to separate, among other things, redundant SSCs and safety functions.

Compartments have been defined by walls, ceilings, and floors with a fire resistance rating of 2 hours according to the Belgian standard NBN 713-020 [16].
The degree of fire resistance of compartmentalizing elements such as doors, dampers or cable penetration closures should be identical to the wall in which it is installed. In some locations, fire doors with a lower rating (e.g. 1 hour fire door in a 2 hours rated wall) have been accepted on the basis of a dedicated analysis in order to demonstrate that the installation was sufficiently protected against the risk of a fire.
Since 2016, new builds and replacements have preferably used elements with the same fire resistance rating and classified in accordance with the newer European standard NBN EN 13501 [17] part 2.

Each compartment has a specially designed and marked access and emergency exit. Doors opening to the outside form airlocks so as not to disrupt ventilation between different zones.

**Construction materials**

The building materials for the structural work and finishing are, as far as possible, non-combustible or have a low fire spreading coefficient. The use of plastics and in particular PVC was limited as much as possible.

The building materials are usually reinforced concrete, brick, steel, tile, or a cement-based coating. These elements were optionally covered with epoxy paints with the following fire protection properties:

- the steel supports and frames and the metal sealing skin of the primary containment ("liner") are painted with paint of category M1 or M2 (non-flammable - flame-resistant) [27].
- the concrete floors or top layers are painted with paint with moderate flame spread, class 3 according to NEN 3883 [35].
- the walls and ceilings are painted with paints of category M2 [27] or class 1 according to NEN 3883 [35].

Some floor coverings are made of vinyl tiles applied over the top layer (changing rooms and laboratories) or linoleum. These floor coverings are acceptable within the meaning of the RG 1.120 [37] par. C.4.a. (4).

### Electrical Cables

The cable trays are made of non-combustible material; the cables selected for the wiring of electrical equipment meet the requirements of the IEEE 383 [19] (1974 version) standard with regard to fire resistance and resistance to extreme environmental conditions in normal operation and in the event of an accident, thus limiting insulation degradation and fire spread.

The insulation of cables is fireproofed by non-halogenated additives and releases very few corrosive gases in the event of a fire. The cables are provided with electrical protections against overloads and short circuits so as to reduce the probability of a fire due to an electrical fault. The power cables are sized to reach a maximum of 90°C with nominal current, 130°C in temporary overload (120 h/year) and 250°C at the end of a short-circuit.

The routing of the cables in the consoles and switchboards of the main control room is carried out in cable trays made of fireproof material. As it is not always possible to maintain a sufficient distance between the devices and the bundles of wires of different trains, use is made of screens made of fireproof material to separate them. The actual crossing of the cables is filled with fire-resistant materials.

The cable glands are made of a fire-resistant material. In addition, an intumescent paint is applied to both sides of the cable glands, as well as to the cables over approximately one meter in length on either side of the bushing.

### Batteries

The Class 1E batteries (for 115 Vdc and 220 Vca networks) are "*Planté*" SPF25 and tubular OPzS lead-acid batteries. The containers that contain the electrolyte are made of transparent, impact-resistant plastic and the lid of these containers is made of the same material and glued to the container, so as to ensure the lid/tray seal.

Explosion-proof caps are provided to prevent any contact of sparks with the electrolyte and thus limiting the risk of explosion and fire.

Battery rooms, where production of gaseous hydrogen could occur, are classified as ATEX areas. The ventilation ensures that the formation of an explosive atmosphere by reaching the lower explosion limit is not possible.

### Diesel generators and fuel tanks

The diesel generators are separated from each other, and they have their own fire compartment.

The fuel storage tanks are separated from each other by a partition having a fire resistance of at least Rf 2h according to NBN 713-020 [16].

For CNT3, these tanks are located in a special building separated from the plant´s main buildings. After detection and automatic actuation of the deluge-type extinguishing system, the fire is brought under control within a short period of time.

For KCD3, these tanks are located in the building where the diesel generators are located. After detection and automatic actuation of the deluge-type extinguishing system, the fire is brought under control within a short period of time.

### *Design considerations for specific areas and locations*

CNT3 and KCD3:

Specific design considerations are implemented depending on the location/area:

**Main control room:**

Since the main control room is permanently occupied and equipped with a fire detection and extinguishing system, the risk of fire is already considered low. Nevertheless, additional measures were taken to minimize the risk of fire starting in the main control room as well as the emergency control room; these include:

- Any high energy equipment such as automatic switches, transformers, rotating machines, or other possible sources of projectiles, are not present;
- Only control measuring circuits or lighting circuits are present;
- No flammable products are stored.

In addition to the general prevention means to avoid fire combustible construction materials, the number of electrical cables inside the main control room is limited to the cables that are necessary for the plant operation and all cables that enter the main control room must end inside it. There are no cables under the floor.

CNT3:

The main areas containing combustible materials are: the fuel storage areas for the diesels, the rooms of the day tanks of the diesels, the rooms for the oil tanks of the charging pumps and the primary pumps, the rooms of the oil tanks of the charging pumps of the second level of protection and the supply pumps of the second level of protection, the oil tank for the normal feed water adjustment valves, the turbine oil tank room, oil transformers and the premises of the diesels.

For these areas and equipment, the risk of fire and its potential impact on the plant is minimized by applying generic principles and, to the extent possible, segregating fuel storage by installing only small-capacity tanks in buildings (day tanks).

In the reactor building:

- The fire extinguishing system is fed by two redundant lines;
- A specific circuit measures the concentration of hydrogen and reduces it if necessary;
- A system is installed to measure flammable gases (Hydrogen). The alarm is set at 2%, while the instant explosion limit is 4%;
- A mobile $H_2$-recombinator can be connected to the reactor building if necessary in case of an event;
- The following elements are put in place to avoid the reach of the explosion limit:
    - Presence of 42 PARs (Passive Autocatalytic Recombiners) in the containment,
    - Thermal recombination,
    - Injection of fresh air in the containment.

KCD3:

- In the reactor building:
  - A system is installed to measure flammable gases (Hydrogen). The alarm is set at 3%, while the instant explosion limit is 4%;
  - At the air intake of the ventilation system for the reactor building and the spent fuel pool building, 2 detectors for explosive gases are installed;
  - The control system for the combustible gases in the containment comes into service automatically. By installing the PARs (Passive Autocatalytic Recombiners) in the containment, the hydrogen gas present in the containment is continuously recombined;
  - After POP-2, the primary pumps do not operate anymore and the fire risk is drastically reduced since the oil is removed.

- Spent fuel pool:
  - A study based on Zone Of Influence methodology concluded that the installation of an automatic fire extinguishing installation within this area is not required as the separation between the pumps is large enough;
  - The cables of the PL pumps are coated;
  - The potential presence of transient fire load is kept as low as possible inside the area, especially near the pumps and near the penetrations.

### *Administrative controls and procedures*

CNT3 and KCD3:

The following is an overview of the most important administrative controls and procedures.

**Control of combustibles and ignition Sources**

Management procedures are used to limit the likelihood of fire and its consequences. In practice, the fire load management program is described in specific procedures that identify the “sensitive spaces” or “critical spaces”. These spaces were identified as part of the FHA and FPSA studies and no transient fire loads are allowed in them.

Administrative procedures are also in place for other fire prevention provisions such as the work permits, fire permits, periodical approval of electrical equipment, etc..

**Preferable use of non-flammable lubricants**

In the plant and wherever practicable, materials (including lubricants) are non-combustible or have a high resistance to high temperatures (i.e. materials with an adequate reaction to fire or a high flash point). This is especially true in areas such as the main control room or reactor building.

During plant maintenance, fires caused by cleaning solvents are avoided or minimized by using carefully selected solvents and limiting the quantities available in the areas concerned. However, should a fire involving these products occur, its intensity, duration and impact on adjacent areas will be minimized by limiting inventories in work areas, physically separating redundant safety systems and ensuring that fire protection systems respond quickly.

KCD3:

In the post-operational phase, it is assumed that no additional fire loads will be introduced as a result of dismantling preparation as a (very) limited number of such activities would exceed those normally carried out as part of a normal shutdown. The procedures already in place for fire load management and hot work will continue to apply.

The only work planned during POP-2 and POP-3 is in the turbine hall where the main fire loads (including turbine lubricant) will be removed. Therefore, the fire risk is not expected to increase as a result of these activities.

If subsequent dismantling preparation activities were to result in an increase in fire risk, fire protection provisions would need to be strengthened. In this case, the strengthening would be based on a more detailed analysis that considers the potential for increased combustible loads from sources such as equipment laydown areas, waste accumulation and storage areas, and materials needed to support decontamination and dismantling activities as required by RG 1.191 [36].

***Design basis fire events used for the design of the fire safety provisions***

CNT3 and KCD3:

A fire in an emergency diesel fuel storage tank is the largest possible fire that could affect safety-related equipment. This hypothetical fire is considered as one of the major design basis events for fire protection.

The following fires have also been considered in the design of the fire protection provisions:

- Electrical cable fires;
- Cleaning solvent and chemical fires;
- Fire in main control room;
- Turbine hall fire;
- Transformer oil fire.

These fires were considered in terms of their intensity, location, duration and potential impact on surrounding areas. The fire protection provisions of the areas where these fires could occur were specifically reviewed to assess their effectiveness.

KCD3:

In the post-operational phase, the fire risk is modified:

- Turbine hall: during the POP-2 and POP-3 phases, the turbine is no longer required and the fire load is significantly reduced due to the elimination of the turbine oil;
- Outdoor transformers: during the POP-2 and POP-3 phases, the start-up transformers will remain operational and the associated fire protection system should remain operational. The fire safety design provisions of other transformers, which are de-oiled, are no longer necessary.

*3.1.1.2. Overview of arrangements for management and control of fire load and ignition sources.*

### *Fire prevention during hot work – fire permit*

CNT3 and KCD3:

The purpose of this process is to determine the preventive and protective measures to be taken to ensure that the activities do not result in safety risks, personal accidents, or damage to the installations from fire or explosion. It considers international requirements and best practices, and specifies procedures for monitoring the site for fire risk.

Work may only start if the persons carrying out the work are in possession of a valid work permit. A “hot work” permit is also required for work involving a fire hazard. The hot work permit is the result of a risk assessment and contains a summary of this assessment together with the measures to be taken to reduce the identified risks to an acceptable level. Preventive measures are adapted to the level of risk and are determined based on the insurer’s recommendations and NFPA 51B [38].

The assessment takes into consideration:

- The type of work and equipment required (welding gases, cutting…);
- Personal protective equipment;
- Required fire protection measures: fire resistant screens and blankets, fire extinguishers, metallic (sealed) garbage containers…

Approval of the hot work permit must be obtained from the Fire Safety section of the ISPPW and from Operations. This process includes determining and validating the need to temporarily disable automatic fire protection equipment, such as detection and/or extinguishing systems.

A hot work permit is issued for a single day, and the date is indicated on the work permit. It may be renewed up to 6 times if necessary. The maximum duration of a hot work permit is therefore 7 days. Should the associated activities last more than 7 days, then a new fire permit should be requested.
A daily visit to each fire permit site is carried out by a dedicated work manager.

The following work is considered "high risk" and requires a hot work permit

- ATEX: in all cases (ATEX : ATmosphère Explosive);
- Welding, grinding and working with an open flame;
- Working on roofs with bitumen;
- Working with or in the vicinity of titanium-containing components;
- Work involving temporary storage of gas bottles in technical installations;
- Storage and use of aerosols and highly flammable products;
- Topping up and checking batteries, both in battery rooms and on mobile devices.

Where a fire watcher is required, the person responsible shall remain in place for 30 minutes after the end of the activities in order to ensure that there is no smouldering fire.

As soon as possible and no later than the end of the day, workers shall notify the main control room operators that work has been suspended, possibly until the following day (or days). The relevant inhibited fire detection/protection systems shall be reactivated (unless prevented by other interlocks) and the unavailability management program shall be updated.

### *Mobile fire loads*

CNT3 and KCD3:

For historical reasons and site constraints, the fire load storage policies of the Doel and Tihange sites are slightly different. Following a major revision of the strategy in Tihange, a harmonization process is ongoing. This harmonization will make it easier for employees, internal and external, who work on both sites, to respect the fire load expectations.

The general rule is that the storage of materials (combustible or not) is prohibited inside buildings and within a distance of 9 meters outside buildings, except in areas specifically authorized for this purpose. These authorized areas are:

- Buildings and areas designed for the storage of materials such as oil depots, waste collection and sorting centers, changing rooms. These various storage areas do not require specific signage authorizing storage in the area, and there is no defined limit to maximum allowable calorific load. Storage in these areas does not require a specific authorization;
- Dedicated storage areas, which can be either closed (with wire mesh) or open (marked on the floor with black/yellow markers). This type of area is assigned to a department/section, or for storage of equipment;
- Permanently open storage areas for general use are marked in the same manner as dedicated storage areas, but are freely accessible to anyone needing to store materials;
- Temporary storage areas are delineated by removable black/yellow markers and are created for a limited time and for a specific need. Prior authorization must be obtained before the zone is set up on site. This type of zone is assigned to a department, section, or for the storage of specific material/equipment;
- The perimeter of a work zone is delimited by red/white markings and materials may be stored in this zone during work activities. The work permit must be permanently posted on the site.

In premises where safety is a major concern, the presence of equipment stored as part of the worksite will only be permitted under permanent supervision. At the end of the activity, or at the end of the day at the latest, this material will be moved to a duly authorized storage location.

The storage of material (combustible or not) is prohibited:

- In premises with high stakes for safety. This classification is determined by a specific analysis and is based on the outcomes of the fire risk analyses (FHA);
- In main control rooms and associated premises belonging to the same fire compartment;
- In stairwells and elevator shafts;
- On exclusion zones associated with firefighting equipment (extinguishers, hydrants, and hose reels);
- On passageways and evacuation routes from premises/buildings (compliance with the legal minimum width to ensure the intervention of emergency services and the evacuation of personnel);
- In the battery rooms and other ATEX areas;
- In FME areas;

- In ventilation ducts and plenums;
- In buildings specifically dedicated to Diesels and associated fuel storage;
- In the Diesel rooms and associated fuel storages of ultimate safety equipment

An exemption to this prohibition is possible and can be granted based on a specific risk analysis.

Additional guidelines related to the storage of materials:

- Fire-resistant blankets: these blankets, available in rolls, are specifically qualified to resist fire during hot work and protect against heat loads, provided, of course, that they are correctly installed and held in place. They are easily identifiable thanks to their marking.
- Fire-rated cabinets: cabinets for storing flammable liquids and aerosols must have EI 90 fire resistance according to NBN EN 13501 [17] parts 2 and 3 (or Rf 1 1/2h according to NBN 713.020 [16] for older cabinets)

**Oils** are subject to additional measures:

- As the oils are combustible, they must be contained in closed metal containers.
- Absorbent rags/papers:
    - To be present for construction sites with oil handling,
    - Laying down absorbent rags/papers as a preventive measure is not permitted,
    - After use, to be placed in the specific metal bins with lids,
    - Bins to be emptied regularly by the responsible department, without waiting for them to be full;
- Storage of oil drums in storage areas in buildings (industrial and administrative) is prohibited, with the exception of the following locations:
    - Buildings dedicated to the storage of new oils and used oils used,
    - Permanent storage areas in areas dedicated to the storage of oil drums and clearly identified as such,
    - The storage area for the storage of used oils awaiting release or decontamination,
    - Temporary storage areas specifically dedicated to the storage of oils for a construction site ,
    - Metal drums intended for permanent leak collection systems,
    - All stored drums will comply with the anti-pollution prevention procedures defined in the environmental permit, namely:
        - Storage on retainers (handling pallet, or other type of retention) of capacity sufficient and correctly placed to perform its function,
        - Retainers must be kept clean and free of oil, absorbent or water;
- Collecting oil leaks:
    - Enclosure in place, or
    - Collection system defined in the leak management procedure.

