Authority for Nuclear Safety and
Radiation Protection

National Assessment Report of the Netherlands for the Topical Peer Review 2023 on Fire Safety

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Glossary

10 EVA	10-Yearly safety evaluation. In the Netherlands, it represent a comprehensive and integral Safety Review that the licensees need to carry out every 10 years, and which is to be reviewed by the regulatory body for activities under the Nuclear Energy Act.
ANVS	'Autoriteit Nucleaire Veiligheid en Stralingsbescherming' (Authority for Nuclear Safety and Radiation Protection) – Regulatory body
ATEX	ATmosphères Explosibles, European Directive on workplaces with an explosive atmosphere
BHV	'Bedrijfshulpverlening', i.e. company internal Emergency Response Organization
BMI	'Brandmeldinstallatie', Fire alarm system
BNO	'Bedrijfsnoodorganisatie' (BNO), i.e. Emergency Preparedness and Response (EP&R) organisation.
CCV	'Centrum voor Criminaliteitspreventie en Veiligheid', i.e. Centre for Crime Prevention and Safety; a Dutch institute developing among other things, certifications and inspection guidances, some applicable for fire detection and suppression systems
CDF	Core Damage Frequency
Containment approach	In this approach, items are physically located in different fire compartments.
COVRA	'Centrale Organisatie Voor Radioactief Afval', i.e. Central Organisation for Radioactive waste
EHC	'Energy and Health Campus' in Petten; site of the HFR and other nuclear and non-nuclear facilities
EP&R	Emergency Preparedness and Response
EPZ	NV Elektriciteits-Productiemaatschappij Zuid, i.e. licence holder, owner and operator of Borssele NPP in the Nederlands
ENSREG	European Nuclear Safety Regulators Group
FCF	Fuel Cycle Facility
FHA	Fire Hazard Analysis
Fire barrier	(from IAEA SSG-64): Elements of the fire barrier, e.g., walls, ceilings, floors, doors, dampers, penetration seals. Explanatory remark: Some elements are purely passive, such as walls, floors, or ceilings. However, elements with active functions, such as fire doors, fire or smoke dampers, et cetera., are also fire barrier elements.
Fire cell	(from IAEA SSG-64): Fire cells are separate areas in which redundant items important to safety are located. Since fire cells may not be completely surrounded by fire barriers, spreading of fire between cells should be prevented by other protection measures. These means include the following:

	(a) The limitation of combustible materials, (b) The separation of equipment by distance, without intervening combustible materials, (c) The provision of local passive qualified fire protection such as fire shields or cable wrap, (d) The provision of fire detection and extinguishing systems.
Fire compartment	(from IAEA SSG-64 and formerly [NS-G-1.7]): A fire compartment is a building or part of a building that is completely surrounded by fire resistant barriers: all walls, the floor and the ceiling. The fire resistance rating of the barriers should be sufficiently high that total combustion of the fire load in the compartment can occur (i.e. total burnout) without breaching the fire barriers.
GRIP	‘Gecoördineerde Regionale Incidentbestrijdingsprocedure’, i.e.Coordinated Regional Incident Management Procedure of a Safety Region
HFR	High Flux Reactor in Petten
HOR	‘Hoger Onderwijs Reactor’ in Delft
IAEA	International Atomic Energy Agency
IBB model	‘Model Integrale Brandveiligheid Bouwwerken’, Integral fire safety model for buildings, strengthens fire safety by cooperation. Involving all parties and jointly following the roadmap ensures that there is good consistency between different fire safety measures.
Influence approach	In this approach, items are physically located in different fire cells.
INSARR	Integrated Safety Assessment for Research Reactors (IAEA mission)
IPSART	Integral Probabilistic Safety Assessment Review Team (IAEA mission)
JRC	Joint Research Centre
KCB	‘Kerncentrale Borssele’, Borssele Nuclear Power Plant
Kew	‘Kernenergiewet’, i.e. Nuclear Energy Act
LTO	Long Term Operation
NEN	‘Stichting Koninklijk Nederlands Normalisatie Instituut’, i.e. Royal Netherlands Standardization Institute, issuing many industry standards
NPP	Nuclear Power Plant
NRG	Nuclear Research and consultancy Group
NVR	‘Nucleaire Veiligheids Regels’, i.e. Nuclear safety rules. Requirements added in the individual licences, mostly based on IAEA Safety Standards.
OSART	Operational Safety Review Team (IAEA Mission)
PoR / PvE	Programme of Requirements / ‘Programme van Eisen’: The drafting of a Programme of Requirements (PoR) for fire alarm installations arises from the Regulation on Fire Alarm Installations, as part of the 2012 Building Decree. The PoR contains all agreements and requirements that underlie the fire alarm installation, which prevents the installation from possibly not meeting the necessary requirements. Requirements are set by the competent authority and/or insurers.

PSA	Probabilistic Safety Assessment
PSR	Periodic Safety Review, the 10-yearly PSRs are called 10EVAs in the Netherlands.
RB	Regulatory Body, the ANVS in the Netherlands
REOB	‘Regeling Erkenning Onderhoud Blusmiddelen’, i.e. Regulations for the maintenance of (fire) extinguishing equipment
RID	Reactor Institute Delft; operator of the HOR
RI&E	‘Risico-inventarisatie & -evaluatie’; i.e. Risk Identification & Evaluation
RR	Research Reactor
RPS	Reactor Protection System
SAR	Safety Analysis Report
SFS	Spent Fuel Storage
SSC	Structures, Systems and Components
TCDF	Total Core Damage Frequency
TSO	Technical Support Organisation
UPD	‘Uitgangspuntendocument brandbeveiliging’; The basic fire protection document forms the basis for the fire protection design. The purpose of the document is to clearly record agreements on fire protection between the user and the parties that determine the framework (such as the competent authority and insurer).
Urenco	URanium ENrichment COrporation Ltd
UNL	‘Urenco Nederland’, the Dutch branch of Urenco
VR	‘Veiligheidsregio’, i.e. Safety Region. The Netherlands are divided in a total of 25 ‘Safety Regions’ (Dutch: ‘Veiligheidsregio’s’). These are public bodies whose task is to facilitate regional cooperation in dealing with crises, disasters and disruptions of public order. Each municipality belongs to one of these safety regions. Together they are responsible for drawing up joint regulations for crisis management and for administering the emergency services (fire brigades and Regional Medical Assistance Organization) in their respective region. See section 1.2.1.1.
VR-H	‘Veiligheidsregio Haaglanden’, relevant for the HOR
VR-NHN	‘Veiligheidsregio Noord-Holland Noord’, relevant for the HFR
VR-Z	‘Veiligheidsregio (provincie) Zeeland’, relevant for NPP Borssele and COVRA
VR-T	‘Veiligheidsregio Twente’, relevant for Urenco
WENRA	Western European Nuclear Regulators' Association
WSF	Waste Storage Facility

Preamble

This is the National Assessment Report (NAR) of the Netherlands for the Topical Peer Review (TPR) 2023 on the Fire Safety and Fire Protection concept and its implementation. It is the second in the series of TPRs after the first one focused on Ageing management of NPPs and RRs. The structure and content of this report complies with the requirements as specified in the guideline developed by WENRA[1] for the Peer Review process, led by the European Nuclear Safety Regulators Group (ENSREG). This national report has been prepared by the Authority for Nuclear Safety and Radiation Protection (ANVS), and as far as it concerns the requested information on the fire protection aspects of the nuclear installations, it was developed in close cooperation with the licensees of these installations.

Background and scope

In 2014, the European Union (EU) Council adopted directive 2014/87/EURATOM, amending the 2009 Nuclear Safety Directive, 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 conducted every six years thereafter. The purpose is to provide a mechanism for EU Member States to examine topics of strategic importance to nuclear safety, to exchange experience and to identify opportunities to strengthen nuclear safety. The process also provides for participation, on a voluntary basis, of States neighbouring the EU with nuclear power programmes.

The 41th Plenary Meeting of ENSREG identified fire safety of nuclear installations as the topic for the second Topical Peer Review, based on a WENRA proposal of some options after consulting the Commission, WENRA's Reactor Harmonization Working Group and the ENSREG Working group on nuclear safety. It was also decided that, in principle, all nuclear installations falling under the jurisdiction of the Nuclear Safety Directive should participate (in the first TPR only reactors were required to participate).

Objectives of the Peer Review process:

- Enable participating countries to review their provisions for fire safety of nuclear installations, to identify good practices and to identify areas for improvement.
- Undertake a European peer review to share operating experience and identify common issues faced by Member States.
- Provide an open and transparent framework for participating countries to develop appropriate follow-up measures to address areas for improvement.

The Table below contains all participating facilities.

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[1] Report – Topical Peer Review 2023 Fire Protection – Technical Specification for the National Assessment Reports; Ad-hoc TPR II WG report to WENRA, WENRA, June 2022

Process outline

The TPR is executed in three phases:

- National assessment (July 2022 – 31st October 2023) – the present report presents the results of the assessment conducted in the Netherlands.
  - licensees' self-assessment in line with the WENRA technical specification;
  - the assessments were independently reviewed by the national regulator, during preparation of the national assessment report;
  - the national assessment report was edited and finalized by the ANVS.
- Peer Review (1st of November 2023 – end of 2024) - including publication of a summary report and country specific reports.
  - Pre-workshop review of national reports (November 2023 – April 2024);
  - Site visits (May-June 2024) and Peer review workshops (second half 2024).
- Follow-Up (> 2024) - definition and implementation of measures to address relevant findings from national assessments and peer review process.
  - Publication of National Action Plans;
  - Publication of ENSREG Action Plan;
  - Status of action plans (periodically > 2025).

Participating facilities

Participating facilities in the Netherlands

Nuclear facility	Characteristics	Licensee
Borssele NPP	PWR/2-loop	EPZ NV
HFR RR	Tank in pool, 45 MWth	NRG
HOR RR	Open pool, 2 MWth	TU Delft
Enrichment facility	Centrifuge enrichment	Urenco
HABOG, spent fuel and HLW storage	Aboveground storage buildings	COVRA

1. General Information

A comprehensive description of the nuclear installations in the Netherlands, together with the national regulatory framework, is provided in the Convention on Nuclear Safety report (2023) [2]. Therefore, this current NAR will focus on the specific information relevant for the assessment of the Fire Safety and Fire Protection Concept and its implementation.

1.1 Nuclear installations identification

1.1.1 Qualifying nuclear installations

The Netherlands has a small but broad nuclear program, with at least one nuclear installation of each different type. In the year 2017, an independent and centralized governmental Nuclear Regulatory Body was formally created (ANVS- 'Autoriteit voor Nucleaire Veiligheid en Stralingsbescherming'). Since then, all the civil nuclear and radiation related activities in the Netherlands are overseen by this regulatory body.

The location of the existing nuclear installations in the Netherlands is shown in Figure 1.1.:

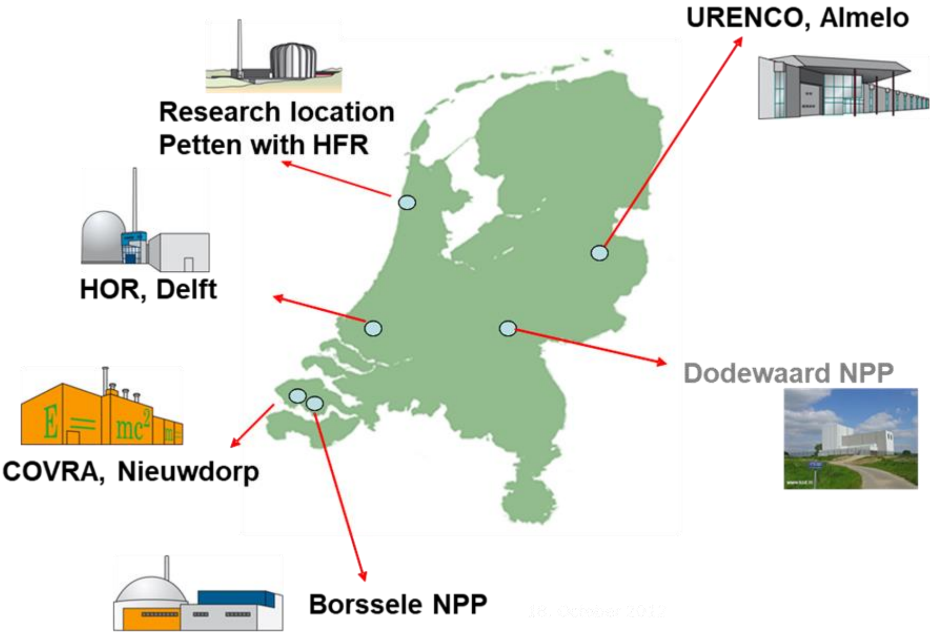

Figure 1.1 Nuclear installations in the Netherlands

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[2] National Report of the Kingdom of the Netherlands for the combined 8th and 9th Review Meeting 2023, link: https://www.rijksoverheid.nl/documenten/rapporten/2022/12/20/bijlage-report-of-the-kingdom-of-the-netherlands-for-the-combined-8th-and-9th-review-meeting-in-2023

Operating installations:

- The Borssele NPP, located in the south-west of the country, in Borssele (province of Zeeland), also known as the ‘Kerncentrale Borssele’, the KCB.
- Two research reactors, one is located on the premises of the Delft University of Technology in Delft (province of Zuid-Holland), this is the so-called ‘Hoger Onderwijsreactor’, the HOR. The other one is located on the Energy and Health Campus (EHC) in Petten (province of Noord-Holland), this is the High Flux Reactor (HFR). Additional nuclear research facilities and laboratories can be found at both the Delft University of Technology and in Petten (Nuclear Research & consultancy Group, NRG and the EU Joint Research Centre, the JRC).
- The uranium enrichment facility of Urenco Netherlands, located in the eastern part of the country, in Almelo (province of Overijssel).
- The COVRA interim radioactive waste storage facility located in the south-west of the country close to the Borssele NPP, in the municipality of Nieuwdorp (province of Zeeland). COVRA has facilities for the storage of conditioned low, intermediate and high level waste, including spent fuel from research reactors, NPPs and waste from reprocessing of spent fuel.

Installations under Decommissioning:

- In the east of the country, in Dodewaard near Arnhem, a small NPP (60 MWe) was located. This installation has been permanently shut down and is awaiting decommissioning, the plant is in so called ‘Safe enclosure’. There is no nuclear fuel remaining in this installation.

Additionally, there is a newbuild project:

- PALLAS project: A new research reactor (named PALLAS) is under consideration in order to replace the HFR, on the Petten site. In June 2022, the PALLAS organization submitted its licence application to the ANVS. In addition various activities have been completed at the site in Petten, such as demolishing buildings and levelling part of the site in preparation for the construction of the new reactor and associated buildings. According to the PALLAS organization, the current plan is to have the new reactor in operation around 2030.

1.1.2 *National selection of installations for TPR II and justification (brief summary of)*

The Netherlands has decided in principle to include all the existing nuclear installations under the scope of the Euratom Nuclear Safety Directive, according to the selection criteria described in the TPR Technical Specification for the NARs document[3], Section 00.3. Refer to Annex A of this NAR for further explanation.

Table 1.1 lists the installations excluded from the NAR, and the reasons for this exclusion.

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[3] 'Report Topical Peer Review 2023, Fire Protection Technical Specification for the National Assessment Reports’, Ad-hoc TPR II WG report to WENRA, 21 June 2022

Table 1.1 Nuclear installations excluded from this NAR

Nuclear facility	Type of installation	Reason of exclusion
Dodewaard NPP	BWR	All non-fixed radioactivity has been removed, as well as the fuel. (TS section 00.3, sub 2, 1st bullet, 3rd sub-bullet)
PALLAS project	Research Reactor	Construction licence granted in February 2023, later than the cut-off date for the NAR Cut-off date: 30th June, 2022.
COVRA VOG-, LOG and COG buildings	Radioactive waste storage	Not on same site as nuclear installation and not containing spent fuel
DWT (Petten site)	Waste treatment facility	No storage facility but buffer for short term storage before transport to COVRA
Delphi assembly (TU Delft)	Subcritical assembly	Subcritical assemblies are out of scope

In the particular case of the PALLAS reactor project, even if it falls out of the scope of the installations to be included in the NAR and after the suggestion from the TPR board, the Netherlands decided to include on a voluntary basis some information of interest. The PALLAS construction licence was granted and went in force in April 2023.

The information on PALLAS is included in Annex B of this report.