The **storage of gas** bottles, cylinders and racks (combustible or not) is prohibited on the site, with the exception of the following locations:

- Depots and dedicated storage areas for gases and racks in mobile containers authorized via the environmental permit;
- Dedicated permanent or temporary storage areas, fitted out for the storage of gas cylinders (double attachments) and clearly identified as such;
- Cylinders connected to fixed installations;
- Outdoor storage areas near the mechanical workshops for the storage of welding trolleys;

- The perimeter of a construction site delimited by red and white markings.

**Controls** include quantitative checks of permanent and temporary free storage areas for common use, carried out on an ongoing basis by the maintenance team using a storage database. Qualitative and quantitative checks on allocated storage zones are performed at least every 6 months by the owner and the process manager.
The ISPPW carries out several controls:

- Independent qualitative/quantitative spot checks;
- Checks of all the premises with high safety stakes (as part of the Fire Load Index, see below) and a selection of specific premises: premises with storage areas and a sample of premises with a low to zero load margin.
  This control is recorded in the storage database and the frequency of these checks is adjusted during the overhaul period.

CNT3:

Every storage area, with the exception of worksites, is registered in a dedicated tool and is uniquely identified with a barcode displayed on the location. A maximum allowed calorific load is assigned.
The on-location labelling includes the storage area reference, the maximum allowed calorific load, as well as a short list of the most commonly stored materials and corresponding contribution to the area calorific load allowing a quick semi-quantitative evaluation of the stored calorific load.

For all open storage areas, the equipment stored in them must also be encoded in the tool, as a group for miscellaneous equipment or individually for specific equipment and tools. In the case of the item identified as combustible, an evaluation of its calorific load is carried out, and the total calorific load on the storage area is tracked.

### *Fire Load Index*

CNT3 and KCD3

The Fire Load Index (FLI) is one of the main indicators used for the management of the mobile fire loads in facilities. In particular, it provides an overview of deviations from fire load expectations established in the reference procedure. This index makes it possible to correctly display and monitor fire load violations after which corrective measures can be taken to eliminate these as quickly as possible.

The management of the Fire Load Index is described in a specific procedure that defines the roles and responsibilities in all stages (selection of premises to be assessed, periodicity, stakeholders, corrective actions and communication) leading to the completion of the fire risk assessment related to the presence of mobile fire loads.

In the event of an acute fire hazard and/or of major breach, the ISPPW Fire Safety section, in collaboration with other teams, will take immediate action to limit or eliminate the risk.

CNT3:

The **premises** concerned and assessed under the FLI indicator are divided into four main categories:

1. 94 premises with high safety stakes (excluding DE building) where storage of all types of materials, combustible and non-combustible, is prohibited;
2. 8 premises with high safety stakes in the DE building;

3. Miscellaneous industrial premises (+/- 1050):
    - premises containing safety-related equipment or the control of safety-related equipment,
    - premises containing radioactive substances or waste (controlled/supervised area),
    - premises necessary for the production of electricity (turbine hall),
    - or premises in which a fire may have a direct impact on critical premises, and where there is a significant probability that combustible materials are stored;
4. Premises assessed on request: premises affected by specific worksites (construction, overhaul, etc.) or premises affected by specific events or incidents.

Premises with high safety concern may be temporarily declassified based on a specific risk analysis.

The **periodicity** of the checks depends on the category of the room: weekly for premises with high safety implications and monthly for other industrial premises, but during the outage overhaul period, additional checks are carried out at the plant, preferably on weekends: a second time during the week for premises with a high safety implication and weekly for other industrial premises.

Concerning the **deviation management** and corrective actions:

- Premises with high safety stakes: all deviations identified, without distinction (Fire or housekeeping), must be dealt with urgently and corrective action (typically evacuation) must be taken within 2 working days;
- Other industrial premises:
    - Deviations outside storage areas:
        - All fire or housekeeping deviations must be subject to corrective action,
        - Discrepancies and corrective actions are to be identified via the storage database terminals;
    - Discrepancies in storage areas:
        - All discrepancies are taken into account and corrective action is to be implemented,
        - Discrepancies and corrective actions are to be identified via the storage database terminals and specifically attached to the storage area concerned;
- Delay in resolving discrepancies in various industrial premises:
    - For fire deviations (combustible or flammable material), the corrective action must be taken within 7 days,
    - For housekeeping deviations (non-combustible material), corrective action must be taken within 14 days.

The Fire Load Index indicator is included in the CNT performance indicators.

<u>KCD3:</u>

In addition to the performance indicator (PI) of the amount of fire load, a PI was also developed that indicates the period of time how long it takes to eliminate a breach. This PI provides and indication of Fire Safety Behavior & Fire Safety Awareness, in particular to which extent the seriousness estimated is high enough and prompt action was taken.

Each KCD unit has its own unique fire load index. A global average fire load index is also made for the entire KCD site, based on the indexes per unit.

*Management of the risk of ATEX in the rooms*

CNT3 and KCD3:

All ATEX zones have the following signaling:

- Pictogram: The EX pictogram is placed where ATEX zones may occur;
- Instructions panel: A panel recalling the access rules is placed at the entrances to these ATEX zones;
- Floor painting: ATEX zones are painted on the floor. This painting is squared with the mention EX (except in the case of zoning of the entire room).

When a work needs to be done in an ATEX zone, the instructions are the following:

- Works without consignation:
    - If there is no lockout, ATEX equipment must be used (cleaning, painting, scaffolding, etc.),
    - Explosion-proof tools must be used,
    - ATEX machinery and lighting must be used,
    - Metal tool handles, use wood or polyester. (e.g.: extension cords, paint roller, etc.) have to be avoided, however, stepladders and ladders must be made of wood or polyester (to avoid sparks),
    - Non-sparking tools for, among other things, the erection of scaffolding. (e.g. copper, bronze, etc.) must be used,
    - Working with a watch, a mobile phone, a beep, etc., are prohibited;
- Works with consignation: once the circuit is open, the explosion check has been carried out, and the absence of the risk of explosion has been confirmed, there is no longer any ATEX risk. It is therefore no longer necessary to use explosion-proof tools.

Based on the ATEX risk analysis, each place presenting risks of explosion is classified in zone 0, 1 or 2 according to the frequency and duration of the presence of an explosive atmosphere.

To access an ATEX room, or an ATEX zone, wearing a handset oxygen meter/explosimeter is mandatory. Non-ATEX equipment (watch, beeper, cameras, etc.) must be left outside the area or room. In a controlled area, the dosimeter must be kept.

*Smoking*

CNT3 and KCD3:

Smoking (including electronic devices) is not allowed in all premises except in places designated for this purpose and duly signaled.

#### *3.1.1.3. Licensee's experience of the implementation of the fire prevention*

*General remarks*

CNT3 and KCD3:

- Changing human behaviour was the major barrier to improve, in particular to change the mindset of the employees, essentially from "fire load is allowed" to "Fire Load is not allowed anymore";

- Once that goal is achieved and the fire load is back at an acceptable level, maintaining this level requires continuous efforts. The expectations need to be kept alive and need to be visible in the field otherwise the performance decreases rapidly.

CNT3:

- The site management team openly stating that fire protection is essential has stimulated the organization to improve the level of performance in terms of fire prevention. Having their support is key to improve expectations on site;
- The registration of all locations where fire load can/cannot be stored requires a significant effort.

KCD3:

- To reach a high level in fire preventions, it is important to state that fire safety is not only the responsibility of the Fire Safety team/Operators, but all employees are responsible for this. Putting this focus in the head of all employees is not easy and needs time and efforts;
- Storing gas bottles with acetylene in a dedicated closet requested a lot of effort and sometimes even led to resistance.

*Overview of strengths and weaknesses*

CNT3:

**Strengths**

- The creation of a unique storage database gives the organization a clear overview on the allowed fire load in the unit. (feedback WANO PR & NEIL);
- A solid process is in place to manage the consignment of fire doors (blocked open). After approval, the wedge to block the fire door can be collected at the Main Control Room. This allows the operators to have a clear view on authorised blocked open fire doors at any time. The process allows people in the field to verify if it is allowed to block open the fire door. (evaluated as a strength during WANO PR);
- In the maintenance department, a team has been dedicated to organize the management of the storage of the mobile fire load. They can rapidly react to correct deviations or to remove unauthorized fire load;
- The field visits from NEIL and WANO confirmed that housekeeping and fire load storage management are well managed;

**Weaknesses**

- The verification and inspection process of the status of the seals in fire resistant concrete dals is implemented but not yet integrated in all the maintenance procedures.

KCD3:

**Strengths:**

- The process implemented to manage fire load during the outages was very clear to all employees and its results showed a decrease of fire load during every outage.
- A seismically constructed building houses the emergency equipment to independently cope with loss of off-site power, complete station black out, flooding, on-site and off-site radiation & contamination and a fire on the reactor building after an airplane crash on the reactor building.

***Lessons learned from events, reviews fire safety related missions, etc.***

CNT3 and KCD3:

- WANO Technical Support Mission in Blayais (France) with a focus on fire load led to the development of a new fire load strategy and management.
- The European stress test project after the Fukushima-accident resulted in the purchase of a fire truck that is able to spray water on top of the reactor building.

CNT3:

- After a car fire on the parking lot in CNT, an assessment took place on the available documentation that is provided for the public fire brigade. As a result, additional documents to share with the external emergency services were developed. This improves the safe and efficient intervention on site (outside of the buildings).
- Following information from an external event, a dedicated training on a transformer fire has been organised for the relevant personnel.

KCD3

- After a fire in an electrical switch board, a preventive thermographic screening will be implemented and this screening has been added to the maintenance plans;
- The firefighting equipment was evaluated after a car fire in CNT, see above, and a large fire blanket has been bought to handle a fire of an electrical car.

***Overview of actions and implementation status***

CNT3:

- Improvement of all the documents used for fire protection/inspection: procedures, checklists, etc. were updated and in line with the document management expectations;
- The action plan to manage the turnover of team members of the ESI team requires a continuous follow-up;
- The project to flush the fire water supply system is finished. The one-shot flushing of this has been done in all buildings. To assure the system remains clean on the long term, its flushing has been integrated in the work processes: A software-tool used to monitor the start of the pumps and the injection of the water from the river followed by an evaluation and identification of the part of the system that is potentially polluted. A procedure to flush the polluted part is developed and put in place;
- The 15/25-years control of operation of the fire water supply system has started and a priority list has been made;
- The control of the Carbon steel pipes was recently done. The frequency of this control is once every 5 years;
- All fire doors in critical rooms are replaced;

KCD3:

- The fire trucks were updated and underwent a large maintenance work;
- The replacement of several fire doors in critical rooms is started. The list of fire doors in non-critical rooms is in development;
- The project to improve the fire resistant seals in concrete dals has started;
- The replacement of fire dampers is undergoing some delay due to Asbestos that has been found in the fire dampers;
- The action plan to increase resources, knowledge, competences and experience in the Fire Safety Operators team is ongoing and closely monitored;

- Based on the FHA analysis, additional fire detection has been added in spent fuel building of KCD3.

#### *3.1.1.4. Regulator's assessment of the fire prevention*

See under §3.5.1.

### 3.1.2. Research reactors

#### *3.1.2.1. Design considerations and prevention means*

The governing processes and instructions at SCK CEN related to fire prevention are fully implemented at the BR2 reactor. On top of the general procedures of SCK CEN, the BR2 reactor has additional instructions and means with regards to fire prevention.

The basis is described in the fire safety policy document which describes the principles and refers to several sub processes. This policy lists the minimum requirements with regards to fire safety based on legislation, norms and standards (obligatory and optional) and applicable procedures within SCK CEN.

A second part of the policy details the technical requirements for i.e. evacuation and access routes, construction, compartmentalization, HVAC, elevators, emergency lighting. The goal is to minimize the likelihood of fire through standardized, validated design specifications.

The practical implementation of minimizing the likelihood of fire in an installation is mainly achieved by controlling ignition sources and fire loads. The starting point is the latest version of the fire safety analysis. This analysis weighs ignition potential and fire load as basic parameters for risk assessment.

If, for example, the reactor itself or the experimental facilities require the use of flammable gases ($H_2$, $CH_4$...), a specific risk analysis is carried out to determine whether:

- there is no alternative gas with less hazardous characteristics;
- it is really needed to store the flammable gases in the reactor building, or whether they can be stored outside;
- what is the best place when it can only be placed in a room in the reactor building. Consideration is given to adequate ventilation, presence of fire detection, presence of gas detection, additional fire loads, situation of the compartmentalization, proximity to reactor SSC's, presence of potential igniters, clear risk signage, applicability of ATEX regulations and the need of an Explosion Safety Document.

#### *3.1.2.2. Overview of arrangements for management and control of fire load and ignition sources*

Several processes are in place to control and minimize fire loads and potential ignition sources. For each location in the facility, an inventory of mobile fire loads (tables, chairs, gas bottles, packaging materials...) is made. This information is incorporated into the fire safety analysis, as the reduction of the fire loads can lead to a reduction of the risk in the room.

Several forms of walk-down/inspection of the BR2 facility are undertaken to, among other things, assess the presence of fire loads and ignition sources:

- In general, location with a higher potential fire risk, as indicated in the intervention plans drawn up on the basis of the fire safety analysis, will receive greater attention during regular walkdowns;
- Every year, a major "Health and Safety" walkdown takes place at the BR2 with representatives of the operator, the labour unions, fire brigade, industrial safety and environment. This walkdown focusses on several aspects, amongst which is fire safety;
- In addition to these inspections, representatives of the insurance companies of the SCK CEN organize an annual inspection, that focuses primarily on fire safety;

- Before each BR2 operating cycle, operators perform a fire safety inspection of the facility. This inspection covers not only fire loads, but also the availability of fire extinguishers, the functioning of fire doors, emergency lighting, etc. In addition to these regular internal inspections, an external company verifies the availability of the fire extinguishers once a year;
- Technical inspections and preventive maintenance are also foreseen to reduce the risk of fire ignition. These include thermographic control of electrical cabinets (once per year), emergency lighting battery replacements (every 5 years), etc..

For specific operations and activities, standard control procedures are not sufficient. For any activity involving the use of hot work (open flames, welding, grinding, …) and which can provoke the activation of the fire detection system, a hot work permit is required. In the hot work form, the fire risk is evaluated by the operator or task responsible, and measures are proposed to reduce the risk to a reasonably acceptable level. The following aspects are taken into account:

- Environment: proximity of fire loads and/or EX-zones, work in confined spaces, availability of fire detection, etc.;
- Prevention: ventilation, O2 measurements, signalization, use of personal protective equipment (PPE), deactivation of fire detection;
- Protection: availability of hydrants, other fire extinguishing needs, alarm procedure, need for greater availability of firefighters.

The hot work form is submitted to and approved by the internal fire department. In general, hot work is approved for one working day, but can be prolonged if needed. Some specific locations presenting a permanent fire risk (i.e. workshops) may be granted a permit for up to one year.

In addition, for non-standard operations or activities, a specific form must be completed and submitted. This form describes the task to be performed and the type of risk analysis to be provided. A specific part of the risk analysis also refers to the potential fire safety risk, even if it is not applicable. This procedure for non-standard operations or activities also makes it possible to detect whether a hot work permit has been mistakenly or inadvertently deemed unnecessary.

##### *3.1.2.3. Licensee's experience of the implementation of the fire prevention*

See under §3.4.2

##### *3.1.2.4. Regulator's assessment of the fire prevention*

See under §3.5.2.

### 3.1.3. Fuel cycle facilities

Not applicable.

### 3.1.4. Spent fuel storage facilities

The SCG does not normally contain any combustible materials. Fire loads are mainly present in the employee area in the form of clothing, electrical appliances and cables, electronic equipment, etc., and in the entrance hall in the form of oil.

The risk of fire due to the electrical installation is minimized by the choice of materials and dimensions. Possible causes of fire are an external accident or an incident with the means of transport (loss of fuel). In the event of a fire in a means of transport, the fire brigade intervenes and the public fire brigade may be called in.