1.1.3 *Key parameters per installation*

The following sections provide a description of the key parameters of each installation, together with relevant information in the framework of fire safety. Where possible, an aerial picture provides a view of the immediate surroundings of each installation.

1.1.3.1 NPP Borssele (KCB)

The Borssele Nuclear Power Plant was designed and built by Kraftwerk Union (KWU) and has been in commercial operation since October 1973. The current operating licence is valid until 31 December 2033. The licence holder and operator is 'Elektriciteits Productiemaatschappij Zuidnederland' (EPZ). Companies 'PZEM' and 'Energy Resources Holding' are shareholders of EPZ, and own 70% respectively 30% of the shares.

The nuclear reactor is a 1365 MWth Pressurized Water Reactor with two primary circuit loops, each with one primary pump and one steam generator. The reactor is run in a 12-month cycle with one annual refuelling outage. Currently the gross capacity is 512 MWe and the net capacity is 485 MWe.

The NPP is located in the province of Zeeland, in the Southwest of the country, on the shore of the Westerschelde estuary, which contains the main shipping lanes into and out of the cities of Antwerpen and Ghent (Belgium) as well as Terneuzen and Vlissingen (the Netherlands). EPZ is the sole user of its site. Figure 1.2 shows an aerial view of the site and its surroundings.

The following Table 1.2 Key parameters NPP BorsseleTable 1.2 shows the Key operational parameters of the Borssele NPP.

Figure 1.2 Aerial view of EPZ site

Table 1.2 Key parameters NPP Borssele

Characteristics and measuring units	Value
Primary coolant pressure at the core outlet	154 bar
Coolant temperature at the reactor inlet	292.5 °C
Coolant temperature at the reactor outlet	317.5 °C
Pressurizer temperature	362 °C
Coolant flow rate through the reactor	46,260 m^3/h
Steam flow rate at nominal parameters	740 kg/s
SG pressure at nominal load	57 bar
Steam temperature in SG at nominal load	274.3 °C

The containment is a 46-meter spherical steel shell, which is in turn encapsulated by the concrete reactor building. The spherical shell contains the reactor vessel, the steam generators and also the spent fuel pool. Even if not needed to guarantee a margin to sub criticality, the water in the spent fuel pool contains boron dissolved to provide a greater margin. There is no separate nuclear fuel storage facility outside the containment. The low level waste of the plant is temporarily stored in a dedicated building (Waste Storage Building).

To cope with external hazards, important safety systems like emergency core cooling, spent fuel pool cooling, reactor protection system and the emergency control room are installed in 'bunkered' buildings. These buildings are qualified to withstand earthquakes, floodings, gas cloud explosions, airplane crash and severe weather conditions.

The KCB has its own fire brigade on site. Although a fire truck is not necessary for fighting fires in those buildings containing relevant safety systems, the fire brigade possesses a fire truck for fighting fires on site. In case of a fire alarm, the off-site fire brigade of the villages Borssele or Nieuwdorp will turn out for the KCB.

The site is surrounded by several small and large companies on the industrial area ‘Haven-terrein Vlissingen-oost’ in a radius of a couple of kilometers. The COVRA radioactive waste storage -described later- is located at a distance of approximately 1 km. An oil refinery is located at a distance of approximately 4 km of the NPP.

The distance to the city of Middelburg is about 8 km, to the city of Vlissingen about 10 km and to the smaller villages Borssele, ‘s-Heerenhoek and Nieuwdorp 2 to 4 km.

An ignition system has been installed as mitigation for explosive and flammable gas clouds that could blow in from the Westerschelde estuarium if there were to be a collision on the roadstead of Vlissingen or on the Westerschelde’s busy shipping lanes, resulting in a gas cloud. To reduce the probability of an explosion on site, an automatic detection and ignition system has been placed at a safe distance from the KCB site. It includes igniters at two locations on the seaward side of the dyke in front of the plant. This feature will contribute to prevent damage to the installation in very specific situations.

1.1.3.2 Research Reactor HFR

The HFR (High Flux Reactor) is a multi-purpose pool type research reactor and functions as a neutron source for civil, technological and scientific research, as well as for the production of radioisotopes. The owner of the HFR is the Joint Research Centre (JRC), but it is operated by the licence holder, the Dutch organization Nuclear Research and Consultancy Group (NRG).

The HFR is located on a site by the sea in the North Holland dunes, in the municipality of Schagen,. Recently, this site is also known as the ‘Energy and Health Campus’, the EHC. Over 1,600 specialised employees from different organisations and companies work here on new technologies and smart applications in the fields of energy and nuclear medicine.

Other than NRG, the EHC also houses different organisations: GCO-IE (the Institute for Energy of the JRC) of the European Commission, the research and development organisation TNO, Curium Pharma producing medical isotopes and the Foundation Preparation PALLAS reactor.

Apart from the HFR, other nuclear facilities on the EHC are: the Curium Molybdenum Production Facility (MPF), Hot Cell laboratories (HCL), various research & development labs as well as compliance labs and other supporting facilities for decontamination and waste management. The aforementioned facilities operate under a licence of NRG.

The first criticality of the HFR was achieved on 9 November 1961. The current HFR licence does not contain an end of operation date. Nevertheless, it is legally subject to managerial and operational requirements, as well as regular inspections by the regulatory body.

The HFR nominal operating power is 45 MW thermal, with a licensed capacity of 50 MW thermal. The reactor uses uranium silicide, plate-type fissile materials, with low-enriched uranium and Cadmium as burnable neutron absorber, light water as moderator and coolant, and beryllium blocks and light water as reflector. The reactor vessel is slightly pressurized and is placed under water in the reactor pool.

Fresh fuel elements are stored in appropriate dry storage vaults, while spent fuel can only be stored in the storage racks in the pool, ensuring subcriticality in normal and accidental conditions.

Figure 1.3 Aerial view of RR HFR and its surroundings

External fires are rather frequent in the coastal area where the HFR complex is located. However, given the distance (minimum 125 m) of woodlands / scrubs to the west of the plant, a direct ignition of the reactor outbuilding and primary pump building by the fire is deemed not to be possible. The combustible load of the marram/beach grass that surrounds the HFR is far too low to cause a direct ignition of the buildings. The HFR confinement itself is made of steel and it is very improbable that it will ignite. The other buildings could catch fire by sparks from the woodlands / scrubs.

NRG's internal organization for emergency preparedness and response (EP&R organisation) is referred to as the BNO[4]. The BNO consists of teams and individual employees who can provide assistance during deviations from normal operation, e.g. due to accidents, fire or other incidents with a possible nuclear dimension to them within the EHC. NRG will take immediate action, if necessary assisted by the government's auxiliary capacity in the form of e.g. the fire brigade, ambulance, police and/or other support coordinated by the Safety Region (VR-NHN).

A subdivision of the BNO deals with firefighting, which is the QRT, the Quick Response Team. Due to the specific radiological risks in NRG's facilities, the QRT also has sufficient measuring equipment at its disposal (personal dosimeters, dose rate meters and contamination monitors).

In addition to a number of special scenario types for which the QRT is prepared, basic firefighting task 'firefighting' and 'deployment' are provided for all the organisations located on the whole EHC. For these tasks, a cooperation agreement has been concluded between NRG, the VR-NHN and the municipality of

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[4] in Dutch: 'Bedrijfs nood organisatie' (BNO), i.e. Emergency Preparedness and Response (EP&R) organisation.

Schagen.

The Petten site also locates an interim Waste Storage Facility (WSF), a building in the western part of the NRG site. The radioactive waste is stored in the underground cellars or trenches of this WSF.

1.1.3.3 Research Reactor HOR

The HOR is located at the premises of the Delft University of Technology, nearby the city of Delft, in the western part of the 'Zuidpolder van Delfgauw' area.

The construction of the HOR (and the laboratories of the RID) began in November 1958. After several iterations, a licence was granted under the former 'Hinderwet' on 19 February 1969 for the operation of the HOR at a reactor power of maximum 3 MW. The current HOR licence does not contain an end of operation date. Nevertheless, it is subject to operational requirements and regular inspections by the regulatory body.

The HOR is a light water (research) reactor of the pool type. Although designed for 3MW thermal power, it is normally operated at a power of 2MW, due to the cooling capacity, or at 3 MW for a maximum of one hour per day. The reactor is operated for approximately 200 days per year. Figure 1.4 shows an aerial view of the HOR and its surroundings.

Figure 1.4 Aerial view of RR HOR in Delft

From January 2005 on, only Low Enriched Uranium (LEU) is used, in the form of Uranium Silicide (U_3Si_2). Two types of elements are utilized: standard and control fuel elements. The standard elements contain nuclear fuel plates and the control elements contain a lesser amount of nuclear fuel plates to enable the insertion of a control rod between them.

Fresh fuel elements are stored in the appropriate dry storage vault, while spent fuel can only be stored in the storage racks in the pool, where subcriticality is ensured in normal and accidental conditions.

The reactor hall has three entrances. There is one door for trucks which opening is only allowed during reactor shut down, and there are two air locks for personnel entrance. The fire brigade can use all three entrances.

The HOR is immediately surrounded by several buildings and constructions, containing the Primary Cooling System pumps or the Control Room complex, among others.

External fires may originate from:

- the grass surrounding the plant buildings: the fire load of the grass surrounding the plant buildings is so low that spreading of an external fire to the buildings via the grass is deemed not to be possible.
- Storage and use of combustible materials of organizations outside the HOR site: a fire at these chemical storages could cause heavy smoke and sparks. In an extreme scenario, flying sparks may be able to cause fire on the bitumen roofs of the control room and HOR outbuildings. However, in practice, before the situation has worsened to this extent, there is sufficient time available to shut down the reactor, mobilize the fire brigade and initiate emergency measures.
- Explosion after transportation accidents of trucks, trains and ships carrying flammable material on nearby transport routes -or explosion after pipeline accident- are screened out based on distance, because these accidents cannot occur close to the plant.
- Lightning is screened out due to the protection against lightning of the main buildings).

For TU Delft (RID/HOR), the Safety Region of concern is ‘Veiligheidsregio Haaglanden’ (VRH).

There is no fire brigade on-site, but within the internal Emergency Response Organization (BHVO) , both the internal Emergency Responders (BHV) and the internal Emergency Response Fire Service (BHV-b) are present. The BHVO is specific for RID. The determination of the needed capacity for the different functions of the BHV have been performed on the basis of normative scenario’s.

The BHV-b has the task of fighting (starting) fires until the arrival of the external regional fire brigade and carrying out evacuation actions and perform a guiding function for the regional fire brigade.

The BHV-b works closely with the external fire brigade of the Safety Region (the VRH-b). In practice the VRH-b will be informed for any fire situation which could potentially increase to a more severe level.

1.1.3.4 Uranium enrichment facilities of Urenco

Urenco Nederland B.V. (UNL) owns and operates the facilities in Almelo (province of Overijssel) to produce lightly enriched uranium, in the form of UF_6, for nuclear power plants in nearly 20 countries around the world. Operations started in the early 1970s, with extensions like a Separation Plant in 1981 and another Separation Plant in 2000.

Besides enriching uranium for use as fuel in nuclear power plants, the current licence covers the enrichment of stable (non-radioactive) isotopes using the same ultracentrifuge technology.

This operation licence is indefinite, but Urenco is nevertheless subjected to operational requirements and regular inspections by the regulatory body.

UNL fully owns the site in Almelo. The site covers over 30 hectares and contains different types of buildings. The enrichment plant consists of the separation plants with the associated supporting infrastructure. The main process steps in the enrichment process, occurring in different buildings, are:

1. enrichment of UF_6 in cascades, including feed and ‘take-off’;
2. blending & liquid sampling;
3. recycling and decontamination;
4. storage and cylinder handling.

The enrichment process takes place using ultracentrifuges to which the uranium is added in gaseous state as UF_6 (feed). After enrichment, the enriched portion of UF_6 is tapped as a product and the depleted portion as tails (take-off). Both are stored in UF_6 cylinders as solids at sub atmospheric pressure.

A couple of business parks with various companies are located to the north of UNL. Most of them are companies and organizations with 10 to 200 employees, mainly working in day shifts. At the adjacent ETC NL, which is 50% part of the Urenco Group, the centrifuges for uranium enrichment are fabricated. Furthermore, the business parks include various production companies that work with hazardous substances and where these substances are stored.

Scenarios with release of hazardous substances from nearby companies results in a risk contour on the Risk Map for three companies. The results from these analyses show that these do not extend to the UNL site. Additionally, fire scenarios at nearby companies do not lead to effects for UNL.

UNL is located near a densely populated area but the immediate surroundings are sparsely populated. Within a radius of 1,000 meters from UNL are pastures, the business park and a few houses/accommodations. The good infrastructure in the area and the location of UNL on the main road, increases the quick accessibility and presence of emergency services in case of an emergency. It also facilitates evacuation of immediate neighbours or visitors if needed.

Figure 1.5 shows an aerial view of the URENCO site and its surroundings.

Figure 1.5 Aerial view of UNL site

An on-site fire brigade is not required, but the local fire brigade can be present in less than 6 minutes when needed. UNL has an internal emergency response organization (BNO) to limit the consequences of fire, environmental incidents and accidents. The emergency response organization consists of first responders, a first aid team, evacuation team(s) and an alarm centre with continuous staffing. The emergency response organization complies with legal requirements (e.g. 'Arbowet').

To extinguish starting fires, the operators are trained as first responders. They are available 24/7 on site and have access to all buildings and installations. The first responders are trained in firefighting, wearing of and working with breathing protection, acting in the event of a chemical release (in a gas suit), life-saving actions and CPR.

1.1.3.5 Spent fuel and radioactive waste storage facilities - COVRA

The Central Organisation For Radioactive Waste (COVRA N.V.) is the sole company in the Netherlands tasked with collecting, processing and storing all the radioactive waste. In order to implement this task, COVRA has realised in 1993 a storage and processing facility in the province of Zeeland, next to the Borssele NPP. COVRA is the only organisation present on its site.

The function of the facility is to collect, process, package, and store the radioactive waste generated in the Netherlands, above ground, for at least 100 years. In order to realize this function, the establishment must be able to carry out the following activities:

- Setting up, housing, operating and maintaining a transport group focused on the collection of radioactive waste.
- Supervision and reception of shipments by third parties. The temporary storage of drums and containers with radioactive waste prior to processing, handling and storage. Layer editing, processing and packaging and medium-level radioactive waste. Storing processed or unprocessed layer and intermediate level radioactive waste.
- Handling, packaging and storage of highly radioactive waste.
- Taking care of all necessary administrative and control actions.
- Disposal of the waste that has reached such an activity -through radioactive decay- that it can be categorized as non-radioactive waste.

For the treatment and storage of heat-producing and non-heat-producing high-level radioactive waste, COVRA started operating the High Radioactive Waste Treatment and Storage Building (HABOG) in 2003, and added a two vaults extension in 2022.

The layout of the various buildings on the COVRA site is shown in Figure 1.6.

The COVRA site is surrounded by several small and large companies in the industrial area ‘Haventerrein Vlissingen-Oost’. The most notable neighbouring installation is the EPZ nuclear power plant (NPP) which is located at a distance of approximately 1 km to the south-east of HABOG. The distance to the city of Middelburg is about 8 km, to the city of Vlissingen about 10 km and to the smaller villages Borssele, ‘s-Heerenhoek and Nieuwdorp 2 to 4 km.

In the near vicinity of the COVRA site, several industrial companies are located (300-400m distance). These companies provide offshore related services. The risk these companies pose to COVRA has been assessed, and their impact is seen as negligible.