#### *3.1.4.1. Design considerations and prevention means*

The only credible events leading to a fire that could affect the spent fuel are an external accident, aircraft crash in particular, or an incident with the means of transport. The amount of fuel that could be released in the event of an incident with the means of transport is not significant and certainly insufficient to damage the container and its contents, and a fire resulting from the crash of an aircraft is therefore taken as a design limit case.
The consequences of the kerosene fire, 600°C for 1 hour, were analysed in the safety assessment report for the containers stored in the SCG, and it was demonstrated that the sealing system retained its integrity. Furthermore, all other temperature limits are also respected, except those for the neutron-absorbing resin compound, which can partially degrade. Subsequently, it was demonstrated that even in the very pessimistic assumption that this resin compound would disappear completely, the resulting increase in radiation levels would still meet the safety objectives defined for accidental conditions.

Since the integrity of the container is not affected in case of fire, the terminology of ANSI/ANS 57.9 [39] is adopted for the subsystems without considering the risk of contamination. These four subsystems are:

1. The subsystem of the staff areas covers areas with a fire risk due to the administration and storage of equipment;
2. The main building subsystem (incl. the loading hall and storage hall) consists of places with limited risk of fire:
    - The load-bearing elements of the rooms of the technical zone have a fire resistance of at least 1 hour,
    - The loading hall door is considered an external door;
3. The process subsystem corresponds to areas with limited fire risk;.
4. The site subsystem is made up of places with limited fire risk, such as the zones around the building.

SF2: Both SF2 installations feature a kerosene drainage system. This system was however not credited in the accident analysis.

##### *3.1.4.2. Overview of arrangements for management and control of fire load and ignition sources*

The administrative controls applicable for KCD3 (see §3.1.2.2) also apply to the SCG and to SF2.

##### *3.1.4.3. Licensee's experience of the implementation of the fire prevention*

A strength for the SCG installation is that the approach for fire prevention is the same as for the reactor plants and that lower standards are not applied and not accepted.

A potential weakness is that the building is less visited (less easy to access, low risk for fire) and may thus be overlooked during controls at the site. It was thus decided to explicitly add relevant SCG rooms to the fire load walk downs.

### 3.1.5. Waste storage facilities

Not applicable.

### 3.1.6. Installations under decommissioning

See under §3.1.1.

## 3.2. Active fire protection

### 3.2.1. Nuclear power plants

#### *3.2.1.1. Fire detection and alarm provisions*

The goal of the fire detection provisions is to detect fire in the early stage, send the notification to the main control room via the control panel and interact with the other supervised systems such as the automatic fire suppression and the ventilation.

***Design approach***

CNT3 and KCD3

The fire alarm system contains the following elements:

- Fire alarm control panels or control unit;
- Alarm initiating devices such as detectors, push buttons, etc.;
- Alarm notification devices such as bells, lights, etc.;
- Primary and backup power supplies;
- A remote alarm interface (supervision station).

Fire detection is organized by area or zone, and fire detectors are interconnected to form a detector network or loop. According to the applicable standard [15], a loop may cover only a single fire compartment, and fire-resistant cabling is used to cross compartment-boundaries.
The number and type of fire detection equipment depend on the area, the type of equipment to be protected and the type of fire risk to be covered (optical detectors thermal detectors, flame detectors, etc.). The detectors mainly secure electrical equipment and cable trays as well as the turbine oil tank, diesel engines, laboratories and transformers located outdoors. Where required by a risk analysis, additional fire detectors are installed, for instance inside an electrical cabinet.

This fire detection network is monitored by fire alarm control panels and enables rapid detection and location of any onset of fire. All the fire alarm control panels have a dedicated back-up power supply, in addition to the battery-powered operation required by the design standard. All the fire alarm control units can be supplied by a redundant electrical network. The fire alarm control unit transmits a notification to the supervision station in the main control room. In case of loss of the main power supply, a back-up power supply is automatically provided to ensure operation of all systems.

Alarms can be triggered in the main control room but also in the installation. The alarm in the main control room is both visual and acoustic. It has a unique character that distinguishes it from all other alarms in the main control room. The alarm in the field is only acoustic.

Fire alarm systems are also designed to monitor the actuation of suppression systems. Specific devices detect the activation of suppression systems and initiate an alarm signal. This actuation signal is then detected by the fire control panel in the same way as an alarm signal from a fire detector.

In the electronic relay rooms, the detectors are placed on the cabinets, while others are fixed to the ceiling. In the main control room, the cabinets are also secured, but the back-up detectors are placed in the air ducts. In the cable cellars, the detectors are attached to the ceiling, triggering a faster action than the sprinkler heads. The two systems combined provide a pre-alarm and an alarm.

Safety diesel generators are monitored by means of a diverse detection system (smoke detectors, combined smoke and thermal detectors (i.e. multi-criteria) and flame detectors). The automatic extinguishing system is started only when a smoke detector and a flame detector are activated. This measure is implemented to prevent premature diesel spraying.

The cable ducts in the unit's various buildings and galleries are protected by detectors located above or in the immediate vicinity of the monitored area.

In the electrical rooms, the detection system consists mainly of light-scattering smoke detectors. In rooms where smoke can form, the detectors are adapted to local conditions.

Some detection systems (safety diesels - primary pumps) are composed of different types of detectors (smoke detectors / combined smoke and thermal detectors / flame detectors). The purpose of such a combination of detectors is always to increase performance in line with the local risk to be overcome.

CNT3:

To anticipate an obsolescence issue on the fire detection system – as the manufacturer announced that the current line of products will be discontinued, all systems are being replaced by the end 2023.

The main guidelines for fire detection design are NBN S21-100 part 1 and 2 [15] and NBN EN 54 [18].

*Types, main characteristics and performance expectations*

CNT3 and KCD3:

Fire alarm systems are designed to provide a rapid detection of a fire and notification on the main fire control panel located in the main control room, so that operators can respond as quickly as possible.

The detection system is also designed to automatically initiate suppression. When the actuation of a fire protection feature is likely to interact with a (classified) safety-related system, the manual confirmation by the main control room operator is required to start the actuation.

The type of detectors, designed to withstand the relevant ambient/hazard conditions, are:

- Smoke detectors;
- Multi criteria detector;
- Flame detectors;
- Air sampling detectors;
- Beam detectors for the very big volumes;
- Thermal sensors inside the ventilation duct (charcoal filters protection);
- Detectors for explosive gasses.

In addition, push buttons are present in order to manually report a fire detection by plant operators.

Main performance expectations are:

- The fire detection system shall not be subject to spurious alarms;
- The fire detection system shall remain operational after an SSE;
- The fire alarm shall be available in the main control room after an SSE;
- The fire alarm material shall have the BOSEC[9] certification.

Actions of the fire detection system:

- Send alarm to the remote alarm interface in the main control room;
- Provide an audible alarm in the affected room;
- Close of fire dampers and stop the ventilation;
- Initiate fire suppression.

The power supply of the fire detection system is in accordance with the initial design recommendations of the RG 1.120 [37] rev. 1 par C.5.a (6) a, with a power supply by batteries with a minimum autonomy of 3 hours (resp. 4 hours), given that the applicable national standards requires a 24h autonomy.

The main control room is equipped with a panel displaying all the indications of the fire protection system. Each alarm system is displayed individually, so that each fire can be located immediately. This enables operators to correctly assess the situation and take immediate action.

The warning and alarm panel provides the following information:

- the operation of each fire detection system including the signalling "in operation" or "out of operation",
- the operation of each automatic extinguishing system,
- the "open" position of valves,
- the signalling and alarm of all fire pumps,

CNT3: the following fire detection devices are installed:

- 11 alarm control panels;
- 5059 detectors divided into:
  - 24 smoke optic detectors in the reactor building,
  - 13 air sampling detectors,
  - 18 flame detectors,
  - 13 beam detectors,
  - 4933 multi-criteria detectors,
  - 58 explosion gas detectors;
- 204 detection loops.

***Alternative/temporary provisions***

CNT3 and KCD3

According to the technical specifications, alternative means shall be put in place in case of impairment on the fire detection functionality, by installing a specific mobile detection system or by the organization of a fire watch. These measures are listed in a dedicated procedure, and shall be taken in parallel with corrective actions to make the equipment available again.

[9] BOSEC is a Belgian quality and certification label for fire protection systems.

*3.2.1.2. Fire suppression provisions*

### *Design approach*

CNT3 and KCD3:

Fire suppression equipment of appropriate capacity and sufficient performance is available; it is designed in such a way that its failure, breakage or spurious start does not compromise the safety functions of the structures, systems and components for the safe reactor shutdown.

The goal of the fire suppression system is to control or extinguish the fire. The fire suppression system consists of the following components:

- Water supply system;
- Manual extinguishing system;
- Automatic extinguishing system;
- Specific fire suppression systems.

KCD3:

Fire safety design provisions have not been designed for extensive dismantling activities. In POP-2 and POP-3, when spent nuclear fuel is still present, such extensive dismantling activities are not planned, and it is therefore not necessary to reinforce fire protection provisions.
In later stages, specific dedicated fire risk analyses will be performed to evaluate the need for reinforcement of the fire safety design provisions in function of the specific dismantling activities planned.

### Water supply system

CNT3 and KCD3:

Concerning the design approach of the water supply systems:

- The water supply system is designed to supply fire suppression water to any point on the sites and is resistant to a single failure;
- The outside hydrants are connected to the fire main with a maximum distance of 75 m between them;
- The outside hydrants are installed so that each external wall of each building can be covered by at least two hydrants;
- Each building is connected to the fire water circuit, commonly at two different points.

Besides insurer's requirements, the following standards and guidelines apply to fire mains: RG1.189 [34], NFPA 13 [42], NFPA 15 [43] and ASME B31.1

CNT3

The fire main is divided into two parts: an underground part and an open-air part (made of carbon steel). The underground part of the fire main is a yard loop that surrounds the plant site and provides firewater to the site. The main water source is the river. The fire main can be isolated and sectionalized by control valves (with visual position indication).

Concerning the design approach:

- Two low-volume pumps are installed in the fire circuit to keep the fire circuit filled with clean water. The low-volume pumps can also supply water for the small demands (<400m³), so that the fire pump does not start at any time;

- A pressurizer tank is connected on one side to the fire main and on the other to the well via a dedicated pump. The whole system keeps the fire main pressurized (~10bar) and provides clear water for small demand (<15m³/h);
- Both fire pumps are designed to start automatically at 7.1 bar and 6.2 bar respectively. Both pumps can also be started manually from the main control room;
- The clear water supply pumps are designed to provide a maximum flow rate of 400 m³/h;
- The raw water and ultimate water circuits are designed for seismic Category I and are equipped with hydrants preceded by a manual isolation valve. This allows all equipment necessary for safe shutdown of the plant to be protected in the event of an earthquake;
- The design of the portable extinguisher (extinguishing agent, quantity, location, etc.) depends on the risk being protected.

KCD3:

The extinguishing circuit is fed by three electric pumps, each connected to a pipeline for supplying pond water. The pumps are located in the bunkered emergency building. They force the water into two collectors, each feeding the main loop separately. The main (external) loop belongs to seismic Category I, except for the part in the turbine hall. This makes it possible, after an SSE, to supply the extinguishing nozzles in the vicinity of safety-related equipment.

Two pumps are sufficient to supply the design flow rate determined by the sum of the flow rate, required for the manual extinguishing systems, hydrants, reels, as well as the largest flow rate, requested by the opening of the sprinkler heads in the largest fire zone.

The main loop of the fire water network of the site consists of a yard loop around the unit, fed at two points by pipes from the main pumps. Isolation valves with visible position, which are normally open, allow any defective part of the loop to be isolated. Connectors are used to supply the various parts of the unit. They all have an isolation valve outside the building, which is normally open and whose position is visible.

The main loop is connected to the KCD1/KCD2 fire-fighting network (for which a new pumping station has been built in the framework of the LTO (>2015) project) and which can be used to fight a fire when the standard network would be unavailable.

**Manual extinguishing systems means**

CNT3 and KCD3:

Outside hydrants are connected to the fire main and are used for manual firefighting. Standpipes provide fire hose connections within building for manual firefighting. The hose stations are located so that water can be discharged through hoses and nozzles and reach the necessary fire hazards. Hose stations are supplied by the riser (wet supply piping inside buildings).

Portable extinguishing equipment is installed in the plant to enable plant personnel to fight fires quickly at an early stage. The location and type of fire extinguisher are such that they are appropriate for the fire risk being protected and that there is no negative impact on safety equipment.

Hydrants are the backup system for firefighting:

- automatic fire protection systems in cable distribution rooms and in areas where cable concentration is generally high;
- manual fire-fighting systems in the main control room and in electrical equipment rooms, such as power boards, transformers, rectifiers and inverters, relay boxes and computers.

Fire-fighting inside the reactor building:

- The fire water network within the reactor building is fed from the main pump manifold;
- Two valves in series, one in the bunker and the other outside the containment, are responsible for isolating them.

*Types, main characteristics and performance expectations*

This paragraph describes the design details of the fire suppression provisions and is therefore specific to each site. In general, the characteristics and performance of the fire suppression system are defined in such a way as to ensure adequate protection against the risk and its activation must not pose a safety issue.

CNT3:

The characteristics of the **water supply system** are:

- Two main fire electric motor pumps (2x100% capacity) with qualified electrical power supply;
- The nominal flow rate of each pump is 600 $m^3$/h at 10 bar. Each pump can reach a flow rate of 900 $m^3$/h (150% of nominal flow rate) at 8 bar;
- Water is drawn from the river after filtration. In normal operation, the fire main is filled with demineralized water (clear water);
- The fire water supply system is designed to be available in case of Loss of Offsite Power as the pumps are supplied by the diesel generators;
- The underground fire main pipes are in Bondstrand fiberglass (Glass Reinforced Epoxy or GRE) which are less prone to degradation;
- Aerial fire pipes are made of either carbon steel or GRE depending the size of the pipe (<4'': carbon steel and >= 4'': GRE).

The characteristics of the **manual extinguishing systems** are:

- Hydraulically connected with fire water supply system:
  - Outside hydrants (type BH 100) are connected to the fire main and are used for manual firefighting,
  - Standpipes and Hose: coupling DSP 45,
  - Reels: semi rigid pipe;
- Portable and mobile fire extinguisher:
  - Powder,
  - CO2,
  - Foam;
- Performance expectation:
  - Exterior fire hydrants are distributed to cover the occurrence of a fire in all buildings,
  - Interior hydrants/reels are distributed so that all building points can be reached with at least two lances,

    - A minimum of two seismic hydrants must be capable of supplying a flow rate of 17 $m^3/h$ per hydrant.

The characteristics of the **automatic extinguishing systems** are as follows:

- The automatic extinguishing system is hydraulically connected to the fire water supply circuit and contains:
    - Sprinkler systems, maintained under pressure (water or compressed air) and actuated by the rupture of quartzoid bulbs as the consequence of temperature rise,
    - Deluge systems (open-head sprinklers), actuated by the automatic fire detection;
- The fire suppression system is not designed for seismic Category I. However, raw water and ultimate water supply circuits designed for seismic Category I are fitted, at carefully chosen locations, with unclassified hydrants preceded by a manual isolation valve. In this way, in the event of an earthquake any equipment needed to safely shut down the unit can be protected from one or two of these water points;
- Expected performance:
    - Active protection stations are sized according to NFPA requirements,
    - Main pumps must be capable of delivering 600 $m^3/h$ and 10 bar per pump, although in overload they can reach a flow rate of 900 $m^3/h$ to guarantee the highest sprinkler flow rate (696 $m^3/h$) and the flow rate for fire hydrants (192 $m^3/h$).

<u>KCD3:</u>

The main fire water loop belongs to seismic Category I, except for the section located in the turbine hall. This means that, after a 'safe shutdown earthquake', at least the extinguishing nozzles of the equipment with a nuclear safety function can be supplied with water.

In the POP configuration, the three pumps for extinguishing water must remain available as specified in the applicable technical specifications.

The characteristics of the **water supply system** are:

- Water reserve:
    - The water reserve is formed by the lake/pond. The continuously available amount of water is 2000$m^3$;
- Main pumps:
    - The fire-fighting circuit is fed by three electric pumps, each with a pipe line for the supply of pond water. The pumps are located in the bunker. They force the water into two collectors that each separately feed the main loop. Downstream of the non-return valves isolation valves are fitted. A pipe line, starting from each collector, allows the fire protection systems of the intermediate space and of the primary containment with water,
    - The pumps have the following characteristics:
        - Nominal flow rate : 360 m3/h,
        - Manometric head at nominal flow rate: 9.5 bar;
    - Activation of the fire pumps is caused:
        - Either by local manual control,
        - Or by a pressure loss in the system;
    - The pumps can only be stopped locally;

- Auxiliary pump:
    - An auxiliary pump makes it possible to keep the extinguishing system continuously under pressure. To isolate the pump from the circuit isolation valves are fitted. An expansion vessel is fitted downstream the discharge valve of the auxiliary pump.

The characteristics of the **manual extinguishing systems** are:

- During normal operation of the reactor, the valves on the containment penetrations of the FE-system are open. They are closed after the containment isolation signal.
- Fire hydrant
    - The fire hydrant connection within the reactor building consists of reinforced fire hydrants, placed on four separate main columns in the vicinity of the stairs. These columns are fed by a common collector;
    - Around the unit, every 75 m and at approximately 15 m from the buildings, hydrants fed by the main loop are available. Every 300 m there are enclosed fire protection posts with fire extinguishing equipment placed (fire hoses, fire pumps and accessories).
    - In accordance with the alternative recommendation of the RG 1.120 rev. 1 [37], these fire protection posts may be replaced by a trolley containing a quantity of equipment corresponding to the contents of 3 fire stations.

***Management of harmful effects and consequential hazards***

CNT3 and KCD3:

When water is used as the extinguishing fluid for safety equipment, the damage is limited to the immediate vicinity of the fire, and the unit can still be safely shut down thanks to the physical separation of redundant safety equipment.

The fire protection system is designed so that its malfunction or untimely start has no impact on the safety functions. The fire detection system and the safety systems are designed so that a single malfunction would have no effect on the fire protection of the unit.
Moreover, it was verified in the frame of the Periodic Safety Review in 2007 that sprinkling and internal flooding have no impact on safety equipment.

If there is no fixed fire protection, protection is provided by portable fire extinguishers. The extinguishing agent is chosen according to the pieces of equipment to be protected. It will not adversely affect safety equipment.

***Alternative/temporary provisions***

CNT3 and KCD3:

In case of unavailability of the redundant fire pumps, the connection with the other units is opened and their pumps made already available. At the same time, the effort is made to make the pump available again.

Portable fire extinguishers are installed in all buildings of the plant and especially where there is no fixed fire extinguishing equipment. Their installation is determined in accordance with the requirements of the NFPA standards.

#### *3.2.1.3. Administrative and organisational fire protection issues*

**Firefighting strategies and responsibilities**

For historical reasons and because of the difference in the sites' environments (e.g. proximity of the external fire brigade), the organizations in terms of rales and staffing differ between CNT and KCD.

CNT3 and KCD3:

All employees on site can do a first intervention if possible and safe with mobile fire extinguishers wall reels, etc. that are present at several locations.

For both units (and sites), an intervention team is present 24/7 on site. Their most important task is to react to unwanted events, such as fires. If a fire is detected via the automatic fire detection system or by an automatic activation of the fire extinguishing system, a scout is sent out to perform a local verification. Once the fire is confirmed, the intervention team is alarmed. If the fire alarm is reported via the emergency number, the intervention team is directly activated, without a local verification; in that case, the person calling acted as the scout.

In the event of intervention in the installations, mobilization takes place as follows:

- The access to the building where the fire is located is assured by the site security officer;
- The intervention team enters the building through the opened attack gate. On their way through the installation, they roll out a red and white ribbon to the scene of the incident. In a later phase, this ribbon will serve as signposting for the public emergency services, who also enter the building via the same attack gate;
- in the event of intervention in a controlled area, the intervention team is accompanied by a radiation protection expert to give advice about the radiological risks.

If the external fire fighters or public fire brigade are called upon, they will be guided by a site security officer to the rendezvous point and they will take the lead of the intervention upon their arrival. The interactions of public and internal emergency services are adequately documented. Dosimeters for the fire fighters of the public fire brigade are available.

CNT3:

Each of the 3 units of the plant has a permanent **first intervention team** (EPI) that is permanently on site, 24/7. The team intervenes within the framework of the internal emergency plan for any accident situation, including fire events.

Each team is made up of at least 5 people, members of operating teams on shift, to whom a specific role is assigned. One of them is the team leader and at least two are trained in the basics of firefighting (use of fire extinguishers and hose reels). If necessary, the EPI of one unit can act as reinforcement for another unit.

The **second intervention team** (ESI) was created in 2015 to strengthen the organization and to reinforce the first intervention team and ESI comes into force according to procedures described in the emergency process.

The team consists of at least 2 qualified firefighters, permanently present, and a firefighter coordinator during working hours. The members also work as voluntary firefighters for an external fire brigade, which allows them to maintain a good level of knowledge and experience of firefighting.

**External firefighters** are quartered in the same street opposite of the CNT site, which is a unique feature of the site, and which allows for a rapid intervention; they are systematically called upon for each fire event unless otherwise decided based on the assessment of the situation by the ESI. The external firefighting brigade ensures a permanence of 13 agents (11 at night).

<u>KCD3</u>:

The **first intervention** can be carried out by the person in the immediate vicinity of the fire event by using the available fire extinguishers, wall reels, etc. if possible and safe and decide whether support is needed. When necessary and possible, a corrective action can be initiated at this stage.

The **second intervention** is carried out by the KCD (internal) fire brigade team which consists of at least 5 members, including 1 team leader.

The **public fire brigade** is located in the nearby town of Beveren. Regular drills and exercise have demonstrated an intervention time below 20 minutes (usually around 15 min. between call and arrival on-site).

**Administrative assurance**

<u>CNT3 and KCD3:</u>

The fire protection strategy is oversighted by a dedicated fire protection section of the ISPPW, which has the responsibility to organize a fire- and emergency management system, covering all areas related to facilities and day-to-day operations, and regularly evaluate this system to keep risks under control. The fire management system covers: fire prevention, training of personnel and monitoring of fire protection installations; the emergency management system covers: resources required by intervention and on-call teams, hospital assistance, coordination with the relevant authorities, and the conduct and evaluation of drills.

More specifically, the dedicated fire protection section of the ISPPW has the tasks to:

- Contribute to the organization of firefighting at the plant as defined in the internal emergency plan and in the firefighting strategy;
- Organize, carry out and formalize various functional testing of equipment, other visual inspections and controls;
- Ensure the requalification of fire protection equipment after maintenance (annual and five-yearly) or after triggering (functional tests, etc.);
- Ensure documentation management for fire protection topics, such as:
    - Procedures and forms for tests, inspections and requalification,
    - Maintenance plans associated with the control procedures,
    - Technical datasheets, "Firefighters" intervention sheets,
    - Plans related to emergency and fire management (fire layer of the site Masterplan, etc.);
- Ensure management of portable fire extinguishers: periodic control, placement of new devices, provision for temporary activities, etc.;
- Ensure the management of “breathing air” equipment;

- Ensure the management of emergency and fire equipment:
- Manage the Fire Load Index indicator;
- Provide technical and logistical assistance to certain specific projects: including work at height, confined spaces, storage strategy, etc.;
- Ensure intervention in the case of an event or an emergency (within or outside the Internal Emergency Plan): personal accidents, start of a fire, environmental pollution and other miscellaneous and specific risks;
- Ensure the formation and training of the personnel responsible for interventions;
- Ensure operational relations with the public fire brigade:
  - Implementation and monitoring of the agreement with the public fire brigade,
  - Organization and execution of joint exercises,
  - Organization of specific exercise days.

CNT3:

A specific lockout process for the Fire Resistant (RF) doors is put in place. If a plant operation requires to keep a RF-door open, this can only be done using dedicated wedges available in the unit´s main control room. The number and location of open RF-doors resulting in the unavailability of compartmentalization is kept under permanent supervision. This process was identified as a good practice by a WANO peer-review in 2022.

**Training, drills and exercises**

CNT3 and KCD3:

Dedicated procedures describe the criteria to organise fire drills, intervention exercises and emergency exercises. This includes a list of themes, incidents, events, participants, etc. for the different exercises.

Fire drills are periodically organized to check the effectiveness of the intervention personnel. These drills aim to highlight the strengths, weaknesses, and potential areas for improvement in terms of equipment, technical and human resources, and the adequacy of procedures. They constitute an essential element of training and also make it possible to check the functioning of groups of responders who have to interact in an emergency or crisis situation. Each drill is subject to a feedback analysis.

Exercises may be announced in advance or undertaken without advance notice. In any case they are part of the "Emergency Plan" exercise program. Specific objectives are:

- To identify possibilities for improving the internal emergency plans;
- Demonstrate the efficiency of procedures and equipment, the adaptation of intervention systems and resources in conventional emergencies or personal accidents;
- To test the adaptability of the intervention team and the ability to make forecasts on the likely evolution of the situation;
- To verify the alert and mobilization process of the intervention team, the communication between the different team members (internal intervention team, duty roles, security officers, public emergency services, etc.) and the distribution and delegation of responsibilities for each role;
- To assess that the parties involved know their roles well and are able to carry them out.

Specific field exercises focus on tasks and coordination of "field resources", i.e. the people and teams called upon to work on site, or in the surrounding area, in an emergency situation. These exercises evaluate the integrated performance of internal teams (management, technicians, security, intervention team...), police, first aid, public firefighting, etc.
An on-the-spot debriefing is organized directly with all participants to build up the feedback on exercise.

Scenarios and themes for the exercise are selected from inputs such as the risk register, specific local hazards, recent (near-) accidents of more standard scenarios. The scenario/theme is selected according to the plant circumstances and, in all cases, by alternating scenarios from one year to on the next with the same team.

An annual training program is scheduled for all emergency responders to ensure that the internal emergency plan remains effective.

The internal emergency plan is regularly evaluated through global and/or targeted exercises on one or more roles or themes. These exercises - carried out at all levels of the organization and several times a year - mobilize, depending on the scenario, all or some of the actors involved in the emergency.
To this end, an annual exercise program is established by the ISPPW department to ensure that the internal emergency plan remains effective.

These internal emergency exercises aim to:
- Improve the chronological management of a crisis;
- Familiarize players with crisis tasks, tools and documents;
- Improve the process and adapt procedures accordingly;
- Integrate feedback into future practices.

Exercises are part of an annual and long-term schedule (5 years) considering the schedules of other organizations, such as national emergency exercises.

In addition to classroom trainings, each duty role member participates in at least one large-scale exercise per year. To ensure the effective participation of each duty role member in all training courses, a participation table is kept.

Each duty role member and first response team member must follow an initial training course (basic training) and continuous training (refresher courses and exercises) after which a certification (qualification) is granted to perform the role assigned to him in an emergency situation.

This qualification may be renewed later subject to reassessment by the line manager, participation in continuous training including theoretical refresher courses and participation in practical exercises.

For emergency-related roles, a qualification system through training and exercises is set up and monitored by the training department and/or the site's Emergency and Fire Plan managers.

At least one fire exercise is carried out annually in collaboration with the public fire brigade.

CNT3:

At a minimum, one practical emergency exercise per year must be organized for each shift team, representing a total of 21 exercises.

The heath physics department develops the emergency drill program by combining the different categories and types of exercises listed in procedure, considering the following aspects:

- At least one exercise per year must be of a multi-unit nature;
- Some exercises must be carried out once a year, such as national emergency exercises;
- As far as possible, effective succession of the on-call management team will be tested during these exercises;
- A balance between short and long exercises is sought, with 1 exercise in 3 (per team) focusing on a long theme;
- A rotation of the exercise types is organized over a 5-year period;
- A team-building exercise is also carried out every year.

A specific firefighting training program on simulator has also been developed.

For first intervention team roles, a procedure lists the criteria in the form of tables:

- Prerequisite:
  - Instructions to staff in emergency situations
  - Knowledge of the Tihange facilities
- Basis:
  - Pollution prevention agent
  - Fire Fighting – Fire School
  - Basis for the first aid at Tihange
  - Basic knowledge of hazardous products, including application to kerosene
  - General knowledge of the first intervention process
  - Emergency Specific Means
  - Means for sampling radioactive liquids
  - Means for sampling radioactive gases
  - Security: respiratory protection devices
- Recycling:
  - First aid
  - Deployment of the reception and back-up centre
  - Location of deployment of the reception and back-up centre
  - Firefighting - recycling
  - Training EPI – Return of experience
  - Revision of the process related to the EPI
  - Exercises EPI
  - Evacuation

KCD3:

A minimum frequency of 2 drills per intervention team per year has been set. This minimum must be achieved by each intervention team member in order to retain his/her rating. In practice, the aim is for a higher drill frequency, namely 2 per team, per entity and per year. Failure to meet the target frequency due to illness, leave or cancellation of a drill has no impact on the authorization of the individual intervention team member.

Fire brigade drills are spread over the entire calendar year so that each operations team can attend 1 drill per year. Every operation team member must participate in at least 1 drill over a period of 3 years.

Fire drills are organised by the health physics department and are assessed by an external observer, specialized in the subject matter. This observer observes and grades according to certain criteria. If the intervention team underperforms, the drill is repeated for the entire intervention team, in consultation with the health physics department.

The content of the drills (type of fire source/location/...) is focussed on the high-risk locations:

- Rooms in which fuel is stored or pumped;
- Oil rooms ;
- Cable rooms and galleries;
- Rooms where hazardous chemical agents are stored
- Oil-filled transformers;
- EX zones;
- (Active Carbon) filters and rooms.

Depending on the introduction of new firefighting equipment and techniques, relevant feedback and experience management, the content of the fire brigade drills can be adapted.

Six scenario drills a year are planned for each intervention team. Drills are organized in both hot and cold zones.

For the site’s other buildings, two drills per year are planned for each intervention team, spread across the different buildings or as "wet" drills on the fire training site. Only members of the fire brigade intervention team take part in these drills.

For the fire exercise carried out annually in collaboration with the public fire brigade, the scenario of an already planned drill is expanded to include an intervention by the public fire brigade. These scenarios generally take place in the controlled zone.

The main purpose of the joint exercises with the public fire brigade is to give them the opportunity to participate in a realistic intervention exercise in the KCD installations. The most important aspects for the public fire brigade are:

1. Call and sequence;
2. Local access (site/building) and information transfer;
3. Strategy formulation, deployment, radiation & contamination and attack;
4. Collaboration with the internal KCD services.

Beside the fire drills, the members of the emergency organisation have to attend classroom training. The ongoing trainings are listed as part of a specific KCD procedure.

**Firefighting documentation**

CNT3 and KCD3:

Each room where a fire alarm is received and processed, has a procedure that guides the personnel through the diagnosis phase to get a picture of the event in progress and the necessary response.

On both sites, intervention files have been developed. These files exist for each level of each building and contain essential information and instructions for the emergency response teams (internal and external).
These intervention files contain information on:

- location of firefighting equipment;
- building compartmentalization;
- escape routes;
- available fixed and mobile extinguishing installations;
- the nature, and quantity of the hazardous substances stored:
    - (bulk) products of 200 litres and more, permanently present in the installation,
    - Cross-section of the different floors with a presence of hazardous substances with a total volume of over 1000 litres;
- Site plan ("Installation plan");
- The available pesticides.

A copy of the intervention manual is available in the respective main control rooms, in the command car and at the Fire Safety department, and a copy was made available to the local fire brigade.

These documents are revised periodically.

KCD3:

In addition to the intervention files, standard operating procedures have been drawn up. These contain all relevant information regarding non-nuclear accidents that may occur, and the intervention strategy that should ideally accompany them.
These standards are an indispensable source of information for the education and training of intervention teams.

In addition to the information on how to respond to possible emergency scenarios, basic training courses are also available for public fire brigade. This can range from how to deal with a fire/explosion, how to deal with an incident involving a hazardous product, as well as how to perform rescues and how to respond to them.
These are available in the library in the command car.

**Specific provisions**

CNT3 and KCD3:

A system of drains is used to evacuate water used to extinguish a potential fire; this system covers in particular areas where such water could cause damage to safety-related equipment.