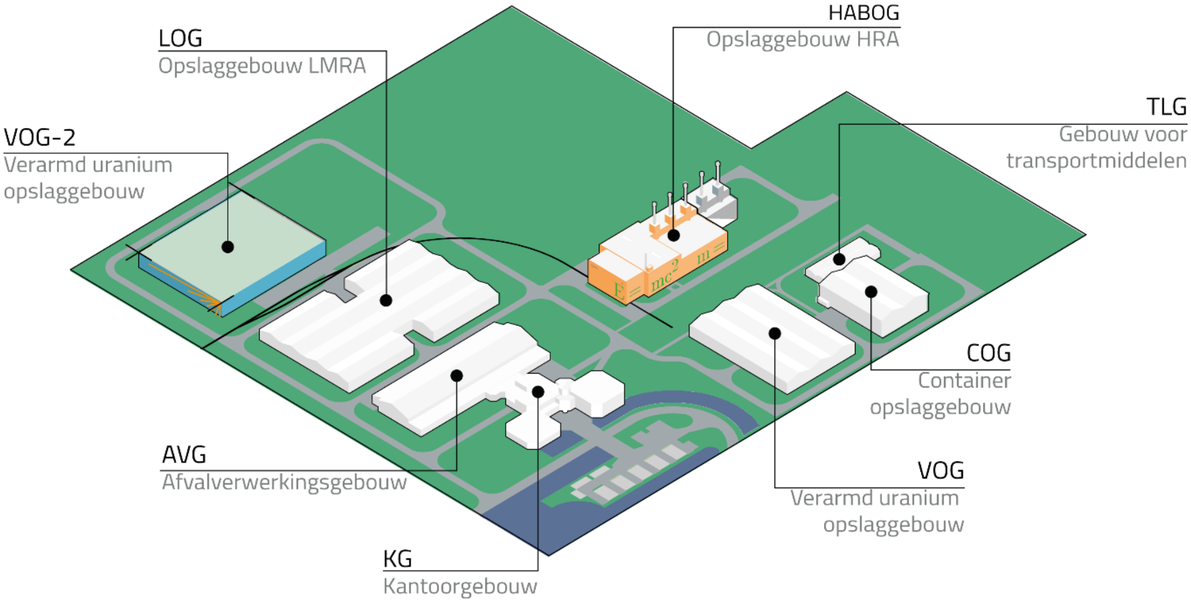

Figure 1.6 Layout of COVRA premises, with: KG: office building, AVG: waste processing building, VOG and VOG-2: depleted uranium storage buildings, COG: container storage building for mainly TENORM wastes, TLG: building for storage of transport vehicles, LOG: building for storing LMRA, and HABOG: building for storage of HRA.

The highly radioactive waste that is offered to COVRA can be classified into Heat-Producing (HPW) and Non-Heat-Producing Waste (NHPW).

The heat-producing waste makes it necessary to have provisions to remove the released heat. This category also includes materials that contain significant quantities of fissile materials and, given the associated criticality and non-proliferation aspects, cannot be stored in another building or in the non-passively cooled storage compartments of the HABOG.

- *Waste from reprocessing:* The irradiated nuclear fuel elements of the Borssele NPP are reprocessed abroad, and the waste resulting from this process is delivered back to the Netherlands. The fission products and actinides are homogeneously fixed in a durable glass matrix contained in a stainless steel canister. The vitrification process is carried out abroad as well. This waste is packaged in such a way that it can be directly stored by COVRA in the HABOG.
- *Waste from decommissioning*: All of the highly radioactive waste from the Dodewaard nuclear power plant (in decommissioning) has been stored at COVRA.
- *Fuel from research reactors*: this category includes irradiated fuel elements, fuel-containing control elements, fuel residues and fuel-containing material from research reactors in the Netherlands. The irradiated fuel elements and control elements are packed by COVRA in stainless steel canisters, which are welded shut and filled with an inert gas. This activity takes place after the several years of decay time in the reactor pools. Compared to the waste from reprocessing , this waste has a relatively low heat production.

The non-heat producing waste includes waste with such a limited heat production that no special facilities are required to remove the released heat. This waste is hereinafter referred to as non-heat-producing high-level radioactive waste (HRA). The non-heat-producing HRA includes:

- *Waste from reprocessing*: the reprocessing of the irradiated fuel elements from the nuclear power plants Borssele and Dodewaard also produces high-level radioactive waste consisting of the activated construction materials of the fuel elements, such as metal sleeves and finials. This is compacted and packed. The waste from cleaning installations, such as concentrated sludge and alpha-containing waste, is vitrified and packed. This packaging is directly put into storage by COVRA.
- *Waste from decommissioning*: part of the decommissioning waste belongs to the category of non-heat-producing high-level radioactive waste. This waste is pre-treated and packed by COVRA before it is put into storage.
- *Other high-level radioactive waste*: The other highly radioactive non-heat-producing waste originates, among other things, from research reactors and laboratories of research institutes. This waste has a very diverse composition and is treated and packaged before being put into storage at COVRA.

COVRA N.V. does not have an internal company fire brigade, but does have a company Emergency Response Organization (BHV). Only a beginning fire will be extinguished by COVRA personnel, and in case of larger fire, the arrival of the fire brigades of the Safety Region Zeeland will be awaited.

Periodically, internal exercises are organized and further training takes place in accordance with the guidelines of the NIBHV [5].

1.1.4 Approach to development of the NAR for the national selection

In June 2022, right after the first version of the TPR Fire Protection Technical Specification and the Terms of Reference documents were available, the ANVS organized a kick-off meeting with the licensees of the nuclear installations selected for the development of the NAR. In this meeting, the content of the NAR was presented and discussed.

Afterwards, the ANVS designated an internal coordinator for the development of the NAR, and in parallel each nuclear installation defined a team of employees with relevant knowledge to be involved in the writing of the corresponding contents for Chapters 1, 2 and 3. Licence holders were encouraged to develop both Chapters 2 and 3 in an integrated manner, considering the interfaces between them.

The ANVS withheld the task of developing Chapters 0, 1, 4 as well as the corresponding 'Regulator Assessment' sections of Chapters 2 and 3.

Three draft versions per installation were planned and shared with the ANVS, that proceeded to give separate feedback in a period of maximum 45 days after reception of each version. The review covered topics like scope, clarifications of the expected content per section, security of the information to be published and harmonizing the narrative and wording. Emphasis was placed on the identification and description of regulations and guidelines applicable to each installation.

In the period from June 2022 to June 2023, several meetings were held between the ANVS coordinator, ANVS experienced personnel and plant inspectors together with the employees from the nuclear installation to discuss the comments on each revision. At least one physical meeting was organized per licensee, and the rest were conducted via videoconferences.

The definitive versions from each installation were shared with the ANVS by June 2023, completed with internal documents and references. For security and practical reasons, references to internal documents are not included in the NAR.

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[5] Dutch: 'Nederlands Instituut Bedrijfshulpverlening' (NIBHV), ie. Dutch Institute for training of emergency response officers.

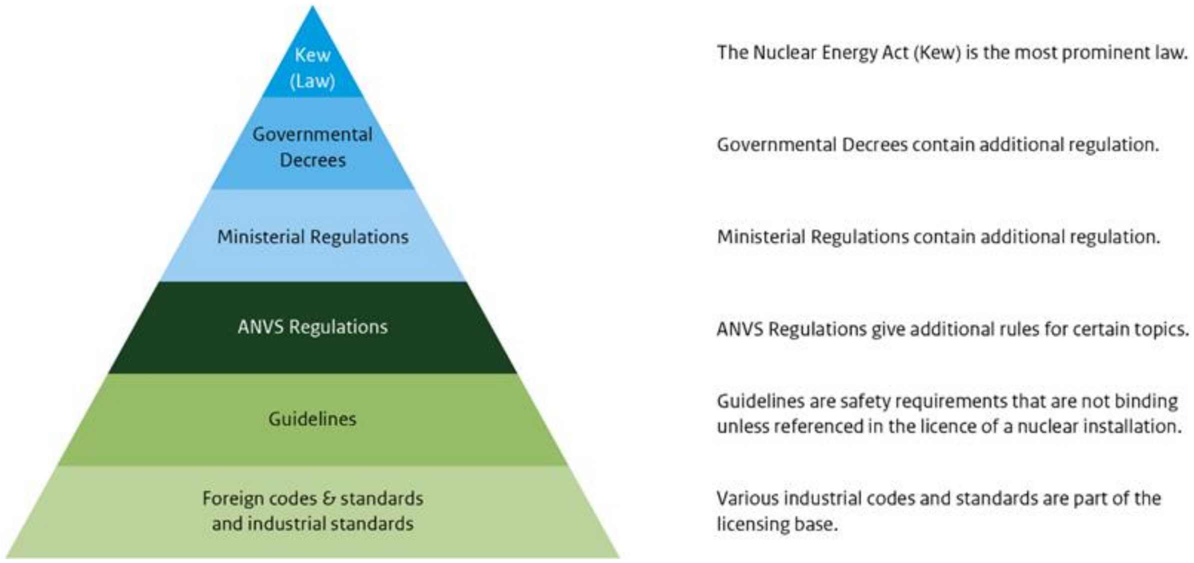
In the period between June 2023 and October 2023, the definitive versions were integrated in the NAR, together with the sections developed by the ANVS itself. Given the amount and scope of the information to be presented, the ANVS decided to have only one *'Licensee's experience on the Fire Protection concept and its implementation'* as well as '*Regulator assessment*' sections per facility and per Chapter (2 and 3). The texts written by the regulator were discussed with the Licence Holders as well.

The final integrated version of the NAR was shared with the Licence Holders for a final check and acceptance.

1.2 National regulatory framework

A comprehensive description of the national regulatory framework is provided in the Convention on Nuclear Safety report[6], as referred to in the first sentence of Chapter 1. The regulatory framework consists of a hierarchical arrangement containing, at the higher level, the legally binding instruments, including the Nuclear Energy Act (Kernenergiewet) and the governmental and ministerial regulations (including those implementing the EU-Nuclear Safety Directive).

On a lower level, the legally non-binding instruments include guidance documents and industrial codes and standards. These can be made legally binding through licence conditions in the individual licences. This hierarchy is shown in Figure 1.7.



The Nuclear Energy Act (Kew) is the most prominent law.

Governmental Decrees contain additional regulation.

Ministerial Regulations contain additional regulation.

ANVS Regulations give additional rules for certain topics.

Guidelines are safety requirements that are not binding unless referenced in the licence of a nuclear installation.

Various industrial codes and standards are part of the licensing base.

Figure 1.7 Simplified representation of the hierarchy of the legal framework as presented in CNS report

An extensive body of legislation is based on the Nuclear Energy Act. This includes Governmental decrees, ministerial regulations, the regulations issued by the ANVS, and a number of general operating decisions. These include:

- Nuclear Installations, Fissionable Materials and Ores Decree (Bkse[7])

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[6] Convention on Nuclear Safety, National Report of the Kingdom of the Netherlands for the combined 8th and 9th Review Meeting in 2023

[7] Dutch: 'Besluit kerninstallaties, splijtstoffen en ertsen', Bkse

- Transport of Fissionable Materials, Ores and Radioactive Materials Decree (Bvser[8])
- Basic Safety Standards for Radiation Protection Decree (Bbs[9])
- Ministerial Regulation on Nuclear Safety for Nuclear Installations (MR NV[10])
- Ministerial Regulation on the Security of Nuclear Facilities and Fissionable Materials[11]
- Ministerial Regulation on Nuclear Pressure Equipment[12]

A more detailed explanation regarding the Dutch national regulatory framework and its requirements is found in the Convention on Nuclear Safety report, in its chapter on compliance with Article 7 of the CNS.

The NAR will focus on legislation of interest in the framework of Fire Safety and Fire Protection concepts.

1.2.1 National regulatory requirements and standards

Depending on the type of installation, when deemed necessary, specific nuclear (fire) safety related requirements are listed in the individual licences, tailored to the particular characteristics, and based on a graded approach. An example of the fire related requirements included in licences in the Netherlands is shown in Appendix C. The practice of including specific requirements in the individual licences is suitable for a country like the Netherlands, with a small number of different nuclear facilities and only one operating NPP.

The following sections provide a description of additional non-nuclear related legislation and guidelines which are relevant since they have an impact on Fire Protection aspects. These sections aims to provide context to the reader, since these legislations and guidelines are mentioned and used by at least one of the licensee's in their specific texts.

1.2.1.1 National non-nuclear Acts and Decrees relevant for fire safety

Safety Regions Act (Wet Veiligheidsregio's)

Decree Safety Regions (Besluit veiligheidsregio's)

The Safety Regions Act and the Safety Regions Decree based on it, determine especially the tasks of the management of the Safety Regions and set a number of basic requirements for the organization of the emergency services and the quality of the personnel and equipment.

The Netherlands are divided in a total of 25 Safety Regions ('Veiligheidsregio's'). These are public bodies whose tasks include identifying risks of fires, disasters and crises and preparing to fight fires and organising disaster and crisis management. Each municipality belongs to one of these safety regions. Together, they are responsible for drawing up joint regulations for crisis management and for administering the emergency services (Fire Brigades and Regional Medical Assistance Organization) in their respective region.

In addition to extinguishing fires and providing assistance in the event of an accident, the fire brigades also

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[8] Dutch: 'Besluit vervoer splijtstoffen, ertsen en radioactieve stoffen', Bvser

[9] Dutch: 'Besluit basisveiligheidsnormen stralingsbescherming', Bbs

[10] Dutch: 'Ministeriële Regeling Nucleaire Veiligheid kerninstallaties', MR NV

[11] Dutch: 'Ministeriële Regeling beveiliging nucleaire inrichtingen en splijtstoffen'

[12] Dutch: 'Ministeriële Regeling nucleaire drukapparatuur'

carry out measurements of the presence of hazardous substances, solicited and unsolicited fire safety inspections, and fire prevention information for companies and institutions.

The fire brigades provide information but not advice to companies. This advisory role lies with the specialized consultancy firms for fire safety. Fire safety requires an integrated approach: an architectural, installation-technical and organizational assessment of the building. Specialized consultancy firms map out the safety risks of the building and provide tailor-made advice based on this.

Article 31 of the Safety Regions Act gives the boards of the Safety Regions the possibility to oblige organisations to have an internal company fire brigade, were these organizations to pose a particular risk to public safety in the event of a fire or accident.

Working Conditions Act (Arbeidsomstandighedenwet)

Pursuant to the Working Conditions legislation, each company in the Netherlands is responsible (among other things) for fire safety in their buildings and are obliged to provide it with, for example, a fire alarm system, sprinkler systems and escape route signage.

Additionally, every employer is obliged to organize the company emergency response organization (BHV) the composition of which depends on the size of the company and the risks derived from its activity, including fires.

Building Decree 2012 (Bouwbesluit 2012)

The Building Decree is the national regulation that describes the minimum technical requirements with regard to the construction, use and demolition of structures for new and existing buildings (e.g. from the point of view of fire safety and the robustness of the construction.

In particular, the Building Decree contains regulations for measures to be taken for fire prevention and fire safety for industrial premises:

- design for fire prevention and rules for the storage of flammable and combustible substances;
- detection of fire in time with fire alarm systems and smoke detectors;
- reducing the risk of fire and smoke spreading by using non-combustible or fire-retardant materials;
- escape plans and escape routes;
- fighting fire with extinguishing agents such as fire hose reels and fire extinguishers;
- the accessibility for emergency services via a fire service entrance, fire service lift, connecting roads.

Major Accident Hazards Decree 2015 (Besluit risico's zware ongevallen, Brzo)

The Brzo implements the requirements of the European Directive Seveso-III. The objective is to prevent and control major accidents involving hazardous substances. It integrates laws and regulations on occupational safety, environmental safety and disaster response into a single legal framework.

The Brzo 2015 sets requirements for designated companies in the Netherlands with the highest risks.

Companies subject to the Brzo have to know exactly how much of which type of hazardous substances they have, what the effects may be (risk inventory) and what measures are needed to control the risks. These Brzo-requirements are supervised by an inspection team of various authorities, in which each authority contributes its own expertise regarding specific laws and regulations, e.g.:

- Specialized environmental agencies of the Provinces, having tasks regarding environmental regulations;
- Netherlands' Labour Inspectorate of the Ministry of Social Affairs and Employment, regarding the Working Conditions Act;
- Safety regions, regarding the Safety Regions Act;
- The Dutch State Supervision of Mines, regarding the safe and environmentally sound exploration and exploitation of natural resources like natural gas and oil (a.o. Mining Act).

Regarding hazardous substances that are also radioactive, nuclear installations in that respect are not covered by the Brzo, but by the aforementioned 'Nuclear Installations, Fissionable Materials and Ores Decree' (Bkse). Whenever hazardous substances may be present by licence, or formed as a result of an industrial chemical process becoming uncontrollable, the Brzo does apply largely *mutatis mutandis*.

1.2.1.2 National non-nuclear guides and standards

This section gives an overview of Dutch guides and standards relevant for fire safety in nuclear installations.

Hazardous Substances Publications series (PGS- Publicatiereeks Gevaarlijke Stoffen)

These are Dutch Safety guidelines for companies that produce, transport, store or use hazardous substances, and for authorities charged with supervising and licensing these companies. The PGS integrally describes the main risks of those activities for environmental safety, fire safety and the safety of employees. In addition, it describes the possible consequences of that activity for emergency response.

The relationship with laws and regulations is described, and the goals to control the risks and limit the negative effects for people and the environment are formulated as specifically as possible.

The ANVS can impose the compliance to these standards as part of the individual licences, when deemed necessary.

NEN standards (NEderlandse Norm)

NEN is the Royal Netherlands Standardization Institute, an independent foundation, not a government agency. Norms are therefore not laws, but best practices. NEN is member of the European and international standardization networks CEN, CENELEC, ISO, IEC and ETSI.

These standards covers topics such as Occupational Health and Safety, Construction (and fire protection), and Energy production and distribution.

The ANVS can impose the compliance to these standards as part of the individual licences, when deemed necessary.

1.2.1.3 National nuclear guidelines

ANVS Guide on Level 3 PSA; and approach for the use of a risk analysis/ PSA in Nuclear Installations

Licensees and licence applicants for a nuclear installation in the Netherlands are under the obligation to perform a risk analysis, namely a Probabilistic Safety Assessment, or PSA, which is customarily subdivided into three levels, i.e. a level 1, level 2, and level 3 PSA. The transition to a more risk-informed regulation originated in the 1990s, related to the operation of the Borssele NPP and the use of the PSA to substantiate design changes.

For NPPs and research reactors, level 1 and 2 PSA is mandatory. A level 1 PSA identifies the sequences of events that can lead to core damage, and the core damage frequency is estimated. In the level 2 PSA, the progression of the various systems in the events identified in the PSA level 1 is evaluated, and the probability of releases following core damage is calculated, together with the associated characteristics of those releases (e.g. definition of source term).

A Level 3 PSA is mandatory for all the nuclear installations in the Netherlands, including non-reactor installations.

For reactors, a level 3 PSA determines the external consequences on the basis of the accident releases determined in the level 2 PSA (e.g. doses to the public).

The IAEA has published guides for level 1 PSA (IAEA SSG-3) and level 2 PSA (IAEA SSG-4) in 2010, but no IAEA guidelines are available for level 3 PSA, applicable to all nuclear installations. The Netherlands developed a Level 3 PSA guideline to take into account the latest insights and to incorporate the latest developments in legislation on radiological requirements for nuclear facilities. This document is a guide and it does not impose any binding requirements on performing a level 3 PSA, but includes recommendations for meeting the existing legal requirements when performing a level 3 PSA.

The ANVS guide on Level 3 PSA is a publicly available document, and can be found on the ANVS website[13] with a Dutch and an English version.

Dutch Safety Requirements (DSR-Handbook for a safe design and safe operation of nuclear reactors), part of 'Handreiking VOBK'

The DSR apply to facilities where fission of nuclear fuels takes place, for the generation of electricity (nuclear power plants) and for research reactors. These requirements are applicable for light water cooled nuclear reactors and apply to all the lifetime phases of a nuclear reactor: site evaluation, design, construction, commissioning, operation, decommissioning, and dismantling.

To reflect the latest state of technology and science, the 'DSR' were developed for licensing new build nuclear power plants and research reactors. Existing nuclear reactors shall apply these requirements as far as reasonable achievable, with the objective to continuously improve nuclear safety.

Requirements are established for the structures, systems and components of nuclear reactors as well as for procedures important to safety, that are required to be met for safe operation and for preventing events that could compromise safety, or for mitigating the consequences of such events.

Although the DSR guide is not a ministerial regulation, and therefore does not contain any legal requirements, the assessment of a licence application takes place on the basis of the safety preconditions of it. These specific preconditions are in line with the current insights of, in particular, the International Atomic Energy Agency (IAEA) and the Western European Nuclear Regulators Association (WENRA). They can, where applicable and necessary, serve as the basis for the licensing requirements for new reactors.

The DSR contains a detailed description of the application of the Defense-in-Depth (DiD) concept, as well as requirements for Internal and External Hazards, including fires and explosions (e.g. Section 3.2.1: Plant Internal Fires). Additionally, Annex 4 of the DSR describes the Requirements on Safety Demonstration and Documentation, including requirements for the PSA.

The DSR is a public document written in English, and available on the ANVS website [14].

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[13] https://english.autoriteitnvs.nl/documents/publication/2020/03/10/anvs-guide-on-level-3-psa

[14] https://english.autoriteitnvs.nl/documents/publication/2023/04/05/guidelines-safe-design-and-operation-of-nuclear-reactors-and-dsr

1.2.2 Implementation/Application of international standards and guidance

IAEA Safety Standards and WENRA Safety Reference Levels:

In the Netherlands, it has been a long standing practice to apply IAEA Safety Standards in the regulation of nuclear installations. It started at the NPP and gradually extended to other installations. The IAEA Safety Standards are applied in conjunction with the WENRA Safety Reference Levels in several ways:

- Current practice is to make IAEA Requirements legally binding through licence conditions of nuclear installations. Where needed they are adjusted or complemented by WENRA SRLs to ensure the WENRA SRLs are covered. IAEA Safety Guides are generally handled as guidance.
- IAEA Safety Standards and WENRA SRLs are used as reference documents for the evaluation of new licence applications and periodic safety reviews.

Examples of some fire-related IAEA documents used in the Netherlands are:

- Fire Safety in the Operation of Nuclear Power Plants, Safety Guide, IAEA Safety Standards Series NS-G-2.1, 2000.
- Protection against Internal Fires and Explosions in the Design of Nuclear Power Plants, Safety Guide, IAEA Safety Standards Series, NS-G-1.7, 2004.
- Evaluation of Fire Hazard Analyses for Nuclear Power Plants: A Safety Practice, IAEA Safety Series No. 50-P-9, 1995.
- Preparation of a Fire Hazard Analysis, IAEA Safety Report Series: No. 8, 1998.
- The Operating Organization for Nuclear Power Plants, Specific Safety Guide, IAEA Safety Standards Series No. NS-G-2.4, Vienna, Austria, 2002.
- Safety of Conversion Facilities and Uranium Enrichment Facilities, Specific Safety Guide, IAEA Safety Standard Series No. SSG-5, Vienna, Austria, 2010.
- Safety of Nuclear Power Plants: Design, Requirements, IAEA Safety Standard Series No. NS-R-1, Vienna, Austria, 2000.
- Safety of Nuclear Power Plants: Design, Specific Safety Requirements, IAEA Safety Standard Series No. SSR-2/1, Rev. 1, Vienna, Austria, 2016.
- Safety of Nuclear Power Plants: Commissioning and Operation, Specific Safety Requirements, IAEA Safety Standard Series No. SSR-2/2, Rev. 1, Vienna, Austria, 2016.
- Safety of Research Reactors, Specific Safety Requirements, IAEA Safety Standard Series No. SSR-3, Vienna, Austria, 2016.
- Safety of Nuclear Fuel Cycle Facilities, Specific Safety Requirements, IAEA Safety Standard Series No. SSR-4, Vienna, Austria, 2017.
- Use of a Graded Approach in the Application of the Safety Requirements for Research Reactors, Specific Safety Guide, IAEA Safety Standards Series No. SSG-22, Vienna, Austria, 2012.
- Operating Experience Feedback for Nuclear Installations, Specific Safety Guide, IAEA Safety Standards Series No. SSG-50, Vienna, Austria, 2018.
- Protection against Internal Hazards in the Design of Nuclear Power Plants, Specific Safety Guide, IAEA Safety Standards Series No. SSG-64, Vienna, Austria, 2021.

Additional foreign and international directives, guidelines, codes and standards

The Netherlands has a non-prescriptive, goal-orientated legal framework, meaning that nuclear installations have to demonstrate that they achieve the legally required safety standards. For this demonstration of compliance with the national legal framework, nuclear codes and standards of other countries are often used. Examples are the US Code of Federal Regulations, the US NRC Regulatory Guides, the US NRC Standard Review Plan, and the German RSK recommendations.

Additionally, it is noted that the IAEA Safety Guides provide guidance on many specific items, but they do not cover industrial codes and standards. Applicants are therefore required to propose applicable codes and standards, to be reviewed by the RB as part of their licence applications. Codes and standards commonly used in major nuclear countries are generally acceptable (e.g. ASME, IEEE and KTA). The RB has the power to formulate additional requirements if necessary.

Some examples of German KTA (Kerntechnischer Ausschuss) documents used by installations in licence applications are given below:

- KTA 2101.1 (12/2000), Fire Protection in Nuclear Power Plants. Part 1: Basic Requirements, (Brandschutz in Kernkraftwerken, Teil 1: Grundsätze des Brandschutzes).
- KTA 2101.2 (12/2000), Fire Protection in Nuclear Power Plants. Part 2: Fire Protection of Structural Plant Components, (Brandschutz in Kernkraftwerken, Teil 2: Brandschutz an baulichen Anlagen).
- KTA 2101.3 (12/2000), Fire Protection in Nuclear Power Plants. Part 3: Fire Protection of Mechanical and Electrical Plant Components, (Brandschutz in Kernkraftwerken,Teil 3: Brandschutz an maschinen- und elektrotechnischen Anlagen).

Other codes and standards mentioned by licensees are:

- **EN Standards**
  European Standards, sometimes referred to as Euronorms, are technical standards which have been ratified by one of the three European Standards Organizations (ESO). Euronorms are usually translated in the Netherlands through NEN standards, as described above (Section 1.2.1.2).

- **NFPA National Fire Protection Association (USA)**
  NFPA is a global self-funded non-profit organization, established in 1896, devoted to eliminating death, injury, property and economic loss due to fire, electrical and related hazards. NFPA's code development process is open and consensus-based. That means anybody can participate in the development of these important documents. All NFPA codes and standards are periodically reviewed by approximately 10,000 volunteer committee members with a wide range of professional expertise.

- ATEX Directive
  The abbreviation ATEX comes from the French words Atmosphere Explosible and is used as a synonym for two European directives on explosion hazards under atmospheric conditions. The ATEX 114 directive specifies the requirements that equipment and products used in explosive environments must meet. This directive applies to the manufacture of equipment and products and applies primarily to manufacturers. The applicability of the directive to the entire European Union stipulates, that equipment and protective systems can be used throughout the EU.

2. Fire Safety Analyses

The term fire safety analysis covers both deterministic fire safety analyses, namely the Fire Hazard Analysis (FHA) as well as probabilistic fire safety analysis (Fire PSA), sometimes referred to as risk analyses. Systematic and recognized methods are used and a graded approach is followed considering the type of installation, NPP, research reactors and other nuclear installations.

The purpose of the analyses is to ensure that the (fire) design provides an adequate level of safety by fulfilling the fundamental safety objective.

2.1 NPP KCB – Borssele

2.1.1 NPP KCB Types and scope of the fire safety analyses

The Fire Safety Objective of the Borssele Nuclear Power Plant (KCB[15]) is:

“ *To verify that all the safety systems required to fulfil the three Fundamental Safety Functions: Shut down the reactor, Removal of heat (including decay heat) and Confinement of radioactive material are protected before, during and after a fire*.”

It is essential that the fire protection measures are adequate to ensure safety throughout the lifetime of the plant. This is achieved by the application of the ‘Defence in Depth’ concept. This concept incorporates three main objectives:

(1) To prevent fires from starting (e.g. by control of ignition sources and minimization of combustible material);

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

(3) To prevent the spread of those fires that have not been extinguished, thus minimizing their effect on items important to safety.

The scope of the Fire Safety Analyses covers the nuclear safety systems important for the fulfillment of the three Fundamental Safety Functions. Additionally, according to NVR NS-G-1.7 [16] (IAEA NS-G-1.7: Protection Against Internal Fires and Explosions in the Design of NPPs), non-safety systems with a great fire load are also considered in the deterministic fire safety analyses. Examples of these systems are the turbine oil system and the main transformers located outside.

The Borssele NPP performs two types of Fire Safety Analyses: a deterministic one and a probabilistic one. These are described in corresponding documents, and frequently reviewed.

The deterministic fire safety analyses (FHA) are based on the requirements of the Dutch Nuclear Safety Rule NVR NS-G-1.7. For the ongoing 10-yearly evaluation, compliance of the FHA with IAEA-SSG-64 and IAEA TecDoc 1944 was assessed. The probabilistic fire safety analyses (Fire-PSA) are based on the US-NRC NUREG/CR-6850 (Fire Probabilistic Risk Assessment Methodology for Nuclear Power Facilities).

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[15] Dutch: ‘Kerncentrale Borssele’(KCB), i.e. NPP Borssele

[16] NVR means ‘Nucleaire Veiligheids Regel’ i.e. Nuclear Safety Rule, as explained in the General information Chapter, section 1.2.2.

The Fire Hazards Analyses covers all operational states of the KCB: Normal operation, Start-up, Hot stand-by, Hot-subcritical, Cold stand-by, Cold-subcritical, Outage (fuel reshuffling) and Storage in the Spent Fuel Pool. According to NVR NS-G-1.7, par. 2.5 (b), the scenarios analyzed in the FHA postulate that only one fire at a time will occur.

Fire safety scenarios are also combined with the external events such as earthquake (design earthquake) and external flooding (external flooding (7,30 m + NAP)). Fire detection and extinguishing systems are seismic qualified and are available for coping with a fire caused by the earthquake in one of the affected safety systems.

The PSA is full scope and the Fire-PSA is a part of the PSA. The PSA covers all plant operational states for the reactor and fuel storage in the spent fuel pool. The Fire-PSA is used to determine the influence of fires on the core damage frequency. The main scenarios of the Fire PSA (the most important accident sequences) and their consequences can be found below, in Table 2.3. The level 1 PSA (up to Core Damage) is used in day-to-day decision making. As Dutch law requires to calculate Individual Risk and Group Risk as level 3 criteria, the level 2 PSA is only used to calculate Source Terms as an input for the level 3 PSA.

The combinations of hazards (external events, internal fire and internal flood) are also covered in the PSA. The approach to the hazards analysis is such that the combinations are dealt with within the conservative boundary conditions of the individual initiating events. E.g. all non-explosion resistant buildings are assumed to be completely lost after external explosion, external flooding assumes loss of external grid, etcetera. As part of the current PSR, all combinations were analyzed in detail and no combinations of hazards with significant consequences in the safety of the installation were identified.

The PSA does not have an extensive Seismic– PSA. EPZ decided to do an Seismic Margin Assessment (SMA), where consideration was given to fires resulting from a seismic event.

In relation with the fire analysis and the combination of other PIEs likely to occur independently of a fire, it can be mentioned that:

- For Design Extension Conditions (DEC), mobile equipment is available (fire truck and mobile pumps).
- For fighting a fire caused by an airplane crash (kerosene fire) a special crash-tender truck is available. The crash-tender truck and the mobile pumps are stand-by in a shelter approximately one kilometer from the plant.

2.1.2 *NPP KCB Key assumptions and methodologies (for DSA and PSA)*

As mentioned previously, the deterministic Fire Hazard Analysis (FHA) is based on the requirements of the Dutch Safety Rule NVR NS-G-1.7. The methodology followed to achieve the fire safety objectives of the Borssele NPP considers the following steps:

- identify items important to nuclear safety and their location;
- analyze the anticipated fire growth and the consequences of a fire in relation with nuclear safety;
- determine the required and built in fire resistance of fire barriers;
- determine the type of fire detection and protection means to be provided;
- identify cases where additional fire separation or fire protection is required, especially for common mode failures in order to ensure that nuclear safety functions will remain functional during and following a fire;
- from NVR NS-G-1.7 also non-safety systems with a great fire load are involved in the deterministic fire safety analyses.

According to NVR NS-G-1.7, par. 2.5 (b), the scenarios analyzed in the FHA postulate that only one fire at a time will occur. For every safety system important to fulfill the Fundamental Safety Functions, it is assumed that a fire will threaten the safety function in one redundancy. The systems to be protected against fire together with their safety classification are listed in Table 2.1.

Additionally, as per the NVR-NS-G-1.7 also non safety systems containing a high fire load are important to be protected in case of a fire. For KCB these systems shown in Table 2.2.