Drains that may evacuate water containing radioactive substances are collected and transferred to the fluid treatment circuit before discharge to the environment.

CNT3:

As the public fire brigade is located across the street of the Tihange site, there is no need for a procedure to give directions to the public fire brigade to come to the site.

The basic rule related to not blocking access point or firefighting equipment is endorsed in specific procedures. Moreover, in case of fire in a specific location, the different paths to reach the fire will be analysed using plant layout and, most of the time, multiple ways to reach a location are available. The different locations where the interveners gather before they start their intervention is predefined.

Concerning the access to the place of the intervention, at all times, it is the responsibility of the exploitation coordination manager or the manager of shutdown and projects to guarantee access to the roads to allow the intervention. They must ensure the general coordination of the various actors and must guarantee access for the interveners. In the event of an on-site road blockage, they must notify the health physics department and the operations department.

The emergency plan procedures describe the instructions to be followed by the rescue teams to enter and intervene in a controlled area. The document describes the methods of dosimetry and protection against contamination of people intervening in an emergency in a controlled area. It is a summary of the training given to external emergency services in order to familiarize them with the instructions to follow for entering a controlled area.

During the activation of an internal emergency plan, if outside help is called up, these are received by the security services as soon as they arrive on the site.
When an emergency vehicle arrives at the access, a guard opens the barriers to allow it to enter the site. A guard accompanies the vehicle with another car to ensure that it arrives as quickly as possible at the scene of the intervention.

The drivers of the vehicles receive a map of the site on which the route to follow to get to the place of intervention is highlighted with a fluorescent marker.

In order to facilitate orientation on the site, a series of revolving lights is activated by the main control room in order to guide the emergency services towards the concerned location.

In order to give priority to the speed of the intervention, at these relays, a radiation protection agent awaits the emergency services and ensures that they have:

- An EPI-type direct-reading electronic dosimeter.
  External emergency services may have their own dosimeters, but the EPI agent will ensure that each worker has their own dosimeter and, if not, they will be given a dosimeter;
- A helmet;
- Overshoes.

Additional instructions for both the wearing of personal protective equipment and the dosimeter may be given at the time of the accident depending on the nature and location of the accident.

KCD3

The access route to the nuclear site for the public fire service access routes is provided by the security room and/or the team leader of the intervention. Several access routes are available.

Upon arrival at the site, the public fire brigade receives an approach route from the security service, in which the indicated route to the attack gate is marked. The emergency door of the attack gate (depending on entity to entity) is opened from the outside by a security operator. Note that the emergency door of the attack gate to the controlled area is immediately closed by the security operator of the gate after entering.

The basic principle is that the public fire brigade has access to all relevant rooms and buildings at all times in the event of a fire. During interventions, the necessary keys are available at predefined locations and/or persons. Rooms that turn out to be closed at the time of intervention with other cylinders or additional padlocks are mechanically forced open by the internal fire brigade.

When an intervention takes place in the controlled zone, the internal and external fire brigade are supported by a representative of the Radiation Protection service (health physics department) who carries out the necessary dose rate measurements in advance and thus guarantees the safety of the parties involved.

The internal and external fire brigade receive personal electronic dosimeters from a representative of the Radiation Protection service. These dosimeters are present at the scene of the intervention (fire truck attack gate). The radiation protection officer present at the attack port decides which type of dosimeter is to be handed over to the intervening public fire service.

Initially, ordinary dosimeters are used with alarms at the value 500 µSv/h and 1000 µSv. If the Radiation Protection service judges that the alarm settings are not adequate for the given situation, intervention dosimeters with alarms will be used.

### 3.2.2. Research reactors

#### *3.2.2.1. Fire detection and alarm*

The entire BR2 complex is equipped with fire detection systems in line with the national technical standards [15][18]. The architecture is based on fire detectors connected in loops, and the information from each loop is collected in a fire detection installation. Different types of detectors are implemented, and their selection is based on good practices or, as needed, a more dedicated analysis:

- Optical detection;
- Infrared detection;
- Beam detection;
- Aspiration detection.

Several fire detection installations are located in different buildings of the BR2 complex. All detection installations are interconnected by communication wiring. Some older installations and communication loops are being modernized. The status of detectors and detection installations is collected on a control and supervision unit. The information of the unit is available in the control room of the machine building where action can be undertaken if needed.

In principle, the loop type detection arrangements are, as far as practicable, configured in line with the compartments. Nevertheless, it is unavoidable that some compartments will cross each other, and full independency between adjacent compartments cannot therefore be achieved. The loop type configuration with position verification, however, guarantees that the loss of one or more detectors in series due to hazard conditions will not lead to the loss of all detectors on the loop. Immediate action will be undertaken in case of the loss of one or more detectors to restore the situation.

The BR2 fire detection and alarm system are connected to the company wide fire detection system of the SCK CEN. Additional supervision units – not only for BR2 but also for the site – are located at the security and access control buildings. These buildings, like the control room in the machine hall, are manned (24/7), and staff can initiate all necessary actions to call for internal and external assistance. Finally, a supervision unit is also located in the internal fire department.

The entire installation is fail-safe, which means that all alarms, manipulations, interruptions, malfunctions, etc. are signalled via the control panels of the detection installations and the supervision units. Each fire detection installation has its own backup battery with an autonomy of 24 hours. This autonomy is actively prolonged, as these installations are also connected to diesel generators with an autonomy of over 72 hours.

In some cases, detectors need to be disabled for a period of time. This is usually due to activities that may create dust or smoke and would continually trigger detection. This process is covered by the BR2 hot work permit and work approvals. For such activities, the fire department carries out an evaluation to determine whether compensatory measures are needed, like regular checks, removal of certain fire loads or fire initiators, or even permanent fire watch.

All fire detection systems are designed and operated according to standards [15][18] and/or the manufacturer's instructions. This implies that they are robust and suitable for operation in the most common environments. Even in accidental or hazardous conditions, the functioning of the fire detection system is not affected.

The design basis accidents of the BR2 reactor are not initiated by fire-related events, and the safety functions can be performed in case of fire, since the mission time for safety-related actions is short and the actuating cables are sufficiently fire-resistant. For long-term safety, no active power supply is required. Loss of power supply due to fire (which triggers loss of flow) is enveloped by the combined postulated events of loss of flow and loss of pressure.

Design basis accidents avoid fuel damage and do not generate fire hazards. Design basis accidents do not give rise to harsh environmental conditions, as the reactor coolant loop operates at low temperature (<50°c) and low pressure (1.2MPa). In case of the maximum credible accident, the integrity of the reactor containment building is guaranteed by design; the maximum credible accident has no effect on firefighting capabilities in other buildings.

#### *3.2.2.2. Fire suppression*

The fire suppression strategy is based on a stepwise approach. The first line of defence provisions are obligatory [11] and generally includes portable extinguishers, fire blankets and hoses. At BR2, all members of the operating crew are qualified to use all first line of defence extinguishing means.
Deviations from the requirements may be allowed when certain risks are identified, such as the criticality risk in fresh fuel storage. In those cases, alternative fire extinguishing strategies, like the use of specific extinguishing agents instead of water, are identified where necessary. Selection of the most appropriate extinguishing agent in portable extinguishers is also needed to protect, for instance, electrical cabinets, batteries, installations using flammable gases and liquids.
It is of course important that operating personnel is duly trained in the use of these means.

A specific fire hose is the riser in the reactor building. The riser in the BR2 containment is the main firefighting water supply in the reactor building up to the highest floor (27 m) and delivers up to 500 l/min. It is fed with a main pump connected to the normal drinking water network. The water supply can also be provided via the main fire extinguishing network of the SCK CEN, from the potable water network at SCK CEN or from a nearby surface water. The switch to the fire water mains is automated. The loss of the riser would mean a severe degradation in the available firefighting provisions in the reactor building, although an emergency connection is provided so water can be pumped into the reactor building via portable pumps or a fire truck. An assessment of the riser and its support structures has pointed out that earthquake accelerations higher than 0.4 g would lead to damage of the pipes due to failure of the anchoring. Additional anchoring at selected positions was placed to reduce the maximum tensions in the riser to about 50% of the allowable values.

The second line of defence consists of fixed fire extinguishing provisions. a distinction can be made between fixed manual and automatic systems. The choice between manual and automatic extinguishing systems is based primarily on a risk analysis. Several aspects are taken into account: the importance of the asset to be protected, operating limits and conditions, the availability of personnel to perform tasks in areas as these may be difficult to access, nuclear and/or radiological risks, etc..

An exhaustive list of the manual and automatic fire extinguishing provisions at BR2 are:

- The manual CO2 extinguishing system for the BR2 hotcell:
  - The system consists of 2 CO2 bottles of 50 l that need to be manually activated similar like a small extinguisher. The extinguishing principle is based on inertization. The manipulators of the hotcell are equipped with handles for guidance of the extinguishing process, i.e. which section in the hotcell. CO2 is used because it is a clean agent and does not contribute to additional contamination of the interior of the hotcell,
  - This is an installation built according to good practices at the time it was approved for operation;
- The manual NOVEC 1230 gaseous extinguishing system for the SOLID experiment (see page 83):
  - Consists of 1 bottle chemical agent NOVEC 1230 and needs to be manually activated similar like a small extinguisher. It is implemented to protect the installation inside the SOLID unit (recovery of data processing equipment) and it is not harmful for operators working nearby the experiment,
  - This installation is constructed and maintained according to [22];
- The automatic deluge system for the basement (cable trays) of the BR2 process building:
  - Consists of 2 deluge units as the basement is divided into 2 sections. The system is activated through a detection line equipped with sprinkler bulbs (activation temperature 68°C). In case of a real fire the detection line is activated, which then operates the valve and water flows through an inline mixing device, creating a medium foam extinguishing agent in the basement on the cable trays. The foam forming agent (AFFF) is injected into the piping (Venturi system) and in the basement via perforated foam hoods injected on the cable, so the entire room is filled with foam, extinguishing the fire,
  - This installation is constructed and maintained according to [22];
- The automatic water/mist system for the diesel generators of the BR2 complex (Powerhouse):
  - Consists of 2 water reservoirs (H2O jet), put under pressure when activated by 2 nitrogen bottles, creating a water mist spray over the diesel generators. The activation is automatically according to a predefined sequence (at least 2 detectors must be activated, one of them must be a flame infrared detector). The water mist system can also be activated manually by push buttons in the diesel generator rooms.
    When the extinguishing system is activated the diesel generator is stopped not to influence the extinguishing process,
  - This installation is constructed and maintained according to [22];
- The automatic SINORIX 1230 gaseous extinguishing system for the UPS and electrical cabinet rooms in the new powerhouse:
  - Consists of a gas bottle (Sinorix 1230 chemical agent) and is used in the UPS rooms and also in the electrical cabinet rooms. The activation is automatically according to a predefined sequence (at least 2 detectors must be activated to activate the system). The system can also be activated manually by the push buttons in the rooms. The UPS units are equipped with aspiration detection with 2 alarm levels, this however does not activate the suppression system on its own, an alarm of the aspiration unit together with another optical detector will activate the suppression system,
  - This installation is constructed and maintained according to [22];

- The automatic FM200 gaseous extinguishing system for the elevator machine room in the containment building:
    - Consists of 3 gas bottles mounted to the outside of the elevator machine room and the system is connected to the fire detection inside this room. The gaseous extinguishing system will operate automatically in case of double fire detection, but can also be activated manually from inside the elevator cage and from the bottles,
    - This installation is constructed and maintained according to vendor specifications.

The last onsite line of defence is provided by the fire extinguishing network (fire water mains) at the SCK CEN site. Capacity and dimensions are based on a worst-case accident (aircraft crash) and guarantees at least 2 hours' independency from external emergency services such as the public fire department or civil protection. The network consists of a large pressurized nested water loop with:

- A water buffer of 2800 m³ (200% of required capacity)
- 4 diesel driven pumping units with capacity 12000 l/min (400% of required capacity)
- 2 separated locations (reservoirs and pumps) each able to supply the entire network

The loop also serves as backup option for the BR2's specific automatic extinguishing systems and for the BR2 containment building riser.

The fire extinguishing network as a whole has not been designed to withstand earthquakes, but is in line with international norms and standards [40][41]. The only parts of the systems which are designed to cope with earthquakes are the water reservoirs. Sufficient connections to the water tanks are foreseen to allow mobile units, like fire trucks, to connect to the tanks and foresee the needed firewater supply all over the technical site.
Moreover, as part of the network design, it was justified that earthquakes will initiate fires that demand a massive volume of water. Small fires, for instance in electrical cabinets, are anticipated and can be handled without the site fire extinguishing network.

The final line of defence is the public fire department, which are obliged to be able to set up a large water transport system within 2 hours after being alarmed. This large water transport system can foresee an infinite water supply of at least 4000 l/min over a distance of 3 km. Since the site of SCK CEN is located very close to a canal and a set of large surface waters, it is expected that the flow rate can be augmented up to 8000 l/min in less than 2 hours. A large exercise to test this procedure and its performance has been conducted in 2012; it confirmed the feasibility of the large water transport.

Inadvertent operation of the automatic fire extinguishing provisions is considered in the design. For instance, the activation of the automatic water-mist extinguishing system for the diesel is based on a sequence of multiple and diverse (simultaneously 1 smoke detector and 1 flame detector) fire detectors before activation starts automatically. Since high reliability fire detectors are used, the unduly activation of the extinguishing system is not very likely. Furthermore, the diesel generators are not physically affected by the water-mist extinguishing system and remain available after the system has stopped.
The automatic extinguishing system for the cable tray basement is activated based on the activation of the detection line (sprinkler bulbs must break due to high temperature of 68 °C or more). Maintenance procedures are implemented for entering the basements and locking the suppression system during the stay of technicians and operators, making unduly activation unlikely. A potential inadvertent operation of this system will not damage the cables; activation is detected in the control room in the machine hall, and the system can be shut down manually.

The other automatic suppression systems are based on agents which are not harmful for installations and personnel. An inadvertent operation of these provisions will therefore not cause any problem.
For the hot cell, inadvertent operation could lead to a risk of oxygen deficiency for operating personnel in case of intervention inside the hot cell. Given the manual activation required for the suppression system, this risk is unlikely. An audible and visual warning system is in place to enable personnel to timely evacuate the area.

Another secondary hazard may arise in the event of rupture or leakage of fire water pipes. Mainly the riser in the reactor building can potentially give rise to a small flood in the reactor building. Any water leak will automatically drain to the bottom of the reactor building. An undetected rupture of the riser at full capacity would produce about 1 cm of water in 15 minutes on the lower level. A flood of this magnitude will not cause any damage to SSC's operations. There is no hampering of the reactor scram, main automatic blocking valves remain operational and the building can still be isolated if required. Secondary damage to electrical cabinets, for instance, cannot be excluded. A flooding of the fuel storage is highly unlikely, as it is located on an elevated floor. Nevertheless, safety assessments have demonstrated that potential flooding of the fresh fuel storage area can never lead to a criticality accident.
Apart from the flooding risk, which is minor, a severe accident management procedure is available to manage and redirect large volumes of potentially contaminated water. Even though the potential rupture of the riser is only a minor contribution to the total amount of water that can be collected in the reactor building, this procedure is available for evacuation of the waste water and cleaning of the building.

A large rupture of the fire water mains of the site will lead to a local flood. The fire extinguishing network is a nested loop however, so the ruptured pipeline can be easily isolated while keeping the network fully operational.
Such a rupture activates the fire pumps and triggers an alarm, therefore intervention time is limited to a maximum of 15 minutes if this would happen after working hours. The pump has a flow of approx. 12000 l/min, the estimated amount of water that can leak out is then 180.000 litre before isolation. The isolation is done manually by closing the Post-Indicator-Valves on the main loop.

The reliability of the systems is regularly checked by operators and/or accredited specialists:

- Handheld extinguishers: yearly;
- Hot Cell extinguishing system: yearly;
- Fire alarming and detection system: yearly;
- Riser in reactor building: two-yearly;
- Primary riser pump:
  - Daily visual check,
  - Weekly automatic test,
  - Weekly check of taps, pressures and main switch,
  - Physical test of the riser: (verification of pressure and flow rate) two-yearly;
- Diesel generators:
  - Water mist system: yearly,
  - UPS & electrical cabinets SINORIX 1230 automatic system: yearly;
- Cable tray basement system: yearly;
- Solid experiment NOVEC 1230 manual system: yearly;
- Elevator machine room FM200 automatic system: yearly.

***Experiments***

At SCK CEN a process is established to perform experiments safely. For experiments, either in the BR2 reactor core or pools, a safety evaluation file is presented to the competent safety committee. The evaluation is conducted in 4 phases, each of which is relevant for fire risk and fire protection.

- The conceptual design contains a preliminary risk evaluation where the fire risks, associated to the experiment are identified and design principles and codes are identified in order to mitigate risks.
- In the second evaluation phase, the detailed design is evaluated to appropriately analyze and mitigate the risks, including fire risks, identified over the entire life cycle of the experiment.
- The third evaluation phase evaluates the commissioning test results and the procedures for installation, operation and end of life of the experiment (including fire protection as deemed necessary).
- The fourth evaluation phase contains operation experience feedback of the experiment in order to identify potential improvement of the experiment and lessons learned for future experiments and repetitive irradiation of the same design of experiment.

Specific design and operational provisions for fire safety for experiments are:

- Application of double barriers with active supervision and actions to protect against exothermic reactions between experimental materials and the environment (e.g. in case of use of inflammable liquid metals).
- Protection of safety important systems and components of experimental devices in case of fire by dedicated fire protection systems (for example automatic fire detection and extinguishing systems in electrical cabinets of safety important SSCs of experiments such as pumps for cooling of loops).
- Application of zoning to mitigate risks associated to the use of inflammable materials in experiments, such as the installation of EX zones in case of use of hydrogen in experiments.

In some cases, an experiment may also lead to a modification of the installation. The procedure for managing modifications to the installation is slightly different from the experimentation process, but in both cases a risk analysis has to be performed, leading to the implementation of specific measures when needed. For example, the SOLID experiment concerns the installation of a neutrino detector, which was treated as a modification of the installation since this type of utilisation does not make use of the reactor or pool facilities. As this detector introduced a considerable additional fire load in the reactor building, a dedicated automatic fire extinguishing system was implemented.

#### *3.2.2.3. Administrative and organizational fire protection issues*

The fire safety at SCK CEN is managed within the ISPPW. The organization of the company firefighting brigade in relation to competence, training and intervention is taken up in the policy document. The intervention bases are described in the Emergency Planning process of the SCK CEN.

Different high-level scenarios have been developed in which the internal fire brigade is expected to intervene. This does not only cover fire hazards, but extends to accidents with hazardous substances, rescue missions, assistance to the medical services, sweeping of buildings, etc.

Several instructions have been developed within the emergency plan or other related processes in support of the fire brigade operations:

- A very important role of the fire brigade lies in the consolidation of the fire safety analyses, the review and evaluation of the risk analysis and the impact on intervention plans;
- An alarming matrix for the company fire brigade is available in relation to the different scenarios;
- For interventions in the scope of emergency planning, a high-level instruction is available for the operational coordination. This procedure describes how an intervention is coordinated on an operational level. It determines which disciplines are required (operator, fire brigade, security, medical discipline, company representative, radiation protection officer…) and how they interact internally but also how they interact with public emergency services in emergency situations;
- Related to the operational coordination, a scheme has been developed on how communication between the different internal and external partners and disciplines will take place. Low-level internal communication is achieved via a companywide digital mobile radio. Medium and high level internal communication is achieved via telephone, cell phone, email, Teams, etc.. Communication to public emergency services is achieved via an independent digital mobile radio; communication to authorities (communal, provincial, national…) is via fixed communication lines based on video calling and email;
- A specific process focusses on the establishment of a company crisis centre to deal with small to moderate crises. It explains the relationship between the operational coordination and the company crisis centre, represented by the management, radiological and occupational safety, communications, HR, security, etc. The crisis centre functions as a support centre for the operational services and to take decisions in view of the protection of the personnel and installations of the SCK CEN;
- Specific intervention procedures have been developed on a high level to clarify how the fire brigade engages with certain accidents (radiological firefighting, airplane crashes….)

Based on the applicable legislation and risk assessments a training and competence plan for the different levels of firefighting has been implemented at SCK CEN. This includes the relevant evacuation procedures.

Related to basic firefighting training several levels are maintained:

- **All personnel** (internal and external): A safety film on various topics (radiological safety, security, cybersecurity, environment, fire safety, occupational safety) is available and a list of questions has to be completed successful every year.
- **First Intervention Member**: a number of people (~10% of SCK CEN staff) are trained and qualified in the use of small portable fire extinguishers. A requalification is requested every 2 years.
- **BR2 operations personnel**: trained in the use of small portable fire extinguishers and also the use of breathing devices (full face masks, compressed air…) retraining is requested every 3 years.
- **Company fire brigade**: personnel volunteering in the company fire brigade must have a qualification as firefighter, equivalent to the qualification for public fire brigade. In addition to the basic firefighter qualification, other specialized qualifications may be obtained depending on the needs of the organization: (rescue, chainsaw, command, driver).

  An intensive training programme is organized to maintain the knowledge of already qualified firefighters as well as for volunteers. This program includes:
    - Twice-weekly training for the company fire brigade;
    - Training of specialisms within the team;
    - Annual training under real fire conditions.

Besides the technical training programs listed above, within the emergency planning framework exercises are organized with the goal to coordinate and communicate to and with various disciplines:

- Coordination exercises are intended to train with the in-house emergency services, but also with one or more external partners (fire department, police, medical). Each year, a training calendar is consolidated and every month an exercise is organized, ranging from a tabletop exercise to a full blown intervention.
- The SCK CEN crisis centre regularly participates in coordination exercises as backup centre. Apart from that 2-yearly full-scale exercises are organized by the National Crisis Centre (NCCN) in which a full-scale deployment of the company's crisis centre is required. About 40 people are involved in the emergency planning room in the large emergency exercises. Small scale exercises with about 10 participants are held about 4 times a year.
- Specific for the BR2 reactor a severe management guideline is available to manage excess water which may be originating from internal flooding or firefighting activities. Periodic trainings are organised on severe accident management and the various scenarios.
- Evacuation: every building is subject of an annual evacuation exercise, different scenarios are implemented during these evacuation drills to achieve a realistic effect

SCK CEN plans at least one exercise a year with all external disciplines:

- Public fire department;
- Medical department;
- Police.

These exercises can be multidisciplinary or sometimes only one discipline participates. Recurrent exercise goals are:

- Personal protection;
- Access to the site;
- Risk awareness;
- Terrain knowledge;
- Communication;
- Dosimetry;
- Instructions and procedures;
- Best practices.

At a higher level, a communication platform between the nuclear operators in the region and the public fire department has been established to engage on various topics. Evolutions within the public fire brigade organization are discussed as well as operator incidents and accidents, material issues, synergies in training and/or exercises. A 5-year planning serves as basis for aligning the efforts between the different operators and the public fire brigade as it is important to engage them without laying a burden on their normal operations.

The company fire brigade currently consists out of 36 fire fighters. 8 team-leaders are qualified (chain of command) of which 2 are professionally occupied with fire safety at SCK CEN. The other team members have different occupations within the SCK CEN (scientists, lab technicians, operational staff, etc.) and are available for about 10% (0,1 full-time equivalent) for firefighting training and maintenance activities. Many members from the company fire brigade are employed at BR2 and thus have a good knowledge of the installation and procedures.
There are multiple firefighting and rescue vehicles in the fire station and all PPEs, procedures and means are aligned with the public fire brigade. This also means that the company fire brigade members follow a similar training program as the public fire brigade and train together multiple times per year.

Operational deployment is primarily the responsibility of the leader in command of the company fire brigade. An assessment of the situation is made and the necessary resources are called upon. In the first instance, these will be internal resources. If upscaling to public emergency services is required, protocols are available and this can be easily and swiftly done.

Exchanges of experience and acquaintance with external services is achieved in several ways:
- Yearly exercises;
- 2- monthly meetings with public fire brigade and the nearby nuclear sites operated by other licensees;
- Advice on projects/major modifications.

Different type and contents of firefighting documentation are available to onsite and offsite firefighting resources:
- Inside the building at several locations the evacuation plans and location of small firefighting equipment are displayed and available;
- Company fire brigade uses intervention plans that comprise two parts:
    - Plan part consisting of:
        - Intervention plan: risks, compartments, operating panels ventilation and fire detection;
        - Evacuation routes and small extinguishing devices;
        - Controlled areas;
        - Rooms with a high fire risk;
        - Floor sweeper plan (evacuation and sweep process).
    - Text part consisting of:
        - Specifics of the building;
        - Fire detection and firefighting equipment;
        - Fire compartments;
        - Ventilation;
        - Electricity;
        - Gasses and fluids;
        - Contacts.

The technical site of SCK CEN is located in a flat area with woods and waterways around the domain and external services are able to access the site via 3 different routes and 3 different gates. The principles behind the routes are such that external services can come from different bases in different communities (fire station, police station, hospital) and they should be able to arrive as quickly as possible. The wind direction, in case of radiological releases or large fires, will determine which route(s) should be avoided. The selected gates can be opened automatically without manual intervention. All routes are accessible also considering weather situations. Nevertheless, if none of the 3 access gates is available or accessible, alternative gates can be opened if needed.

The access provisions to the security perimeter of BR2 are very limited to one main entrance/exit for pedestrians and one for vehicles. Should an unexpected event block the vehicle entrance, for instance, there is no alternative for accessing the BR2 perimeter with fire trucks or other emergency vehicles. Nevertheless, emergency workers can always intervene if needed as the fire safety provisions (handheld extinguishers, fire water mains, riser…) are locally available.

BR2 has several procedures that describe evacuation during a fire which are trained at least once a year in the presence of all staff:

- Emergency procedure for evacuation in case of fire;
- Medical evacuation out of the reactor building;
- Evacuation system of reactor building/Air locks of reactor building.

All BR2 fire equipment is periodically tested and maintained, often in consultation with the SCK CEN fire brigade. The frequency of these checks can be consulted in an electronic database on BR2, and the results are available in hard copy or electronically. The following procedures are available:

- Periodic checks of the BR2 complex:
- Functioning of the automatic fire extinguishing system in the basement of the administrative building of BR2:
- Testing the automatic extinguishing system in the Powerhouse BR2;
- Test scheme of pressure and flow rate of the riser at BR2 containment building;
- Test scheme of the non-return valve of the riser in the containment building.

### 3.2.3. Fuel cycle facilities

Not applicable.

### 3.2.4. Spent fuel storage facilities

#### *3.2.4.1. Fire detection and alarm provisions*

For the subsystems, see §3.1.4.1, the following detection provisions are implemented:
- In the subsystem of the staff areas: areas all rooms of the staff room are equipped with a fire detector of a type that corresponds to the expected fire. These detectors give an alarm to the site surveillance room;
- In the main building subsystem, the loading hall is equipped with flame detectors fitted against the walls to enable detection of a trailer fire;
- In the process subsystem, no fire detection is installed in the storage zone of the SCG;

For SF2, every room will be equipped with an automatic fire detection system in order to detect each fire outbreak. The automatic fire detection system will consist of:
- Fire detectors, whose type is chosen according to fire risk and room layout;
- A fire detection panel;
- A fire alarm system.

A fire protection room will be located close to the main entrance, in which the commands and signalizations of all the fire protection systems will be grouped.

#### *3.2.4.2. Fire suppression provisions*

For SCG, portable powder extinguishers are provided in the administrative rooms with the exception of the electrical rooms, where CO2 extinguishers are provided. A fire reel and a hydrant are installed in the corridor to the loading hall. The length of the reel covers the entire surface of the loading hall. These devices are connected to the fire suppression circuit using a Ø4" pipe, with a view to possible extensions of this extinguishing system in the building.

The SCG can be reached from five different outdoor hydrants.

The SF2 facility buildings will be equipped with portable extinguishers to provide fire protection coverage to all areas. Three hydrants allow covering the entire installation considering 80m outreach from each hydrant to the outer surfaces of the buildings.

Neither SCG nor SF2 has automatic fire suppression systems.

For other aspects, in particular details on the water supply system, administrative measures and the firefighting organisation for both SCG and SF2, see KCD3 (and CNT3) under §3.2.1.

### 3.2.5. Waste storage facilities

Not applicable.

### 3.2.6. Installations under decommissioning

See under §3.2.1.

## 3.3. Passive fire protection

### 3.3.1. Nuclear power plants

CNT3 and KCD3:

The NPPs are subdivided into separate fire rated zones named fire compartments. These subdivisions serve the primary purpose of confining the effects and spread of fire to a single compartment, thereby minimizing the potential for adverse effects from fires on redundant structures, systems, and components important to safety.

Fire barriers are made up of a number of constituent parts. The fire compartment elements are normally 2 hours fire rated and include walls, floor and ceiling, slabs, fire doors, fire dampers, and penetration seals.

A firewall separates the two coupled main transformers. The rules of good practice in networks, based on several years of experience, means that no protective screen is required when two transformers are at least approximately 10 to 12 m apart.

For CNT3, the minimum distance between TRh transformers is 15 m. Between transformers TRa and TRt the distances are less than 10 m. Rf 90 firewalls have therefore been installed between these transformers.

#### *3.3.1.1. Prevention of fire spreading (barriers)*

#### *3.3.2.1 Design approach*

CNT3 and KCD3:

The separation between compartments is achieved by means of walls, ceilings, floors and doors of a fire resistance Rf 2h according to NBN 713-020 [16]. The degree of fire resistance of compartmentalization elements such as doors or cable penetrations has also been established in accordance with [16].

In accordance with RG 1.189 [34], **fire doors** must have the same fire resistance as the compartment wall in which they are placed. Some of the fire doors currently installed have only half the fire resistance (i.e. 1h fire rated door in a 2h fire-rated wall), which has been justified on the basis of a specific risk analysis..

Since 2016, new designs and replacements have preferentially used elements of the same degree of fire resistance classified according to NBN EN 13501-2 [17] and are tested according to NBN EN 1634-1 [44].

The **evacuation paths** are also compartmentalized. The stairwells and lifts are made of masonry or concrete and have a fire resistance Rf 2h according to [16].

The **cable decks** are insulated by fire resistant walls, ceilings, floors, and doors Rf 2h.

**Ventilation** ducts passing through several rooms shall be fitted at the limits of the fire compartments with fire dampers having a fire resistance at least equal to that of the wall they pass through. Closing is ensured by fire detection or fuse.

**Wall penetrations**, e.g. for electrical cables, are sealed with materials having a fire resistance at least equal to that of the wall they pass through.

Passive fire protection is also ensured by the selection of the **insulation material** of the **cables**. With regard to fire resistance and behaviour under extreme environmental conditions, in normal operation and in the event of an accident of electrical equipment cables, the recommendations of the IEEE-383 [19] are taken into account, thus avoiding damage to the insulation material and limiting fire propagation.

Following the RGIE/AREI [10], the cables must have a specific fire resistance according to IEC60332 and EN50399, depending on the configuration and area of application.
Since the insulating material is non-combustible, mainly due to non-halogenated additives, cables must be also compliant with EN 61034 for smoke production, and EN 60754 and EN 50267-2-1 for corrosive gasses in case of a fire.

Power and control cables are not laid on common cableways. Filling of funiculars is based on the following rules:

- control cables are laid in layers or bundles, the maximum number of which is limited by the dimensions of the cable trays.
- low voltage power cables with small cross-sections may be laid in layers or bundles.
- low-voltage power cables with a large cross-section, as well as medium-voltage power cables, are laid in a single layer.

Permissible cable currents are specified in accordance with the manufacturer's recommendations. The cross-sections of cables laid on racks are determined by taking into account the following factors:

- power consumption in continuous operation.
- starting current.
- voltage variation and voltage drop.
- cos.phi.
- ambient temperature (normal and accidental).
- proximity effect.