Table 2.1: Safety systems to be protected, and their Safety Class

Emergency power systems (SC 1E)	Reactor coolant system (SC 1)
Main steam system (SC 2, 3)	Radioactive gas treatment system (NC)
Auxiliary feed water system (SC 2, 3)	Backup coolant makeup system ((SC 3)
Backup feed water system (SC 2, 3)	Backup cooling water system (SC 3)
Demin water supply system (SC 3)	Control rods (SC 1E)
Safety injection system & residual heat removal system (SC 1, 2, 3)	Conventional component cooling water system (SC 3)
Chemical control system (SC 3)	Containment (SC 2)
Coolant storage and regeneration system (SC 4)	Demineralized water distribution system (SC 3, 4)
Backup residual heat removal system (SC 3)	Steam generators (SC 1, 2, 3, 4)
Component coolant water system (SC 3)	Reactor pressure vessel (SC 1)
Spent fuel pool cooling system (SC 3)	Reactor coolant pumps (SC 1, 4)
Volume control system (SC 3)	Pressure control system (SC 1)
Nuclear ventilation system (including filter for containment venting (SC 3)	Conventional emergency cooling water system (SC 3)
Reactor protection system (SC 1E)	

Table 2.2: Non safety systems containing a high fire load

Step up transformer	Turbine oil system
Auxiliary transformers	Generator gas cooling system
Main feed water system	Coolant cleaning and degassing system
Turbine bearings	

The Dutch Safety Rule NVR NS-G-1.7 identifies two configurations for use in the fire protection analyses of redundant safety systems equipment that is identified as part of a safety function: containment approach and influence approach, as defined in the Glossary.

- Containment approach: A fire compartment of the KCB has a fire resistance of at least 60 minutes (F60) according to the rules of the Buildings Decree (Bouwbesluit).
- Influence approach: A fire cell has a lower fire resistance than F60. In this case, extra fire measures are required ((automatic) extinguishing equipment, detection, etc.).

The containment approach is the preferred approach; the influence approach is an alternative for it. The influence approach is applicable in about 54 % of all cases.

Temporary fire loads are carefully controlled through administrative measures. For bringing in temporary fire loads into the plant, a permission of the plant's fire brigade is obliged. Special precautions are applied to prevent and control fires that could originate from these activities. Temporary fire loads shall be removed from the plant as soon as possible when the use of it is not applicable anymore (see Section 3.1.2.3.1).

The KCB has its own fire brigade on site. Although a fire truck is not necessary for firefighting in buildings containing relevant safety systems, the fire brigade possesses a fire truck for fighting fires on site. In case of a fire alarm the off-site fire brigade of the villages Borssele or Nieuwdorp will turn out for the KCB.

In parallel, the national Safety Regions regulation (Wet Veiligheidsregio's, see Chaper 1), article 31 requires the firefighting organization to be based on normative fire scenarios. Based on this scenarios, the size and reaction times of the company fire brigade (first attack crew) are established. Fire scenarios and described task analyses are included in the Industry firefighting report. There are six normative fire scenarios that determine the minimum or basic size of the firefighting team (the first attack team) and the reaction times, assuming normal business operations (more information in Section 3.1).

The Fire Hazard Assessment (FHA) report is to be revised every two years for further improvement and to cope with uncertainties. The FHA has a conservative approach. The FHA is reviewed every two years by EPZ's Engineering Department. The PSA is reviewed every 10 years as part of the PSR by the PSA specialists, also from the Engineering Department. The PSA is a living document/model and is updated as EPZ deems necessary.

The probabilistic fire safety analyses (Fire-PSA) are based on the US-NRC NUREG/CR-6850 (Fire Probabilistic Risk Assessment Methodology for Nuclear Power Facilities). The main scenarios of the Fire PSA (the most important accident sequences) and their consequences can be found in the next section, in Table 2.3.

The combinations of hazards (external events, internal fire and internal flood) are also covered in the PSA. The approach to the hazards is such that the combinations of events are dealt with within the conservative boundary conditions of the individual initiating events.

2.1.3 NPP KCB Fire phenomena analyses: overview of models, data and consequences

The data for (revising) the Fire Hazard Analysis is collected during diverse plant walk downs and documentation such as plant modification plans and work orders. For all the Safety and High fire load systems, a deterministic fire safety analyses is performed. For each system, the following data in relation to fire safety is collected and described in the FHA-report:

- Relevant systems and components;
- Compartmentation, fire cells and which approach is applicable (containment or influence);
- Compartment characteristics (doors, floors, ceilings, hatches, penetrations);
- Fire loads (permanent);
- Ignition sources;
- Ventilation;

- Fire detection systems;
- Fire suppression systems (automatic, semi-automatic or manual) and the extinguishing material.

As previously mentioned, the systems to be protected against fire together with their safety classification are listed in Table 2.1, and the non- safety systems containing a high fire load that are important to be protected in case of a fire are shown in Table 2.2.

The fire detection system design considers the possible ignition source and is certified according to the Dutch national standard NEN 2535[17].

KCB has defined three categories of fire load: small (< 100 MJ/m^2), middle (100 – 1000 MJ/m^2) and high (> 1000 MJ/m^2). The fire suppression systems are designed based on these fire loads, for example:

- The capacity of the low pressure extinguishing system (water mist system) is based on the fire loads in the electrical building (2.400 l/min).
- The high pressure extinguishing system (for manual firefighting) has a maximum required capacity of 150 l/min.
- The transformer extinguishing system has a maximum capacity of 3.600 l/min for the step-up transformer.
- The capacity for the automatic firefighting of the oil systems of the main coolant pumps is 33 kg CO_2.
- The 'Inergen' system for the conventional marshalling rack in the electrical building (greatest fire load for the gaseous extinguishing systems) has a capacity of 6.320 liter at 200 bar.

Once the data has been collected, the consequences of the postulated fires are analyzed and documented, and the adequacy of the fire detection, protection and containment are confirmed. Whenever improvement points are identified, corresponding actions are consequently implemented in the systems, in the organization and / or in the procedures.

The main scenarios of the Fire PSA (the most important accident sequences) are shown in Table 2.3.

Table 2.3 Main scenarios identified in the fire PSA

Event	Clarification
Fire in cable room at power	This room contains cables of components important to safety.
Fire in RPS compartment at power	This room contains redundancy of the RPS. Fire will cause RESA.
Fire in specific rooms at Cold shutdown	Fire induced actuation of RPS signals is assumed possible.
Fire in RPS compartment at Cold shutdown	

The contribution of fires to the overall core damage frequency (of 2.85 10-6) is 41 %. After implementation of NUREG/CR-6850 a fire in the control room appeared important to consider. The fire risk from the control room is reduced by replacing the carpet. Significant effort is put in reducing the fire risk from 'a Fire in cable

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[17] NEN 2535: 'Fire safety of buildings - Fire detection installations - System and quality requirements and guidelines for detector siting', in Dutch; 'Brandveiligheid van gebouwen - Brandmeldinstallaties - Systeem- en kwaliteitseisen en projectierichtlijnen'.

room at power'. Changing the cables from the bunkered systems so they route via another room proved contradictory to general design rules. As part of the PSR of 2013 the fires dominating the PSA risk were further investigated. It was demonstrated that the calculated risk was very conservative and further actions to reduce this fire risk are not justifiable.

2.1.4 NPP KCB Main results / dominant events (licensee ' s experience)

The main result of the current FHA-report is the conclusion that the Borssele NPP is sufficiently protected against fire. That means that every relevant safety function is protected against fire. To further improve the fire safety of the plant, a number of potential improvement measures have been defined in the most recent version of the FHA (2022). The most important suggestions for improvement of fire safety are described in Section 2.1.5.

The dominant scenario for the FHA is a fire in the cable spreading room, since it has the greatest fire load. This room contains mainly power cables (6 kV) for supplying motors of safety equipment. In case of a fire in this room, redundant systems can be affected when the fire is not timely extinguished, which can result in the failure of safety functions of engineered safety features, and would therefore have a significant influence on nuclear safety. Fire in the cable spreading room will be extinguished by an automatic water firefighting system. In that scenario also a fire truck can simultaneously be supplied with water by the running fire pump.

The main results of the Fire PSA (the most important accident sequences) are shown in Table 2.3. The contribution of fires to the overall core damage frequency is 41%. The contributions of fires to the level 3 PSA results are: 15% for group risk and 34% for individual risk.

The safety systems which are protected against flooding and earthquake are situated in the bunkered buildings. This buildings contain the reactor protection system, the backup coolant make-up system and the backup cooling water system. The redundant systems in this buildings are built in in their own fire compartments, following the containment approach.

Additionally, 'normative' scenarios are postulated for the definition of the fire brigade size. These normative scenarios are further described in Section 3.1.

2.1.5 NPP KCB Periodic review and management of changes

Since 1997 the KCB has a FHA-report to describe fire safety in relation with nuclear safety. The periodic update of the FHA-report is executed every two years in combination with the legal 2-yearly evaluation.

During the 10-yearly evaluation (10EVA), the FHA-report goes through a comprehensive revision.

For the 10EVA Periodic Safety Review (PSR) of 2013, the most important fire scenarios were evaluated for improvements in the plant. After the evaluation of the scenarios, they turned out to be conservative and no relevant improvements were to be implemented.

For the ongoing 10-yearly evaluation, also IAEA-SSG-64[18] , IAEA TecDoc 1944[19] are included as input to the review.

The original PSA was developed in the early 1990s, and became full scope in 1995. In 2005, the full scope Fire PSA was updated according to the NUREG-6850[20] and it is an integral part of the KCB PSA. As part of the

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[18] IAEA-SSG-64 'Protection against Internal Hazards in the Design of Nuclear Power Plants', IAEA, 2021

[19] IAEA TecDoc 1944 'Fire protection in Nuclear Power Plants', IAEA, 2021

[20] NUREG/CR-6850, EPRI 1011989 'EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities, Final Report' , EPRI & US NRC, 2005,

Periodic Safety Review 2023, the PSA was updated for the combinations of hazards to have a more understandable approach. No new combinations did arise from this update. Additionally, the (Fire) PSA will be used to identify other potential improvements.

2.1.5.1 Overview of actions

The most important measures that are based on the FHA and have been implemented during the 10-yearly evaluations of 2003 and 2013 are:

1. Exchange of many fire dampers in the plant (2003);
2. Replacing the Halon systems by Inergen gaseous extinguishing systems (2003);
3. Replacing fire doors (2003);
4. Smoke and heat removal system in the roof of the turbine building (2013);
5. Extinguishing systems for coal filters of the nuclear ventilation system (2013);
6. Making the high pressure extinguishing system earthquake resistant (2013);
7. Purchasing of diverse mobile systems (2013).

Additionally, as a result of the Seismic Margin Assessment, the plant was retrofitted with the possibility to connect a fire truck to seismic resistant fire lines to mitigate a fire in seismic relevant areas.

The current FHA (2022) of the KCB gives a total overview of the fire safety of the plant, and it also describes suggestions for improvement of the fire safety. The following main issues for improvement of the design of the fire safety systems have been identified:

1. Direct supply of the extinguishing system for yard transformers from the low pressure extinguishing system instead of supply from the dedicated tank (ongoing);
2. Improvement of the design of the electric busses in the bunkered building to reduce the risk of a fire in one of the redundant buildings (ongoing);
3. Improvement of the compartmentation of the ventilation system in the electric building and the auxiliary building by installing extra fire dampers (ongoing);
4. Extra spray nozzles around the oil conservators of the yard transformers (study).

With respect to the PSA, after completion of the Fire-PSA following the PSR of 2003, the carpet in the control room was replaced with a fire resistant carpet. Currently, one issue from the Fire PSA for improvement of the plant remains under investigation: the spatial dependency of power supply for the RPS.

2.1.5.2 Implementation status of modifications / changes

As described in section 2.1.5.1, some improvements are in the implementation status at this moment. The modification plans for these are being developed at the time of writing of the present report. In the next two-yearly review of the FHA-report (2024), these improvements will be described and evaluated in detail.

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supplement 2010.

2.1.6 NPP KCB Licensee's experience of fire safety analyses

2.1.6.1 Overview of strengths and weaknesses identified

The strengths of the FHA-report are that all significant items of fire safety in relation with nuclear safety are described in a well-organized way, and that it is periodically reviewed. It can be concluded that the FHA is a strong tool for the continuous improvement of fire safety of the KCB.

The FHA identifies various strengths of the fire safety of the KCB like:

- the large number of automatic or semi-automatic extinguishing systems, water mist as well as sprinkler and gaseous systems;
- the comprehensive fire detection system with a diverse range of detector types (smoke (optical/thermal), flame, aspiration, etc.). The detection system is certified according the Dutch standard NEN 2535:2009+C1:2010.

A weakness is that no Fire Hazard Analysis of the waste storage building has been developed.

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

The FHA method was reviewed during the 10EVA23 (2023). The conclusion was that it is still sufficiently developed, there were no shortcomings and thus no adjustments were necessary. The review covered the alignment and compliance with regulations, standards and requirements in the field of fire safety analyses. The 10EVA review is carried out every 10 years.

From past experience, the most significant events for the KCB were a fire in one of the auxiliary transformers about 40 years ago and a fire in a tumble dryer machine (about 30 years ago). In the past decades, no significant fire related events occurred, and only minor events have been recorded. In most cases the events originated in spurious activation (alarm) of the detection system. The reason is a very sensitive adjustment of the detection system.

The KCB has undergone several peer reviews conducted by IAEA (e.g. OSART) and WANO. These resulted in several suggestions for improvement of fire safety mainly focused on the fire brigade organization.

In 2019, the ANVS in cooperation with the German TSO GRS, performed a fire safety inspection at the Borssele Nuclear Power Plant. The most important improvements requested after this inspection are:

- Removal of plastic containers from the plant buildings (finished);
- Improving the compartmentation of some electric rooms (ongoing);
- Improving the compartmentation of the electric building by protecting a ventilation duct with fire resistant material (finished).

KCB is a long-time participant in various activities of the international organization of NPP operators, WANO. It has joined the WANO program to support the high standard of operation of the KCB plant. This is called 'the way to excellence programme', which yielded some suggestions for further improvement. Examples are: improving compartmentation and renewal of the high-pressure fire pumps. The compartmentation is ongoing and will be ready by mid-2024. It concerns the replacement of the fire doors. Adjusting compartmentalisation is specific (control smoke density and repair and/or improvement where necessary) due to aging and the reduced or no longer availability of spare parts.

2.1.7 *NPP KCB: Regulator's assessment and conclusions on fire safety analyses*

2.1.7.1 Overview of strengths and weaknesses identified by the regulator

One of the strongest points regarding the fire safety analysis at the KCB, is the early development of both a full scope PSA including fire, and the Fire Hazard Analysis, and their continuous update and improvement. EPZ uses national and international experience to keep these analyses up to date.

Through licence conditions, the FHA is required to be developed based on the IAEA guidelines[21], while the (living) PSA follows the USA-NRC guidelines for Fire PSA as well. The FHA must be updated every 2 years and sent to the ANVS.

Work is ongoing to update and complete the inventory of potential fire loads in the FHA.

The safety functions and the corresponding systems to be protected against fire, together with relevant scenarios, have been identified and assessed, and it is concluded that the safety functions and systems are sufficiently protected.

One weakness is that no specific FHA has been made for the waste storage facilities (low level waste) at the KCB, although the fire load is very low (mainly steel and concrete) and no significant ignition sources are present in that building.

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

Every 10 years, a comprehensive revision of the status of the installation and its Safety Analysis is performed (10EVA), which also covers fire safety. Many modifications have been initiated and implemented in different fire protection aspects.

An IPSART mission was ordered by the ANVS in 2010. In 2013 there was a follow-up mission, where it was observed that:

"...the 'living' PSA of the plant requires updating. The source term data [...] should be re-evaluated using the findings of the analysis of the Fukushima accident and the subsequent R&D activities in this field. "

A Post Fukushima stress test analysis[22] was carried out in 2011, where the results from the IPSART mission were considered, and no additional specific remarks on the Fire Safety Analyses were included.

This activity has been followed up by EPZ and solved by the 10EVA from 2013.

In 2017, the ANVS conducted an inspection on Fire safety and Fire Protection concepts, together with the German TSO GRS and the Safety region, where, among other topics further developed in Chapter 3, the FHA and the (fire) PSA were audited. A follow-up inspections were carried out in 2019 and in 2023. The main observation was that the Fire PSA for the Borssele NPP is based on state-of-the-art methods and clearly structured and comprehensive, including a Human Reliability Analysis (HRA).

It was recommended to EPZ to consider the potential HEAF (High Energy Arcing Fault) events in the FHA and PSA, in particular for electrical rooms with medium of high voltage electrical cabinets, based on three OECD/NEA references, written by the Committee on the Safety of Nuclear Installations (CSNI):

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[21] IAEA NS-G-1.7: Protection Against Internal Fires and Explosions in the Design of NPPs, and including IAEA, Preparation of Fire Hazard Analyses for Nuclear Power Plants, Safety Reports Series No. 8, IAEA, Vienna (1998), and IAEA, Evaluation of Fire Hazard Analyses for Nuclear Power Plants, Safety Series No. 50-P-9, IAEA, Vienna (1995).

[22] Weblink: vi-2011-125-post-fukushima-stresstest-nuclear-power-plant-in-the-netherlands-tcm334-326358.pdf

- OECD FIRE Project – Topical Report No. 1, Analysis of High Energy Arcing Fault (HEAF) Fire Events[23]
- A Review of Current Calculation Methods Used to Predict Damage from High Energy Arcing Fault (HEAF) Events[24]
- Experimental Results from the International High Energy Arcing Fault (HEAF) Research Program Testing Phase 2014 to 2016[25]

This activity is ongoing at the time of this NAR. In parallel, the ANVS is involved in HEAF research activities.

In agreement with EPZ, the ANVS initiates every 10 years an IAEA OSART mission. The last one was conducted in January – February 2023[26], while this NAR was being written. Preliminary findings are:

- Managers of the Borssele Nuclear Power Plant are committed to the operational safety and reliability of the nuclear power plant.
- The plant has developed a unique risk-informed application that categorizes the proposed areas of improvement identified in the Periodic Safety Review (PSR), according to deterministic and probabilistic risk benefits in order to concentrate efforts in areas most beneficial to safety.
- Fire prevention and protection program: All rooms of the plant have been assessed for fire loading and baselined accordingly. During the preparation phase for planned work, all tasks were assessed against the fire loading criteria for the areas where tasks were to be performed. If the fire loading would increase as a result of the task, appropriate mitigating measures were documented in a fire permit and the measures identified implemented prior to the commencement of the task. The OSART team recognized this as a good performance.

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

The licence contains several explicit requirements related to the Fire Safety Analysis and Fire protection concept, similar to the example shown in Appendix C. The information requested by WENRA for the development of this chapter is reflected in the requirements detailed in the licence of the KCB. The licence holder is obliged to draw up, maintain and implement a fire prevention, fire detection and firefighting programme, aligned with all the topics developed in this chapter.

In the year 2016, a revision of the operating permit was issued to EPZ, based on the outcome of the (post Fukushima) stress test (2011-2012) and the previous 10-yearly evaluation (2012-2013).

Based on the information developed in the previous section, together with the information presented in the corresponding section in Chapter 3, EPZ has proven compliance to the assessment framework.

The licensee has shown a continuous commitment to the improvement of safety related aspects, including fire related topics.

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[23] OECD FIRE Project – Topical Report No. 1, Analysis of High Energy Arcing Fault (HEAF) Fire Events, NEA/CSNI/R(2013)6, Paris, France, June 2013, http://www.oecd-nea.org/documents/2013/sin/csni-r2013-6.pdf

[24] •A Review of Current Calculation Methods Used to Predict Damage from High Energy Arcing Fault (HEAF) Events, NEA/CSNI/R(2015)10, Paris, France, 2015, https://www.oecd-nea.org/nsd/docs/2015/csni-r2015-10.pdf

[25] Experimental Results from the International High Energy Arcing Fault (HEAF) Research Program Testing Phase 2014 to 2016, NEA/CSNI/R(2017)7, Paris, France, (2017), http://www.oecd-nea.org/documents/2016/sin/csni-r2017-7.pdf

[26] https://english.autoriteitnvs.nl/documents/report/2023/07/03/iaea-report-osart-review-borssele-nuclear-power-plant-2023

2.2 Research Reactor HFR

2.2.1 RR HFR Types and scope of the fire safety analyses

The Fire Safety Analysis of the HFR aims to establish the qualitative identification of safety systems and the (fire) hazards against which they should be protected. The approach to the development of the Fire Safety Analysis is a combination of deterministic and probabilistic assessments.

The objectives of the fire analysis are as follows:

- Identification of deficiencies concerning the fire protection design requirements;
- Identification of internal fire scenarios that could lead to any of the plant damage states (including core damage) that are considered in the PSA;
- Calculation of the contributions of the internal fire scenarios to the total frequencies of these plant damage states.

In the first stage, a review is performed to evaluate the fire protection design of the plant and to detect and document any deficiencies concerning fire protection design requirements. The nature of the assessment performed till this stage is deterministic. Following this stage, the nature of the assessment becomes probabilistic, where the internal fire scenarios that may impact reactor safety are identified and modelled using event tree modelling. The corresponding contributions to the core damage frequency and the frequencies of other plant damage states that are considered in the PSA are then quantified.

The Fire Safety Analysis is developed as a part of the full-scope PSA, with the following objectives:

- To assess the frequency of core damage, spent fuel damage and irradiation facility damage of the HFR (Level 1 PSA);
- To assess the nature, magnitude and frequency of radiological releases outside containment due to accident sequences derived in Level 1 PSA (Level 2 PSA);
- To assess the risk to the population and the environment caused by the HFR operation (Level 3 PSA).

This Fire Safety Analysis is performed for all the plant operating states as considered for the full-scope HFR-PSA (full power and shutdown). This full-scope HFR-PSA includes the assessments of the Spent Fuel Pool, experiments and production facilities, and considers internal events, internal hazards and external hazards. The Plant Operating States (POS) considered in the (internal) fire analysis are A, B, C and D, as shown in Table 2.4.

Table 2.4 Plant Operating States (POS) considered in the HFR PSA

State	Description
A	Reactor in operation, full power, 45MW
B	Reactor in shutdown, high water level, reactor cooled with primary pumps
C	Reactor in shutdown, reactor vessel lid closed, low water level, in-core irradiation facilities with core-lid feed through unlocking after reactor stop and locking before reactor start
D	Reactor in shutdown, reactor vessel lid closed, high water level, in-core irradiation facilities with core-lid feed through removed after reactor stop, or loaded through the lid before reactor start
E	Reactor in shutdown, high water level, reactor vessel lid open, fuel elements and in-core irradiation facilities without core-lid feed through unloading and reloading

F	Reactor in shutdown, and the core is completely unloaded
G	Reactor in shutdown, low water level, core inspection and maintenance activities performed

For POS A, the following internal fire scenarios are identified in the different locations, see Table 2.5.

Table 2.5 Analysed fire scenarios for the HFR and their location

Scenarios per building	Reactor building	Reactor outbuilding	Primary pump building	Secondary pump building	Ventilation building	Emergency diesels building
Fire in building requiring a reactor shutdown	X	X	X	X	X	X
Hot short leading to spurious instrumentation signals	X	X	X	X	X	
Loss of AC power to control rod magnets	X					
Fire disabling scram functionality	X	X				
Fire-induced internal explosion	X					
Fire-induced heavy load drop	X					

For each building, scenarios for the other POSs (B, C, and D) are the same as the ones of POS A with the difference that a reactor shutdown is not required since the reactor is already in a shut-down state.

No internal fire models have been created for POSs E, F, and G, as in these POSs, the reactor is shut down and no actions or systems are required to ensure the decay heat removal because the head reactor vessel is open or removed, thus in this state no valves have to be opened and long term cooling is assured by passive means.

Furthermore, within the scope of HFR PSA, a Combination of Hazards (CoH) analysis has been performed. It is conceivable that the simultaneous occurrence of hazards can have a more severe impact on the nuclear plant compared to the hazards occurring individually. With this CoH analysis, these possible hazard combinations are addressed and analysed. Initiating events occurring in the plant may result from the impact of an individual hazard or a combination of hazards. Internal fire hazard has been considered within this analysis as a hazard initiating a secondary hazard, as a hazard initiated by a primary hazard and as a hazard occurring individually and randomly with another hazard, as shown in Table 2.6.

Table 2.6 Combinations of hazards considered in HFR PSA that include internal fire

Primary hazard	Secondary hazard
Internal flood	Internal Fire
Internal fire	Internal Flood
Internal fire	Dropped or impacting loads
Internal fire	Strong wind/Tornado
Internal fire	Extreme rain
Internal fire	Extreme snow
Internal fire	Earthquake
Internal fire	High water level (external)
Internal fire	Aircraft crash
Dropped or impacting loads	Internal Fire
Strong wind/Tornado	Internal Fire
Extreme rain	Internal Fire
Extreme snow	Internal Fire
Earthquake	Internal Fire
High water level (external)	Internal Fire
Aircraft crash	Internal Fire

2.2.2 RR HFR Key assumptions and methodologies (for DSA and PSA)

NUREG/CR-6850, IAEA No. NS-G-1.7 and IAEA No. NS-G-2.1 were used in performing the internal fire analysis in 2016.

The NUREG/CR-6850 provides the detailed methodology for performing the internal fire PSA for nuclear plants and is currently state-of-the-art. IAEA safety guide NS-G-1.7 provides recommendations and guidance on concepts for protection against internal fires and explosions in nuclear plants. And, NS-G-2.1 is an IAEA safety guide that provides guidance for plant managers, operators, safety assessors and regulators on suitable measures for ensuring that an adequate level of fire safety is maintained throughout the lifetime of a nuclear power plant.

The HFR and its supporting systems are contained in several buildings, each of which is divided into fire compartments or fire cells. A fire cell is a subdivision of a fire compartment that may not be completely surrounded by fire barriers. A full description of fire compartments and fire cells is given in Section 3.2.3.

A fire protection design review is performed to (re) evaluate the fire protection design of the plant and to detect and document any deficiencies concerning the IAEA fire protection design requirements of IAEA NS-G-1.7[27] and IAEA NS-G-2.1[28]. Partitioning of the buildings in the HFR is based on the floor plans of the buildings

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[27] Protection against Internal Fires and Explosions in the Design of Nuclear Power Plants, IAEA guideline NS-G-1.7, Vienna, 2004

from which fire cells are determined. In order to identify the relevant cells and to eliminate non-relevant fire cells from further analysis, a qualitative screening of fire cells is performed. The nature of the assessment performed till this stage is deterministic.

Following the qualitative screening, the nature of the assessment became probabilistic where the internal fire scenarios that may impact reactor safety were identified and modelled using event tree modelling according to NUREG/CR-6850[29]. The corresponding contributions to the core damage frequency and the frequencies of other plant damage states that are considered in the PSA were then quantified.

Some of the conservative assumptions are listed below:

- Upon ignition of a fire in a fire cell, it is assumed that this space is not accessible and therefore all local operator recovery actions to be performed from this location are assumed to be unavailable;
- Upon ignition of a fire in a fire cell, the reactor shall be shut down either manually or, eventually, automatically. In case of failure of both, core damage and experiment damage are assumed;
- Following a successful reactor shutdown, the removal of decay heat shall be ensured by the proper functioning of a decay heat removal system and its back systems. If all these systems fail, core damage and experiment damage are assumed;
- In case a fire is neither automatically nor manually (and timely) detected, it is assumed that the fire will spread to the adjacent cell;
- In case a fire is not timely suppressed, it is assumed that the fire will spread to the adjacent cell; otherwise, the fire is assumed to be contained within the fire cell in which it ignited.

It is worth noting that the methodology and guidance document available to perform this fire analysis were originally meant for Nuclear Power Plants. Therefore, the methodology was adjusted to suit the configuration of the HFR, and all the assumptions made in this regard are conservative. According to the state of the art Internal Fire PSA methodology of NUREG/CR-6850, a detailed fire phenomena analysis eliminates the conservatisms in the initial part of the analysis. In the HFR however, this detailed fire phenomenon analysis was not performed, as it was not required based on the initial results, which are therefore still conservative. The analysis considered detailed fire ignition, and propagation was modelled in detail using CFD and other tools.

Regarding the combination of hazards, as done with single hazards, a screening process in order to focus on the significant combinations can be carried out. At the moment this report is being written, there is very little guidance on the assessment of combinations of hazards in PSA – the most detailed reference found to date is the SKI Report 02:27 [30].

2.2.3 *RR HFR Fire phenomena analyses: overview of models, data and consequences*

The first part of the internal Fire Hazard Analysis is a qualitative analysis, consisting of two separate parts:

Part 1: a qualitative screening of fire cells for further (quantitative) analysis;

Part 2: a facility design review from a fire protection standpoint.

The objective of the Part 1 qualitative screening is to identify the relevant cells and to screen out non-relevant fire cells from further (quantitative) analysis. Non-relevant fire cells are considered to be those cells that do

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[28] Fire Safety in the Operation of Nuclear Power Plants, IAEA guideline NS-G-2.1, Vienna, 2000

[29] Electric Power Research Institute (EPRI), EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities (NUREG/CR-6850), 2005.

[30] M. Knochenhauer and P. Louko, 'Guidance for External Events Analysis', SKI Report 02:27, Swedish Nuclear Inspectorate (SKI), February 2003.

not contain SSCs required for the safe shutdown of the reactor, or cells in which the ignition of a fire does not have an effect on the safe shutdown of the reactor.

The basis of the qualitative screening is formed by collecting fire-relevant data on the level of individual fire cells by performing a plant walk-down. Subsequently, the possibility of fire spread across fire cell boundaries is investigated by means of a fire cell interaction analysis. The template in Table 2.7 shows the data collected during the plant walkdowns.

Table 2.7 Template used at HFR for collection of data from plant walkdowns for internal fire hazard analysis

<table>
<tr><th colspan="4">Fire cell</th><th>Room/Section#</th></tr>
<tr><td colspan="4">Identifier</td><td></td></tr>
<tr><td colspan="4">Location</td><td></td></tr>
<tr><td colspan="4">Building</td><td></td></tr>
<tr><td colspan="4">General inventory</td><td></td></tr>
<tr><td colspan="4">HFR Components</td><td></td></tr>
<tr><td colspan="4">Safe Shutdown Equipment (SSE)</td><td></td></tr>
<tr><td colspan="4">Plant Trip Initiators (PTI)</td><td></td></tr>
<tr><td colspan="4">Fire-relevant inventory</td><td></td></tr>
<tr><td colspan="4">Fire ignition sources</td><td></td></tr>
<tr><td colspan="4">Fixed combustibles</td><td></td></tr>
<tr><td colspan="4">Transient combustibles</td><td></td></tr>
<tr><td colspan="4">Fire detection</td><td></td></tr>
<tr><td colspan="4">Fire suppression</td><td></td></tr>
<tr><td colspan="4">Cell boundaries/ propagation potential</td><td></td></tr>
<tr><td colspan="4">Design review result</td><td></td></tr>
<tr><td colspan="5">Exposed fire cells</td></tr>
<tr><td><i>Cell identifier</i></td><td></td><td><i>PTI</i></td><td><i>SSE</i></td><td><i>Comments</i></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
</table>

A set of screening criteria that considers the fire cell’s safety relevance and the possibility of fire spread to bordering fire cells is then applied to each fire cell. For each fire cell boundary, it is checked whether one or more of the following screening criteria applies:

- Criterion 1: The fire cell boundary is a boundary in which the exposed cell does not contain safe shutdown equipment (SSE), nor plant trip initiators (PTI), on the basis that a fire spread to the exposed cell would have no adverse effect on safe shutdown capability.
- Criterion 2: The exposing cell contains a fire load density of less than 900 MJ/m2 (as defined in HFR internal documentation) and the fire cell boundary consists of a one-hour rated fire barrier on the basis that the fire barrier will prevent a fire spread to the adjacent cell.
- Criterion 3: The fire cell boundary is a boundary in which the exposing cell contains a fire load density of less than 230 MJ/m2 (low fire load) and has automatic fire detection installed, on the basis that manual suppression will prevent a fire spread to the adjacent cell.
- Criterion 4: The fire cell boundary is a boundary between cells that both contain fire load densities of less than 230 MJ/m2 (low fire loads), on the basis that fire load densities of this size are insufficient to cause a fire spread to the adjacent cell.

If at least one of the above criteria applies, the fire cell boundary is screened-out on the basis that a fire spread across the fire cell boundary cannot occur and/or cannot affect reactor safety. If none of the screening criteria applies, the fire cell boundary is screened-in for further analysis (as opposed to screened-out).

The result of the qualitative screening is a list of remaining fire cells in which the ignition of a fire may eventually lead to a plant damage state scenario. For all these fire cells that remain screened in, quantitative analysis is performed on these cells and corresponding fire scenarios are identified and modelled. The objectives of the quantitative analysis are as follows.

- identify internal fire scenarios that could lead to any of the plant damage states (including core damage) that are considered in the PSA;
- calculate the contributions of the internal fire scenarios to the total frequencies of these plant damage states.