The **connections** in the electrical equipment must meet the qualification corresponding to the equipment to which they belong. In particular, the connections of equipment used in extreme conditions are made to meet the same extreme requirements, and are qualified according to an equivalent qualification sequence. This meets the objective of IEEE- 383 [19].

KCD3:

Due to delays in the certification process and lack of availability of some type of products classified against the newer European standard, fire doors that have been tested and certified according to NBN 713-020 [16] have been installed until 31/10/2019.

Special attention is also given to the design of the **electrical (power) cables**.

The **cable penetrations** through the walls and floors that border fire zones or fire cells are sealed in such a way that the fire resistance of the wall or floor is restored at the location of the penetration.

Two types of penetrations must be taken into account:

- Penetrations whose watertightness and/or airtightness must be guaranteed during normal operation and in the event of an accident: these penetrations consist of metal frames with packing and guarantee the desired leak-tightness on the one hand, and the necessary resistance to fire on the other hand. The packing has a length of 6 cm and is made of fire-resistant material. In addition, fire resistant paint is applied to the two sides of the packing as well as to the cables, over a length of 1 meter on either side of the penetration;
- Other wall or floor penetrations: the cable racks or ladders extend to approximately 10 cm from the penetration. The cables penetrate the walls and floors through fire-stop systems that are made of glass wool or a hard fire-resistant material.

***Description of fire compartments and/or cells design and key features***

<u>CNT3 and KCD3:</u>

The fire compartments are designed to prevent fire to spread beyond the compartment. Fire compartment elements can be the following:

- Wall/ceiling/floor;
- Doors;
- Slabs;
- Penetration sealed;
- Stairwells and elevator (made of masonry or concrete);
- Fire dampers;
- Ventilation ducts.

All the fire rated elements can be easily identified, e.g. by a red line marker or tag.

The rooms containing equipment relevant to the redundant safety functions are compartmented, depending on the calorific load and/or fire hazard.

The following rooms are specifically compartmented:

- the main control room;
- each electric safety train (the relay rooms, reactor protection circuits, the cable rooms, the panel and battery rooms belonging to a same train form fire islands);
- each safety diesel;
- each safety diesel fuel storage tank;
- stairways.

In general, each zone has a specially studied and placed emergency entrance and exit. On the one hand, they make it easy in the event of an accident to evacuate the personnel and on the other hand they increase the number of access ways to the possible fire.

Exterior doors form a lock so as not to disturb the ventilation and the negative pressure. The stairwells are designed to prevent smoke infiltration and have a Rf of 2h.

<u>CNT3:</u>

The unit is divided into fire compartments of Rf 2h and all the fire rated elements can be easily identified, e.g. by a red line marker or tag.

<u>KCD3</u>

The unit is divided into fire zones and cells. The zones are determined with a mutual fire resistance of two hours. The cells are subdivisions of the zones and have a mutual fire resistance coefficient of one hour.

The safety equipment in the main control room is grouped per train by separate parts of the control panels. The cables of these panels are separated from the cables of the other redundant trains and of the non-safety related cables by structures made of non-combustible material.
Each safety related train is separated from the other redundant trains and of the non-safety related by:

- minimum distances of 1 m (horizontal) and 1.5 m (vertical);
- closed ducts when these minimum distances cannot be met.

### *Work on fire penetrations and fire-resistant walls*

CNT3 and KCD3

Dedicated procedures describe the rules and methods of application concerning the work of opening and closing penetrations in fire-rated compartment boundaries (walls, floors, ceilings) as well as restoring the fire rating and conformity of these barriers when defects (e.g. cracks) are observed that could jeopardize the functionality of the structure.

The general principle is that, no fire-rated penetrations may be opened during power operation of a reactor unit. If this is nevertheless necessary, the requesting service must first draw up a risk analysis (which cables pass through the transit, which equipment is served by it, what is the risk of damaging other cables). If no permission is obtained, the fire-resistant transit may only be opened during the next outage of the entity concerned.

If the fire penetrations are open, they must be closed as soon as possible, and in any case before the maximum time allowed by the operating limits and conditions (OLCs) applicable to the buildings and premises concerned by the OLCs. The maximum time limit is 14 days, from identification of the fault, when the fire rated penetration is unavailable.

If a fire penetration is to remain open, or when a new penetration in a fire-rated wall is created (for pulling new cables, placement of piping…) it must be temporarily sealed using intumescent bags (“seal bags”), until the definitive closing can be performed.

A dedicated team is responsible for opening fire penetrations. Once the work has been completed and the fire penetration sealed, a qualification on the fire penetration is carried out.

To meet the inspection requirements of the OLCs, the health physics department conducts one inspection campaign every 18 months during which all buildings are fully inspected, the plans adapted if necessary, and penetrations repaired if required. These checks are spread throughout the year and are guaranteed by maintenance plans.

If an RF wall must be repaired, this should be done within 14 days from the date of confirmation of the diagnosis when the damage calls into question the physical integrity of the wall.

CNT3

The documentation associated with the intervention must be produced and filed in such a way that the CNT can establish at any time the link between the crossing, the sealing procedure and the laboratory type test report. Each fire-rated penetration must be recorded in SAP with the link to the report number and the number of the filling procedure. Reports, filling procedures and reports of intervention must be archived. All fire penetrations have a visual tag in the room.

Some fire penetrations can be classified as “temporarily OK”, when it is justified that the observed damage will not significantly impair the fire rating, but could cause the penetration to be more easily damaged in the future. The deadline to repair these fire rated penetrations is 6 months, , from the identification of the fault.

For all other damage that does not pass through and does not call into question the fire rating criteria, the wall must be treated as soon as reasonably possible with a maximum period of 6 months following the date of creation of the notice.

KCD3

Both sides of all fire penetrations have a visual tag and all fire penetrations are recorded in the management system.

*Performance assurance through lifetime*

CNT3 and KCD3:

The performance of the passive fire protective equipment through lifetime is guaranteed by:

- Preventive and curative maintenance;
- Preventive testing;
- Regular facility upgrades.

The firewall management process is described in a procedure that sets out the rules and modalities related to work affecting the firewall.

Maintenance of fire protection and detection installations is carried out and coordinated by maintenance, electrical and mechanical services and unit services. Periodic maintenance is described in a procedure containing the verifications to be performed on fire equipment (penetrations, doors, firewall…).

Any changes to the fire protection facilities are carried out in accordance with the modification management process, which takes fire-related aspects into account.

Fire doors, penetrations and fire dampers are systematically evaluated by fire safety operators to ensure their performance. If defects are found, the equipment is reported as unavailable and will be repaired or replaced.

The testing - scope and frequency - of the fire protection equipment is described in chapter 5 of the OLCs of each unit:

- Verification of the absence of obstructions for normally open or open fire doors equipped with an automatic closing mechanism.
- Visual inspection of fire doors, including checking the closing mechanism
- Visual inspection of a 10% sample of fire penetrations in each building concerned. If deterioration is discovered, an additional 10% sample will be inspected in that building until the sample is free of defects.

Additionally, fire rated walls are also inspected to ensure that they are still in place as originally built (no cracks, no fragmentation, no missing materials, etc.).

Every year, inspections, visits and audits by internal and external parties take place. In addition, several WANO and OSART reviews took place in Doel and Tihange.

All impairments, including fire protective equipment, are reported to and displayed in the impairment board in the main control room.

Equipment ageing is monitored through the ageing management program, based on the applicable IAEA methodology. This program helps the organization to anticipate the ageing of fire protection equipment.

#### *3.3.1.2. Ventilation systems*

***Ventilation system design: segregation and isolation provisions***

CNT3 and KCD3:

Each compartment, and in particular each room containing an appreciable quantity of combustible materials or equipment, is equipped with smoke and hot gas evacuation circuits which are independent of adjacent compartments, or which can be isolated from them by closing fire dampers.

Smoke evacuation ducts are designed in such a way that they cannot transmit the fire to another compartment containing material likely to catch fire.

Smoke from non-contaminable areas is exhausted directly to the outside.

Cable galleries are equipped with smoke extraction systems.

Ventilation ducts passing through several rooms are fitted with fire dampers at the boundaries of the fire compartments. The fire resistance rating is at least equal to that of the wall through which they pass.

Closing of the dampers is triggered by the automatic fire detection system or by a thermal fuse.

CNT3:

Each compartment, and in particular each room housing a quantity of combustible materials or materials likely to ignite, is equipped with smoke and gas evacuation circuits having no common point with the circuit(s) of compartment(s) adjacent or capable of being isolated by the closure of fire dampers. The general rule is that in case of fire, the normal ventilation is switched off and the dampers are closed. In some particular cases (when ventilation system is safety related), a manual validation needs by the operator in the main control room is required before the ventilation can be effectively switched off.

In addition:

- Fume ducts shall be so constructed that they cannot transmit the fire to another compartment;
- Fumes from non-contaminable premises are discharged directly to outside.
- The cable tunnels are equipped with fume extraction;
- The systems are designed to evacuate hot gases layer and smoke.

KCD3

The smoke extraction systems are designed to facilitate access to a room where a fire would have started. They were not installed in buildings where there is a risk of radioactive discharge into the environment; in these buildings, special attention is paid to the use of automatic protection systems when justified by the fire risk or the presence of many cables. The systems also make it possible to prevent the smoke formed from spreading in other rooms. When a fire is detected in a certain zone, the smoke extraction system is activated, while the normal extraction fans and any recirculation are shut down. The smoke extraction can be stopped on site by closing a fire damper. Failure of the smoke extraction system in the event of a fire will in no way endanger the nuclear safety equipment of the unit.

In the turbine hall, the smoke is discharged through a series of outlets, with an opening whose total area is equivalent to 0.5% of the floor area. When temperatures are too high, these outlets open automatically.

In the event of a fire in potentially contaminated buildings, the fire dampers in the ventilation ducts make it possible to avoid the spread of the fire outside the fire zone or the fire island. The spread of contamination is thus limited to the zone or island where the fire started.

During POP, although the reactor is completely unloaded and all spent fuel is stored in pools with significant available grace times, the ventilation of the main control room is still considered as important to safety. It is to remain functional and available for the purpose of ensuring the feasibility of manual operations and accident management at the level of the spent fuel pool.

### *Performance and management requirements under fire conditions*

CNT3 and KCD3:

The smoke extraction ducts are thermally insulated. Smoke extraction aims to:

- Allow entry into an affected area;
- Limit smoke damage and spread to surrounding areas.

In case of fire:

- In a non-controlled zone area, the compartment is isolated. Air supply and extraction are deactivated, while smoke extraction can be activated manually;
- In a controlled zone area, detection of the fire induces the closure of the fire dampers on the air flow of the compartment.

Most smoke extraction flaps are only opened by request of the firefighters, based on their risk assessment and needs for intervention.

The availability of this equipment is guaranteed by:

- Preventive and curative maintenance;
- Preventive testing;
- Regular facility upgrades.

CNT3:

Automation of ventilation and fume extraction systems (starting/stopping fans, opening/closing dampers) is controlled from the main control room or locally.

In some places, e.g. in the turbine hall, smoke dampers are installed which open automatically above a certain temperature.

KCD3

Automation of ventilation and fume extraction systems (starting/stopping fans, opening/closing dampers) is activated via the safety signal F.

If an active carbon filter is installed in the ventilation channel, a fire extinguishing system is installed and activated automatically when the filter catches fire.

### 3.3.2. Research reactors

#### *3.3.2.1. Prevention of fire spreading (barriers)*

Within BR2 fire compartments have been defined, designed and implemented. Since the start of operations, several improvements have been carried out, mostly during the refurbishments of the reactor that took place in 1982, 1996 and 2016.

Details of the current implementation are:

- The **reactor building** is divided in several compartments: the main reactor building itself, the stairs and emergency exit, and the iodine filters. The reactor building is subdivided in several fire zones and fire cells. The control room and the relay room are separate fire cells.
- The **machine hall** is divided in 5 compartments: the electrics building, the hot cell, the fresh fuel storage, the east basement and the other areas of the machine hall. Most of these zones are subdivided in several fire zones and fire cells. For instance, the machine control room forms a separate zone as well as the primary pumps and shutdown pumps.
- The **administrative building** is divided in 6 compartments among which the battery room, the central evacuation staircase, fuel storage and two archive spaces. Most of these zones are subdivided in several fire zones and fire cells. This includes for instance a zone for the electric workshop and a zone for an experiment warehouse.

Regarding tests and verifications of fire compartment provisions, several investigations are carried out among which a yearly inspection of fire-doors by the central technical services of SCK CEN.

For new installations and changes and modifications to existing ones, an advice is required by the internal fire safety department and in some cases also from the external fire department, specifying requirements for components regarding to fire resistance and stability (REI class).

#### *3.3.2.2. Ventilation systems*

The ventilation system of BR2 is robust, but not very flexible in its operations. There are no automatic actions (valves, ventilation regimes) implemented in the ventilation system of the BR2 in case of fire. When the reactor building is evacuated as a consequence of a radiological or nuclear event, the building is automatically and hermetically closed. This action does not rely on external electric power for actuation and the command system has diverse and separated cabling with function guaranteed for 1 hour in case of fire. The tightness of the reactor building is tested twice per year. The isolation valves are located in an area of the containment building that has been evaluated as low fire risk in the fire safety analyses.

For the other areas, the instructions in case of fire are defined in accordance to the lessons learned at the BR3 fire (see § 100). The ventilation is kept in service as long as deemed safe in case of fire by the operators and/or the fire brigade officer in order to maintain the pressure gradients throughout the installation. In case the control room cannot be used in a fire event, control of the ventilation system can be done from the ventilation building, which is well separated from the service building in which the control room is located.

### 3.3.3. Fuel cycle facilities

Not applicable.

### 3.3.4. Spent fuel storage facilities

For both SCG and SF2, the information provided for KCD3 in section §3.3.1 is fully applicable.

For SF2, it is noted that the unconfined spread of combustible fluids will be prevented by containment, drainage, or a combination of both, in particular:

- a dedicated drainage system for kerosene following airplane crash is foreseen in the SFB building storage hall;
- a sewage system is foreseen in the SFB building handling hall for potential fuel coming from the cask transport off-site truck or on-site trailer (and for water), connected to a fuel/water separator.

Lightning protection is installed on the SF2 CNT and will be installed on the SF2 KCD to prevent the ignition of fire loads in the buildings, to protect occupants, and to protect electrical installations.

### 3.3.5. Waste storage facilities

Not applicable.

### 3.3.6. Installations under decommissioning

See under §3.3.1.

## 3.4. Licensee's experience of the implementation of the fire protection concept

### 3.4.1. Nuclear Power Plants

In the past, the KPI on Fire Load index was different between the two sites. Now, they are identical, with both sites applying a qualitative methodology. Fire load is scored using a reference table (for example, a barrel of oil contributes more than a small pile of paper).

Recently, the KPI on Fire Ignitions has been aligned between the two sites. To gain experience and develop a common interpretation of the modified definition, discussion between both sites is necessary. The next step will be to analyse these fire ignition events. The criteria used in this evaluation will be based on the experience of WANO and INPO.

Exchanges between the two sites take place through frequent meetings with the site organization and the fleet manager. Some of these meetings are held on site, so they can be combined with field visits.
These regular meetings have revealed that a certain way of working for ensuring fire compartmentation at one site (e.g. fire-resistant seals in concrete plugs), was not being applied at the other site. A second improvement resulting from these exchanges is the labelling of firewall penetrations on both sides.

CNT3:

It is important to cooperate closely with the regional external fire brigade located in the immediate vicinity of the plant. This makes it easier to organise common exercises and to bring in line firefighting strategies. It also provides public fire brigade with good knowledge of the equipment available at CNT3 and enables to be trained in the specific radiological risk.

The second intervention team on site is composed of professional fire fighters. This ensures the presence of well trained and well-informed fire fighters on site and also fosters close cooperation with the public fire brigade.

To anticipate the risk of obsolescence of the CNT3 fire detection system, the entire fire detection system was replaced by a new system.

KCD3:

Recently, a firefighting network was set up with 4 other SEVESO companies and the public fire brigades in the port of Antwerp. This platform will enable further exchange of knowledge and information.