The Part 2 quantitative analysis consists of three consecutive steps, which apply to each fire cell that was screened-in after the qualitative screening:

- estimation of fire ignition frequencies;
- modelling of accident sequences by use of event tree analysis;
- calculation of fire scenario contributions to the frequencies of plant damage states.

The fire ignition frequency estimated for each (screened-in) fire cell consists of the following components:

- the fire ignition frequencies of components;
- the cable fire ignition frequency.

A list of general fire ignition frequencies is compiled from various fire data sources [31, 32]. Using the identified ignition sources (from the data collected during the walkdowns), the expected fire ignition frequency for each screened-in fire cell is calculated.

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[31] Electric Power Research Institute (EPRI), 'EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities (NUREG/CR-6850)' 2005.

[32] US Nuclear Regulatory Commission, 'Inspection Manual Chapter 0609: Significance determination process (Attachment 4)' 2005.

The ignition frequency for plant-wide cabling is given to be 1.3 10^{-3} per year and per power plant [33] [NS-G-1.7] as based on data from US nuclear power reactors. Application of US data follows the fact that the HFR is built according to a US design. As the amount of cabling of the HFR is much less than the amount of cabling in a typical nuclear power reactor, a correction factor of 0.1 is applied to this value, rendering a cable fire ignition frequency of all HFR cabling of 1.3 10^{-4} per year. This factor is still considered to be conservative, as most of the HFR cabling is in reality flame retardant. In order to estimate the probability of a cable fire in a specific fire cell, the total HFR cable ignition frequency shall be divided among the various fire cells. Based on engineering judgment, the relative amount of cabling present in each of the fire cells and the resulting cable fire ignition frequencies are assigned to each fire cell.

An internal fire can also cause the failure of electric cables, like short or open circuits, short to ground, hot shorts and secondary ignition. These have been evaluated as well. Here three types of cables are distinguished: those that support reactivity control, those that support decay heat removal, and those that support containment of radioactivity.

The result of the quantitative analysis is a list of fire scenarios that may lead to a plant damage state and their corresponding frequency contributions.

2.2.4 RR HFR Main results / dominant events (licensee ' s experience)

The fire protection design of the HFR is reviewed based on observations from plant walkdowns and on plant documentation. The following buildings are considered:

1. Reactor building
2. Reactor outbuilding
3. Primary pump building
4. Secondary pump building
5. Ventilation building
6. Emergency diesel building

An example of the results of the fire protection design review for each of the HFR buildings are summarized below. It is to be noted that the bulleted numbers mentioned in each point describing the findings below are the requirement numbers from the NS-G-1.7 [34] IAEA guidance document.

- §2.7, Combustibles are present which are not directly required for operation and which could threaten safety-related equipment.
- §2.8, A fire ignition source (i.e., an electric heater) which is not directly required for operation and which could threaten safety-related equipment is present.
- §2.12, No automatic fire detection is available.
- §2.12, No fire suppression means (extinguishers) are present in (nor directly near) certain fire cells where a fire development could be threatening to safety-related equipment.
- §2.17, Redundant cabling in RBG K04+K17 is not sufficiently separated.
- §2.17, Open protrusions which are unnecessary exist between certain fire cells.

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[33] Protection against Internal Fires and Explosions in the Design of Nuclear Power Plants, IAEA guideline NS-G-1.7, Vienna, 2004

[34] Protection against Internal Fires and Explosions in the Design of Nuclear Power Plants, IAEA guideline NS-G-1.7, Vienna, 2004

Fire scenarios are determined for each building, as described in Section 2.2.1. Each of them has been analysed quantitatively and the accident progressions from these scenarios have been modelled within event trees in the HFR-PSA model.

The total contribution to the CDF of the internal fire hazards is 1.2 10^{-8}/year. In comparison, the total core damage frequency (TCDF) of HFR is 4.7 10^{-7}/year. This TCDF is estimated from the quantification of the core damage sequences from all initiating events in all the plant operational states (POSs). The TCDF includes the frequencies from both internal and external initiating events (internal events and hazards) during power and non-power operating conditions. The internal fire hazard contribution to the total core damage frequency of HFR is 2.5%. The total core damage frequency is the final result for the Level-1 PSA. In order to perform the Level-2 and Level-3 PSA, the accident sequences leading to core damage in Level-1 PSA are further used.

Furthermore, all the combinations of hazards (including combinations with internal fire as mentioned in section 2.2.1) have been screened out. The detailed analysis of the combinations has been mentioned in the HFR-PSA initiating event analysis report.

The Bkse [35] ('Besluit kerninstallaties, splijtstoffen en ertsen') stipulates that the results from the risk analysis of beyond-design basis accidents shall meet the prescribed individual risk and group risk limit values as mentioned below.

- a probability of less than 10^{-6} per year that a person residing permanently and unprotected outside the relevant facility will die as a result of a beyond-design basis accident.
- probability of less than 10^{-5} per year that a group of at least ten persons present outside the relevant facility will be direct fatalities of a beyond-design basis accident or an n2 times smaller probability for n times more direct fatalities.

Based on these stipulations from Bkse and the results of the internal fire analysis, any further detailed fire analysis was deemed to be unnecessary.

2.2.5 RR HFR Periodic review and management of changes

In the past (early 2000s), as a preparatory step for the renewal of the HFR operating licence, a Risk Scoping Study (HFR-RSS) was performed for the HEU[36] fuel. It was done for the present LEU core fuel, including the planned modifications as well.

Following various reviews of the HFR-RSS and in the framework of the 10-year evaluation, it became clear that the RSS of the HFR should be updated and extended to a full-scope PSA. To this purpose, the HFR PSA project was started in the second half of 2013 corresponding to the plant configuration of date 13/08/2013 (so-called 'freeze date'). As of this date, measures are ongoing concerning mitigating the potential consequences of heavy load drops in the spent fuel pool. Before that date, these accidents were not analysed in the HFR PSA.

Level 1 of this PSA was completed in 2015, except for the seismic model which was introduced in 2019. The L2 and L3 PSA were started following the L1 PSA and subsequently completed in 2019.

A fire analysis was performed for the HFR as part of the HFR Licence Renewal project in 2003. This fire analysis was re-performed in 2018 as an internal fire analysis within the scope of Level-1 HFR PSA, and the internal fire analysis is classified as a part of the internal hazards assessments.

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[35] Nuclear Installations, Fissionable Materials and Ores Decree (Bkse)

[36] High Enriched Uranium (HEU), Low Enriched Uranium (LEU)

The 10-yearly HFR periodic evaluations are performed based on IAEA Guide SSG-25 ‘Periodic Safety Review for Nuclear Power Plants’. SSG-25 describes 14 safety factors that need to be reviewed in a PSR. Within *Safety Factor 7: Hazard analysis*, internal fire and explosions are covered.

In 2012, several fire-related deficiencies were addressed and measures were defined. These are mentioned in the next two sections. In 2022 no new deficiencies appeared.

2.2.5.1 Overview of actions

Measures have been taken regarding fire prevention and early detection:

- the use of burnable gasses;
- standard regulations for the use of flammable liquids;
- periodic checks for the presence of fire-extinguishing materials;
- periodic checks of the central fire detectors, extinguishing pipes and small extinguishing agents;
- reporting of the automatic and manual fire detectors to the central reporting station.

Measures have been taken concerning fire-fighting:

- instructions for reporting a fire or accident;
- reporting via the emergency number;
- arrival time company fire brigade;
- placement of portable and mobile fire-fighting equipment;
- periodic check of the fire-fighting equipment;
- Fire-fighting plan and evacuation route.

2.2.5.2 Implementation status of modifications / changes

Many measures, small and large, have been implemented to prevent and detect fire to continuously improve fire safety. Some examples of larger projects/modifications are:

- Upgrade and replacement of the fire alarm and detection systems for all the (nuclear) installations and NRG buildings at the Energy and Health campus (EHC). This multi-annual project started in 2022 and will be completed in 2024. The result will be a fully compliant and certified fire alarm and detection system for the remainder of the HFR lifetime.
- Complete renewal/renovation of the underground fire extinguishing piping system at the EHC. This project was completed in 2022.
- Large revision of the emergency preparedness and response organization, both central and local (new organizational structure, renewal of emergency plans, installation of a quick response team, embedding in the Integrated Management System, training of staff etc.).
- Modernization of HVAC of control room HFR, completed in 2018.

2.2.6 *RR HFR: Licensee’s experience of fire safety analyses*

2.2.6.1 Overview of strengths and weaknesses identified

At NRG, internal inspections and audits are performed to monitor fire safety in the nuclear installations and buildings. These are performed by HFR staff and the Quick Response Team. Examples of observations in the field are obstruction of emergency exits, unnecessary fire loads and incorrect placement of fire extinguishers. In practice, these measures receive immediate follow-up to reduce fire safety risks as soon as possible.

No large fire events with (serious) damage have occurred at HFR in the last 10 years (source: NRG deviation notification system 'MARS').

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

Several (periodical) external assessments inspections have been performed which also assessed fire safety. The most important assessments are:

- Periodical Safety Reviews (PSRs);
- Integrated Safety Assessment of Research Reactors (INSARR) under the auspices of the IAEA;
- Complementary Safety Margin Assessment ('Stresstest');
- Nuclear Insurance Pool survey.

The findings from each of them are described below. There might be an overlap between the recommendations and measures from the various assessments.

Periodic Safety Review 10 EVA

Every 10 years, a PSR is conducted, known as the 10EVA. Implemented measures defined in PSRs are for example:

- Large revision of the emergency preparedness and response organization;
- Periodical revision of safety hazard analyses, both deterministic and probabilistic;
- Modernization of HVAC of control room HFR (mitigation measure in case of external fire);
- Further reduction of fire loads.

From the 10 yearly evaluation 10EVA (dating from 2012), the following specific actions regarding fire safety were derived and carried out:

- Action A11. Update the fire safety analysis.
- Action I1. Prevent the spread of smoke and fire, apply fire-resistant seals to all penetrations from the floor of the control room to the cellars RBB-K04 and RBG-K017.
- Action I2. Determine in a study the necessity of a manual fire extinguishing system in rooms K04 and K017 and install these fire extinguishing systems if necessary.
- Action I3. To maintain the quality of life in the control room in the event of an external fire by preventing smoke and/or toxic gases from entering the control room, considering the required room conditions.
- Action P17. Set up a procedure to minimize the use of flammable gases in the reactor building (before welding).

INSARR mission

Integrated Safety Assessments of Research Reactors (INSARR) are peer reviews of the safety of research reactors against IAEA safety standards and provide recommendations for safety improvements. These have been held in 2005, 2011 and 2016 with additional follow-up INSARR-missions to monitor the progress. Implemented measures defined in the INSARRs are for example:

- Development of administrative procedures to improve fire safety (an example is a procedure on combustible load control);
- Update of fire hazard analysis;
- Installation of extra fire detectors and fire doors.

Complementary Safety Margin Assessment (CSA, aka 'post-Fukushima stress test')

As part of the comprehensive CSA held in 2012, both internal and external fire hazards have been assessed thoroughly. Implemented measures defined in the CSA were:

- Analysis of the risk profile of natural gas pressure reducing station on the EHC;
- Update of fire hazard analysis;
- Communication protocol with the regional fire brigades.

Nuclear Insurance Pool survey

About every 3-5 years an insurance survey is carried out with a focus on nuclear and fire safety. The last one was conducted in 2022. Proposed measures were among others:

- Improve signage of fire hydrants;
- Upgrading of fire door resistance;
- Minimise fire loads.

2.2.7 RR HFR: Regulator's assessment and conclusions on fire safety analyses

2.2.7.1 Overview of strengths and weaknesses identified by the regulator in the fire safety analysis

The strongest point of the Fire Safety Analysis is that it includes a full-scope PSA (levels 1, 2 and 3) accounting for internal hazards and external hazards, including fires. This PSA is based on national and international state-of-the-art guidelines, some developed for NPPs (NUREG/CR-6850). The PSA has been developed by the Dutch organization NRG, the same organization that is licence holder and operator of the HFR. NRG also provides consultancy services on PSA to other nuclear installations as well. The safety analysis for the HFR is thorough.

The Netherlands is one of the very few countries where full-scope PSAs have been developed for non-power reactors.

The safety functions and related systems to be protected against fire, together with relevant scenarios, have been identified and assessed. In the HFR, being a research reactor, various irradiation experiments are part of the daily activities. A safety assessment, including fires, is carried out for these activities as well.

2.2.7.2 Lessons learned from inspection and assessment as part of the regulatory oversight

Every 10 years, a comprehensive evaluation of the status of the installation and the Safety Analyses (10EVA) is performed by the licensee and assessed by the regulator. Many modifications have been initiated as explained in the licensee section. The most recent 10EVA was finished in the year 2021, with some recommendations to improve further the PSA and interaction between different departments in HFR, but no particular observations were made related to the Fire Hazard Analyses.

Following the accident at the Fukushima Daiichi Nuclear Power Plant (NPP) in 2011, a Complementary Safety Margin Assessment (CSA) or 'stress test' has been conducted for the HFR. Observations related to Fire Safety analysis were:

- The effects of an explosion/fire originating from the natural gas pressure reducing station located on the EHC will be analysed.
- The fire analysis of the HFR will be updated.

These actions have been completed.

In the year 2016, with a follow-up in 2019, an IAEA INSARR mission was carried out. The following recommendations were given in 2016 to improve the status the Fire Hazards Analyses. These were implemented and subsequently closed by the follow-up in 2019.

- The fire hazard analysis should be updated and, accordingly, the different areas within the reactor building should be equipped with fire detectors. The results of the updated fire hazard analysis should define the actions to be taken concerning the operation of the reactor ventilation system in case of fire with the associated justification.

Between 2017 and 2019 the ANVS and the TSO-GRS conducted an inspection on the full scope PSA of the HFR, with a follow-up in 2021. The final conclusions drawn by GRS/ ANVS are:

- The documentation of the HFR PSA Level 1, Level 2 and Level 3 was generally well structured and traceable. Nevertheless, the review of the HFR PSA documentation revealed many findings. These findings were then discussed during the review process. NRG made extensive updates to the PSA Level 1, 2 and 3 documentation (e. g. success criteria specification, accident sequence analysis, human reliability analysis, the extent of the description of source terms and the explanation of tables and graphs) and clarified many issues. These updates significantly increased the traceability of the PSA.
- The PSA methodology principally was applied and followed in particular the PSA relevant Safety Guidelines by the IAEA for PSA Level 1 and 2 as well as the ANVS Guide on Level 3 PSA. As a result of the review, NRG also completed the documentation of PSA Level 2 with respect to the source terms (in accordance with the IAEA PSA Level 2 guide), which initially have only been presented in the PSA Level 3 report.
- No major findings were identified in the scope of the Fire PSA or Fire hazards. In total 26 findings of the targeted review on HFR PSA Level 1 regarding internal fire analysis were collected. The clearly structured HFR Fire PSA following in general the state-of-the-art guidance was also further improved providing clarification and additional explanatory information in the documentation.

The following major improvements regarding PSA documentation and changes in the PSA model were achieved as a result of these findings:

- Some differences between the PSA documentation and the PSA model were aligned.
- Hazard scenarios and event sequences in the case of aircraft crash and meteorite impact were redefined and refined. Correspondingly, the occurrence frequencies were revised.
- The database used for aircraft crash frequency estimation was updated.
- Uncertainties were added to the hazard event frequencies and the mean values were revised.
- Human error probabilities (HEPs) were revised and corrected if necessary. In addition, performance shaping factors for HEPs in the case of hazards were re-vised and corrected if necessary.

2.2.7.3 Conclusions drawn on the adequacy of the licensee's fire safety analyses

The licence contains several explicit requirements related to the Fire Safety Analysis and Fire protection concept similar to the example shown in Appendix C. The information requested by WENRA for the development of this chapter is reflected in the requirements detailed in the individual licence of the HFR. The licence holder is obliged to draw up, maintain and implement a fire prevention, fire detection and fire-fighting programme, aligned with all the topics developed in this chapter.

Based on the information developed in the previous section, together with the information presented in the corresponding section in Chapter 3, HFR has proven compliance with the assessment framework.

2.3 Research Reactor HOR

2.3.1 RR HOR Types and scope of the fire safety analyses

The purpose of the Fire Safety Analysis is to verify and document that the existing fire protection measures are adequate to ensure the safety of the installation. This means that the safety systems required to shut down the reactor, remove heat and contain radioactive material are protected against fires and their consequences, so that the safety systems are still capable of performing the above safety functions.