### 3.4.2. Research reactors

A couple of years ago, it was observed that wooden pallets were a significant contributor to the mobile fire loads everywhere in the facility. At company level, it was therefore decided to abandon wooden pallets and opt for metallic pallets. Also, other wooden materials have been abandoned in the latest years where it is feasible to do.

Operator feedback of spurious systems, near misses and actual fire safety related events are registered in dedicated systems. BR2 logs all operational events, not only incidents and accidents, in a specific system. At company level, a complementary system is available covering all events at SCK CEN related to fire safety, occupational safety, radiological safety, security, environment, etc.. Both systems are used to spread knowledge and experiences within the company and to improve processes and procedures if needed.

A representative set of fire safety related events of the last years are described here below:

- Fires in electrical cabinets
  In the last 10 years, a couple of fires started in electrical cabinets in some installations of the SCK CEN. Most of them were due to failure in older electrical components, but all of them were quickly detected and extinguished without further spreading outside the cabinet.

  In none of the events, there were radiological consequences or damage to SSC's. The damage within the electrical cabinets was nevertheless quite substantial.

  Several improvements were carried out:
    - Gradual replacement of old(er) electrical components;
    - Implementation of aspiration detection in electrical cabinets important to safety to have faster detection and response;
    - Automatic extinguishing systems in some predefined critical electrical cabinets;
    - To avoid poor conditions a thermal check is performed (periodic infrared control of electrical cabinets).

- Hot work
  A larger part of the reported incidents at SCK CEN is related to hot work. One example happened at BR2 in 2019 when a subcontractor was performing works at the roof of the BR2 administrative building. After the renovation of the roofing was carried out, the subcontractor left the burner on the roof while it was still on. Only after a while, the operating personnel could see the glow of the burner and performed an inspection. They saw that the flame was directed upwards and therefore no damage was done to the installation. A hot work permit procedure is implemented at SCK CEN and in this particular case the external contractor neglected to follow up the measures required by the hot work permit.

  As a result of this incident:
    - The subcontractor was expelled from SCK CEN for violating several safety procedures;
    - An enhanced supervision of operators on contractors was implemented;
    - Registration and labelling of burners and related materials is mandatory and checked at entrance and departure of subcontractors performing hot work.

- Fire accident at BR3
  In 2014, a vacuum cleaner in the reactor pool caught fire. The detection and alarming system worked properly and an intervention started swiftly. The reactor building was filled with smoke and dust and reduced the visibility of the first responders. The ventilation rate was increased to facilitate the intervention, but filter banks started to clog and the first filters in line failed quite quickly. The intervention was successful and no radioactivity was released from the reactor building.

  As a result of this incident:
    - Intervention procedures were updated (visibility, confined spaces, areas difficult to access…);
    - Instructions related to ventilation in incidental situations were optimized and conceived in intervention plans.

- Commissioning of firefighting equipment
  During a non-periodic test of firefighting equipment after but not as part of the commissioning of the upgraded fire water mains of the site, it was noticed that no water was available in the network of the BR1 building. Similar tests were repeated outside the building and in other buildings and it was found that the valve connecting the inside water network of the building to the outside network was not yet reopened after the commissioning of the outside network causing the building to be disconnected to the fire water mains of SCK CEN.

  To prevent future lack of water or other malfunction of firefighting materials and equipment, a periodic check of firefighting equipment is organized. This check is performed by an external contractor who is certified to check firefighting equipment.

  The corrective actions after this deviation were:
    - Checking other buildings and outside water points;
    - Looking for the error causing the lack of water;
    - Making and inventory of all fire fighter equipment and access points to the water network;
    - Organizing a periodic check of firefighting equipment by a certified, independent contractor.

Every year about a dozen fire safety interventions are carried out by operators and/or the internal fire brigade for the whole of SCK CEN installations. Root causes are mainly related to human errors (violation of procedures, smoking, etc.) and ageing components. It has also been observed, however, that radiological and nuclear safety has always been preserved due to the robustness of the installations and the safety awareness of the personnel.

### 3.4.3. Fuel Cycle Facilities

Not applicable.

### 3.4.4. Spent fuel storage facilities

See §3.4.1.

### 3.4.5. Waste storage facilities

Not applicable.

### 3.4.6. Installations under decommissioning

See §3.4.1.

## 3.5. Regulator's assessment of the fire protection concept and conclusions

### 3.5.1. Nuclear Power Plants

Inspections and assessments by the regulatory body did not reveal any non-compliances between the fire protection strategy in Belgian NPPs and the requirements of article 17 of SNRI-2011. The regulatory body assessed the fire protection strategy as adequately developed and supported by the management of the licensee.
It is underlined that the existence of first- and second- intervention teams (or on-site fire brigade in Doel) with proper equipment and training at hand, ensures that an appropriate response to any fire event can be provided and that strong relations exist with the public fire brigade, who have a good knowledge of the facilities, as well as adapted equipment..
Moreover, the inspection campaigns and continued evaluation have demonstrated a steady improvement of the housekeeping and the reduction of the mobile fire loads, and no infringement to the applicable regulatory framework has been identified.

Nevertheless, recently the number of notifications by the licensee that are related to fire-rated penetrations was found to be elevated. The penetrations reported upon, were either unavailable either because they remained open after works on the penetration itself, or because of external damages that were not declared and repaired in due time. In response, an inspection campaign was developed by the regulatory body to ensure that the related procedures were still appropriate and applied.

It is also noted that the overhaul of the fire load management and temporary storage strategy on the site of Tihange results from the recommendations of the regulatory body in the framework of the review of the deterministic Fire Hazard Analysis studies:

> The Fire Hazard Analysis has been based on data collected at a given time, and the total fire load in a compartment may vary depending on the operation modes and stored goods in the facility (e.g. fire load is usually expected to increase during outage as the result of the introduction of additional equipment). The regulatory body therefore requested the licensee to ensure that the hypotheses on which the studies are based remain valid at any time. This resulted in the evaluation of the available margins and the quantification of the maximal allowed stored fire load, on which the new temporary storage strategy is based.

In addition to the regulatory oversight, the activities of the licensee, including aspects related to the fire protection, need to comply with the requirements from the insurer. This insurer ensures that safety standards developed and applied internationally to the nuclear industry are also applied to Belgian nuclear installations. No conflicting requirements or practices have been identified.

### 3.5.2. Research reactors

Generally, inspections and assessments by the regulatory body did not reveal any non-compliances between the fire protection strategy at the site of SCK CEN including for the BR2 research reactor and the requirements of article 17 of SNRI-2011, and no infringement to the applicable regulatory framework has been identified. The licensee is still carrying out improvements of the fire protection concept and their implementation is followed-up by the regulatory body.

Specific observations and conclusions arising from recent inspections and assessments performed by the regulatory body are:

- A steady improvement of the housekeeping and the reduction of the fire loads was noted. This was confirmed by an IAEA INSARR mission carried out in 2023 [48];
- Fire-rated doors in the containment building were replaced following observations and comments by the regulatory body regarding their functionality;
- The update of the automatic fire detection system with newer generation equipment has been approved by the regulatory body and is ongoing. Consequently, extension of the fire detection network will be more easily implemented in the near future;
- It has been observed that the storage rules for chemicals and flammable liquids in fire-rated cabinets were not properly applied (in particular compatibility between substances). Following these observations, the licensee established clear storage rules which are now displayed and enforced.

It is underlined that presence of an on-site fire brigade (during working hours) as well as the relation with the local public fire brigade are particularly strong points.

The few notifications by the licensee of events related to fire safety, have led to adequate improvements for their prevention.

### 3.5.3. Spent fuel storage facilities

A specific strength for the Belgian spent fuel storage facilities is that combustible materials can be largely avoided in these facilities and that the spent fuel storage casks provide a very high level of protection against a fire.

See section §3.5.1 for further considerations and conclusions for the NPPs that generically apply also to the spent fuel storage facilities.

### 3.5.4. Installations under decommissioning

See section §3.5.1 for assessment and conclusions.

## 4. Overall Assessment and General Conclusions

The WENRA Safety Reference Levels related to fire safety were implemented in the Belgian regulatory framework by articles 17 and 32 SNRI-2011 [9]. Article 17 covers most WENRA SRLs and is applicable to all Belgium “class I” installations including research reactors, waste and spent fuel storage facilities and nuclear power plants. Article 32, which applies only to nuclear power plants, implements requirements related to probabilistic safety assessments for fire and requirements related to the fire hydrant distribution system.

Action plans developed by the licensees on the basis of gap-analyses stemming from regulatory-change management or resulting from periodic safety reviews, have been carried out or, to a limited extent, are being carried out. Licensees have identified and implemented further improvements based on internal and external experience feedback, and as a result of independent assessments by other third parties.
The analyses and follow-up of the gap-analyses and the action plans complemented by the results from inspections allow the regulatory body to conclude that all Belgian nuclear installations that fall under the scope of the TPR-II comply with the regulatory requirements and with the WENRA Safety Reference Levels related to fire safety.

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## Acronyms

| | |
|---|---|
| ASME | American Society of Mechanical Engineers |
| ATEX | Explosive Atmosphere |
| BEST | Belgian Stress Test |
| CDF | Core Damage Frequency |
| CSD | Chemical System Decontamination |
| CFD | Computational Fluid Dynamics |
| ECCS | Emergency Core Cooling System |
| EPRI | Electric Power Research Institute |
| EPI/ESI | Resp. first and second intervention team at Tihange |
| FANC | Federal Agency for Nuclear Control |
| FCA | Fire Containment Approach |
| FDF | Fuel Damage Frequency |
| FHA | Fire Hazard Assessment |
| FIA | Fire Influence Approach |
| FLI | Fire Load Index |
| FME | Foreign Material Exclusion |
| FP | Fire Protection |
| FPSA | Fire PSA |
| **FRA** | Fire Risk Analysis |
| FSO | Fire Safety Operator |
| GRE | Glass Reinforced Epoxy |
| HEU | High Enriched Uranium |
| HPD | Health Physics Department |
| HVAC | Heating, Ventilation and Air Conditioning |
| IAEA | International Atomic Energy Agency |
| ISPPW | Internal Service for Protection and Prevention at Work |
| LEU | Low Enriched Uranium |
| LOCA | Loss of Coolant Accident |
| LOOP | Loss of Off-site Power |
| **LTO** | Long Term Operation |
| MCR | Main Control Room |
| MUG | Mobile Urgent (intervention) Group |
| MW(th) | Mega Watt (thermal) |
| NAR | National Assessment Report on TPR |
| NCCN | National Crisis Centre (Belgium) |
| NEIL | Nuclear Electric Insurance Limited |
| NFPA | National Fire Protection Association (USA) |
| NIST | National Institute of Standards and Technology (USA) |
| NPP | Nuclear Power Plant |
| NRC | Nuclear Regulatory Commission (USA) |
| NSD | Nuclear Safety Directive |
| NUREG | Nuclear Regulatory Report (US NRC) |
| OLC | Operation Limits and Conditions |
| OSART | Operational Safety Review Team (IAEA) |
| PAR | Passive Autocatalytic Recombinators |
| PAU | Plant Analysis Unit |
| PI | Performance Indicator |
| PMGE | Products with dangerous characteristics |

| | |
|---|---|
| POP | Post-Operational Phase |
| PPE | Personal Protective Equipment |
| PSA | Probabilistic Safety Assessment |
| PSR | Periodic Safety Review |
| PWR | Pressurized Water Reactor |
| RF/Rf | Fire Resistance (rating) |
| RPE | Radiation Protection Expert |
| RPO | Radiation Protection Officer |
| RR | Research Reactor |
| RSC | Reactor Coolant System |
| SFP | Spent Fuel Pool |
| SIF | Seismically-Induced Fires |
| SNF | Spent Nuclear Fuel |
| SNRI | Safety Requirements for Nuclear Installations [9] |
| SRL | (WENRA) Safety Reference Level [4][5][6][7] |
| SSC | Structure, Systems and Components |
| SSE | Safe Shutdown Earthquake |
| TPR | Topical Peer Review |
| WANO | World Association of Nuclear Operators |

## Appendix 1: BR1 fire safety

Regarding fire safety, the BR1 installation has to align with the same high level SCK CEN policies and instructions as BR2. However, the intrinsic risk, the complexity, the radiological source terms, etc. are significantly lower for BR1. And, in addition, the amount of activities (transports, manipulations), the intrinsic fire load and the complexity of the facility are low compared to the BR2 complex. Hence, the general instructions are applied in a graded approach.

A large compartmentalization project is planned to start at BR1 as the installation suffers from deficiencies with respect to passive fire protection in relation to the actual norms and standards. A feasibility study was carried out in 2017 and several improvements were identified and agreed upon to get as close as possible in line with the current standards.

One specific risk is very different than for the BR2 reactor however. Being a graphite moderated low power reactor, one of the main safety issues of BR1 is the accumulation of the Wigner Energy. In the graphite, fast neutrons can move atoms out of their equilibrium position and thus create lattice defects such as vacancies and interstitial atoms. The resulting lattice stresses increase the graphite’s internal energy. This increase in energy due to irradiation damage can be released during controlled or uncontrolled heating, causing a strong local rise in temperature. If an uncontrolled release occurs in a loaded reactor, the temperature rise can induce exothermic oxidation of the fuel and graphite. To avoid this, it is necessary to monitor the accumulation of Wigner energy and, if necessary, anneal the graphite to release the accumulated energy in a controlled manner.

In BR1, the Wigner Energy is measured every 5 GWh of reactor operation and an annealing process is requested when the accumulated Wigner Energy in the graphite reaches 335 J/g. Until now, the graphite was annealed only once in 1962. After the change of the working regime from 4MW to 700 kW, it is observed that Wigner Energy is decreasing slowly.
The reasons are the following:

- Because of the lower power (1 MW) the creation of lattice defect in the graphite is lower;
- A smaller fan is used to cool the reactor and as a consequence the temperature of the graphite during reactor operation is now higher compared to the period that the reactor was working at 4 MW. Because of this higher graphite temperature during reactor operation a small amount of the accumulated Wigner Energy is actually released.

Because of this, the accumulation of the Wigner Energy in the actual working regime will not cause a fire ignition in the reactor. Nevertheless, a fire in the reactor is still considered as a maximum consequence accident that can occur in BR1 and therefore, detection systems and fire-fighting procedures are implemented.

Since no direct fire detection is possible in the reactor, the presence of a fire can be inferred from increased temperatures (fuel or graphite) or increased activity in the air cooling. The detection system is therefore based on a combination of temperature and radioactive measuring systems.
In the core, several thermocouples for measuring the temperature of the fuel, graphite and air are placed. For the releases, the air activity at the exit of each reactor channel is measured. Additional air monitoring is placed before the exhaust filters and at the stack.

In case of potential fire detection (temperature and/or radioactivity), the reactor´s team is in charge to verify that a fire has started and take the first action to extinguish it, according to a well-established procedure. After the reactor channel in which fire is localized, the following actions are initiated:

- The fuel in the channel is unloaded by pushing it to the back of the reactor, where a large collector and channel leads the fuel to a water-filled basin. During this operation, the operator is protected from the fire by the reactor's 2.1-meter-thick concrete shield;
- The reactor channel is isolated from the cooling systems. On one side, it is closed it with a plug equipped with thermocouples, and on the other, an injection tube is inserted;
- Through the injection tube the reactor channel is flushed with argon gas. The argon will suppress the oxygen and as a consequence the fire will fade out.

With this procedure 9 channels can be extinguished simultaneously.

During the last periodic safety review in 2016, an ultimate contingency procedure has been developed in case the argon injection procedure would fail. The purpose of this procedure is to completely cut off the air flow in the reactor, but at the same time to maintain cooling around the channels on fire. The main steps are:

- The channels in fire and all surrounding channels are unloaded;
- The channels around the fire are flushed with water while the air cooling is still present;
- All air supply is stopped to put out the fire.

The channel on fire cannot be flushed with water to avoid any possible production of hydrogen. The execution of these procedures is included in the basic training program of each reactor operator and is practiced annually, sometimes together with the SCK CEN fire department. The fire scenario in BR1 and the related fire-fighting procedures are also sometimes adopted as an on-site and off-site emergency drill.

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