For the HOR, relevant hazards, including fires, are analysed in the framework of the Probabilistic Safety Assessment (PSA). The PSA is part of the Safety Analysis performed for the HOR, which calculates the risk of a radioactive dose to an individual or a group due to the beyond design basis accidents in the nuclear facility. These calculated risks are compliant with the legal risk criteria as defined in the Dutch Decree Nuclear Installations, Fissionable Materials and Ores (Dutch: Bkse).

The Bkse stipulates that the results from the risk analysis shall meet the prescribed individual risk and group risk limit values as mentioned below:

- A probability of less than 10^{-6} per year that a person residing permanently and unprotected outside the relevant facility will die as a result of a beyond design basis accident.
- A probability of less than 10^{-5} per year that a group of at least ten persons present outside the relevant facility will be direct fatalities of a beyond design basis accident, or a n^2 times smaller probability for n times more direct fatalities.

The HOR PSA contains a full scope Level 1 PSA that analyses the events/accidents categorised under internal events, internal hazards and external hazards which can occur in both power and shutdown states. The Level 2 and 3 analyses intend to estimate the conservative results for personal and group risks as described in the Dutch law. The PSA reflects the latest design configuration of the structures, systems and components.

An internal fire analysis has been performed within the scope of the PSA. The objectives of the internal fire analysis are:

- to identify internal fire scenarios that could lead to core damage;
- to calculate the contributions of the internal fire scenarios to the total core damage frequency.

As part of this internal fire analysis, phenomena/elements of the deterministic Fire Hazards Analyses are considered as well (e.g. identification of fire compartments/cells, combustible loads, ignition sources, fire detection and suppression systems, identification of safe shutdown equipment).

Event trees have been constructed on a building level, resulting in a total of three 'single fire scenarios', which are:

- Large fire in reactor building/control room complex;
- Large fire in pump building;
- Large fire in RID Main building.

The results of the screening showed that External fires are screened out, and, for internal fire, a detailed analysis has been performed, as described in the following sections.

Note that in case of an internal fire (among others), a reactor scram will be manually initiated, if deemed necessary. Removal of residual heat of the core and the spent fuel is ensured by the dissipation of the heat into the pool by natural circulation for at least 250 days (for the core) or 3 years (for the spent fuel). Spent fuel can only be stored in the storage racks in the pool and the analysis regarding the spent fuel is included in the internal fire analysis. External cooling of the pool is therefore not needed for a very long period since the removal of heat is completely independent of the availability of electrical power supply and also independent of the ultimate heat sink (the secondary cooling system and the open air). These facts have been established in the Complementary Safety Assessment (CSA) which was conducted post-Fukushima for the HOR.

All relevant combination of events are included in the PSA, and are screened out based on the event frequency. Airplane crash is considered in the Safety Assessment as well.

2.3.2 *RR HOR Key assumptions and methodologies (for DSA and PSA)*

Documents NUREG/CR-6850 and IAEA No. NS-G-1.7 are used as guidelines throughout the conduct of the internal fire PSA.

The internal fire analysis uses a conservative approach for the qualitative and the quantitative part, amongst others with respect to the selection of fire scenarios and modelling of fire scenarios, to the fire load estimations, and to the fire suppression probability. No automatic nor manual fire suppression is credited in the event tree modelling (even if the BHV-b can be present in a maximum of 10 minutes).

The HOR and its supporting systems are contained in several buildings, each of which is divided into separate rooms or fire cells. The HOR reactor hall is a single compartment (for further information see section 3.3.3). The first part of the internal Fire Hazards Analysis consists of a qualitative screening of fire cells. The objective of the qualitative screening is to eliminate non-relevant fire cells from further analysis. Non-relevant fire cells are considered to be those cells in which the ignition of a fire cannot have a conceivable effect on reactor safety. The basis of the qualitative screening is formed by collecting fire-relevant data on the level of individual fire cells. Subsequently, the possibility of fire spread across fire cell boundaries is investigated by means of a fire cell interaction analysis.

Main elements of the used methodology are:

- Plant walk-downs and documentation;
- Definition of the physical boundary of the analysis, identification of the safe shutdown state and systems required to ensure this state (e.g. reactor scram and pool water inventory);
- Qualitative screening:
    - Collection of fire cell data;
    - Fire cell interaction analysis;
    - Screening criteria;
    - Combustible fire load calculations;
    - Results.
- Quantitative analysis:

  - Fire ignition frequency estimation (contribution of fire ignition frequencies of components, cable fire ignition frequencies, and fire ignition frequencies caused by transients and hot work);
  - Event tree modelling;
  - Fire suppression probability calculations;
  - Determination of worst case fire scenarios and models;
  - Results.

In summary, as per the methodology , the qualitative part of the internal fire analysis consists of a screening of relevant fire cells for further (quantitative) analysis. The qualitative screening is based on observations from plant walk-downs (with presence of HOR staff and a consultant) along with available plant documentation on fire protection design. The result of the qualitative screening is a list of remaining fire cells in which the ignition of a fire may eventually lead to a core damage scenario.

The contribution from internal fire events in the Total Core Damage Frequency (TCDF) is estimated from the quantification of all initiating events in all the plant operational states (POSs), within the main Level 1 PSA results.

The limited power and inventory of the HOR allow for a conservative approach for the Level-2 and Level-3 PSA . A conservative approach is applied amongst other in the quantification of the core damage frequency contribution for internal fire, in the fire suppression probability calculations and by use of conservative assumptions for the fire scenarios and models of the reactor building/control room complex.

2.3.3 RR HOR Fire phenomena analyses: overview of models, data and consequences

A set of screening criteria is applied to each identified fire cell, which take into account the safety relevance of the fire cell as well as the possibility of fire spread to bordering fire cells. For each fire cell boundary, it is checked whether one or more of the following screening criteria apply:

1. The fire cell boundary is a boundary in which the exposing cell has a very low fire load.
2. The fire cell boundary is at least 30 minute fire rated and the exposing cell has a low fire load.
3. The fire cell boundary is at least 60 minute fire rated and the exposing cell has a medium or low fire load.
4. The fire cell boundary is a boundary in which the exposed cell:
   - does not contain Safe Shutdown Equipment (SSE) nor Plant Trip Initiators (PTI) and
   - has a very low fire load.
5. The fire cell boundary is a boundary in which the exposed cell:
   - does not contain Safe Shutdown Equipment (SSE) nor Plant Trip Initiators (PTI) and
   - does not have other boundaries across which a fire spread could ultimately lead to affection of cells with SSE or PTI.

If at least one of the above criteria applies, the fire cell boundary is screened out from the analysis on the basis that a fire spread across the fire cell boundary cannot occur and/or cannot affect reactor safety.

The result of the qualitative screening is a list of remaining fire cells in which the ignition of a fire may eventually lead to a core damage scenario. For all these fire cells that remain screened in, the corresponding fire scenarios are identified and modelled by means of a quantitative analysis.

The second part of the internal fire analysis consists of a quantitative analysis of fire scenarios for all screened-in fire cells. The objectives of the quantitative analysis are to:

- identify (worst case) internal fire scenarios that could lead to core damage;

- calculate the contributions of the internal fire scenarios to the total core damage frequency.

The quantitative analysis consists of three consecutive steps, which apply to each fire cell (or group of fire cells) that is screened in after the qualitative screening:

- estimation of fire ignition frequencies;
- modelling of accident sequences by use of event tree analysis;
- calculation of fire scenario contributions to the core damage frequency.

The result of the quantitative analysis is a list of fire scenarios that may lead to core damage and their corresponding contributions to the total core damage frequency. In situations where deficiencies are identified during the analysis, the process requires recommendations to be formulated which, when implemented, will ensure that safety is achieved.

2.3.4 RR HOR Main results / dominant events (licensee´s experience)

As described before, the PSA provides an important basis for taking fire safety measures. The outcome of the PSA indicates that fire hazards represents a relatively small risk of inducing Core Damage. The deterministic analyses that form a part of the PSA did not give cause to implement specific provisions or otherwise take additional measures compared to other university buildings.

External fires are screened out, and may originate from:

- the grass surrounding the plant buildings; the fire load of the grass surrounding the plant buildings is so low that spreading of an external fire to the buildings via the grass is not possible.
- Storage and use of combustible materials of neighbouring organizations: outside the HOR site, a fire at the university chemical storage could cause heavy smoke and sparks. In an extreme scenario, flying sparks may be able to cause fire on the bitumen roofs of the control room and HOR outbuildings. However, in practice, before the situation has worsened to this extent, there is sufficient time available to shut down the reactor, mobilize the fire brigade and initiate emergency measures.
- Explosion after transportation accidents of trucks, trains and ships carrying flammable material on nearby transport routes or explosion after pipeline accident are screened out based on distance; these accidents cannot occur close to the plant.
- Lightning is screened out based on the protection against lightning of the main buildings.

In case of a large fire, systems could be damaged (for example electrical cables) resulting in a fail-safe mode of the safety systems. An internal fire can result in a loss of power. By design, there is no electrical power needed for the HOR to achieve and to remain in a safe shut down state, in case of loss of electrical power. In this situation, the pool and its internals (including the core) stay intact, the reactor is scrammed automatically due to loss of power, and the control rods are driven into the core by gravity. The reactor pool will act as alternate ultimate heat sink for a very long period, without the need for external cooling. Cooling is provided by dissipation of the residual heat into the pool water. It has been shown that the heat processing capacity of the pool (absorption by heating up and boil off) is sufficient to remove residual heat of the core (in a separate section of the pool) for at least 250 days and for the spent fuel (stored in another pool section) at least 3 years.

Due to the design of the HOR, which is an open pool reactor, potential nuclear consequences of a fire are very low. The results show a core damage frequency for internal fire of approximately 2 10^{-8} per year (contribution to TCDF is 0.5%).

The results of the Level 2 and Level 3 PSA show that the HOR is compliant with the risk criteria as defined in the Bkse, for the individual risk and the group-risk.

2.3.5 RR HOR Periodic review and management of changes

The Fire Safety Analysis for the HOR is part of the section of the Safety Analysis Report (SAR) which describes the internal and external hazards. The sections of the SAR are reviewed periodically.

In addition, the RID uses as a source for operational experience from other research reactors, amongst others, the database of the IAEA's Incident Reporting System for Research Reactors (IRSRR). The incident reporting system contains information on events of safety significance with their root causes and lessons learned which help in reducing the occurrence of similar events at research reactors.

2.3.5.1 Overview of actions

As a result of fire analysis and evaluations, improvements are made by e.g. removing fire loads, testing of isolation material of the Reactor Hall on fire resistance, closing cable penetrations with certified sealant.

For example, while performing the Complementary Safety Assessment (stress test), it was not known exactly whether the sound absorber panels in the reactor hall were fireproof (fire inventory quantification). This was tested by a specialised company and approved in accordance with the applicable standards.

2.3.5.2 Implementation status of modifications / changes

In the 10 year evaluation, the topic fire analyses is assessed, also with respect to management of change. For the management of change, an instruction is applied, in which the effects of the modification on Postulated Initiating Events have to be addressed and effects of fire have to be incorporated in the modification process.

In recent years, a facility using hydrogen is built, the CNS facility (Cold Neutron Source), a facility that thermalizes the generated neutrons to very low energies, making them easier to 'guide'. The facility is part of the OYSTER project for technology improvement at the HOR. Several measures, based on fire/explosion requirements, prevention are taken in the design and implementation. See also the HOR section in Chapter 3.

2.3.6 RR HOR: Licensee's experience of fire safety analyses

2.3.6.1 Overview of strengths and weaknesses identified

A strength concerns the development of a (fire) PSA. The HOR is one of the few nuclear facilities with limited power realizing a PSA, including a fire risk analyses. The contribution of the fire scenarios to the TCDF is very low.

A remark can be made that the fire PSA only focusses on Core Damage Frequency, and not at other quantitative nuclear risk parameters (dose for employees for instance). However, the fire risk is maintained at a very low level due to the conventional (not specifically nuclear) fire safety policy and related requirements (licensee experience: no large fire within 60 years at the HOR). This is further explained in the corresponding Chapter 3.

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

The HOR is joining several international groups for improving safety and operation for research reactors. These are the 'International Group on Research Reactors' (IGORR), the IAEA 'Incident Reporting System for Research Reactors' (IRSRR), the 'Arbeitsgemeinschaft für Betriebs- und Sicherheitsfragen an Forschungsreaktoren' (AFR), the 'European Atomic Energy Society Research Reactor Operators Group' (EAES/RROG) and the IAEA 'International Conference on Research Reactors: Safe Management and Effective Utilization'. Safety and operational findings of these groups are evaluated within the HOR. No specific fire issues suggested by these groups can be mentioned at the moment.

The HOR is located on the so-called TU Delft Campus, which is managed by the 'Campus and Real Estate'

(CRE) organisation. On that Campus, fifteen years ago, the Faculty of Architecture of the TU Delft burnt to the ground. Due to this event, the general fire policy of the CRE changed, which influenced also the HOR fire-safety policy. A fire safety policy document was elaborated, with more detailed requirements for the installation (internal document HOR).

2.3.7 *RR HOR: Regulator's assessment and conclusions on fire safety analyses*

2.3.7.1 Overview of strengths and weaknesses identified by the regulator

The strongest point of the Fire Safety Analysis is that it includes a full scope PSA (levels 1, 2 and 3), and has been developed accounting for internal and external hazards, including fires. This PSA is based on national and international state-of-the-art guidelines, some developed for NPPs (NUREG/CR-6850). The PSA has been developed by the Dutch organization NRG, which is also the licensee and operator of the HFR, and which provides consultancy services on PSA to other nuclear installations as well.

This practice of developing full-scope PSAs for non-power reactors is almost exclusive for the Netherlands.

The safety functions and related systems to be protected against fire, together with relevant scenarios, have been identified and assessed. Being a research reactor, at the HOR experiments are carried out as a daily activity. For experimental assemblies no specific extinguisher equipment would be needed, due to the fact that the design of the installations are within the scope of the present provisions installed in the fire compartments/cells.

Additionally, the low power of the reactor allows it to remove the decay heat after a SCRAM by natural circulation of water in the reactor pool. In this sense, the reactor does not rely on any system that may be affected by fires to ensure heat removal (e.g. electric systems).

One weaknesses identified is that, in comparison to other nuclear installations in the Netherlands, the last complete revision of the licence was done in the year 1996, and the explicit requirements for fire safety were developed with lesser details than the example shown in Appendix C. The licensing revision process is ongoing at the moment this NAR is being written.

2.3.7.2 Lessons learned from inspection and assessment as part of the regulatory oversight

In 2013, a post-Fukushima stress test analysis was carried out, with a follow-up inspection in 2015. Some observations from this activity were:

- Proposals for the overall improvement of fire safety in fire cells or fire compartments, considering risks of fires and explosions;
- Analyse potential fire loads;
- Verify the capacities of the fire brigade to counter the effects of calamities.

These actions have been considered and implemented at the HOR.

Every 10 years the regulator carries out a comprehensive review of the status of the installation from a safety perspective (PSR) including fire. Modifications have been initiated and implemented in different fire protection aspects. The last one was carried out in 2021.

In recent years, a project for technology improvement at the HOR has been implemented (OYSTER project), including the installation of a Cold Neutron Source next to the reactor core. A safety analysis has been updated and developed accordingly, including the added fire and explosion hazards. This project is now in the commissioning phase. Several preventive measures, based on fire/explosion requirements, are taken into account in the design and implementation.

IAEA conducted an INSARR mission on the HOR[37] in the year 2021, where the scope of safety analysis presented in the 2020 version of HOR SAR was considered to be comprehensive. Several recommendations were given to improve the evaluations of some events and the revision of the OLCs. No relevant recommendation were given in the framework of fire safety analysis.

2.3.7.3 Conclusions drawn on the adequacy of the licensee's fire safety analyses

The information requested by WENRA for the development of this chapter is reflected in the previous sections. At the moment, the requirements detailed in the individual licence of the HOR with respect to fires are rather general. The licence holder is obliged to draw up, maintain and implement a fire prevention, fire detection and firefighting programme, aligned with all the topics developed in this chapter.

Based on the information developed in the previous section, together with the information presented in the corresponding section in Chapter 3, HOR has proven compliance to the assessment framework.

2.4 Fuel Cycle Facility Urenco enrichment facilities

The fundamental safety objective of Urenco Netherlands (UNL) is to protect people and the environment against possible harmful effects of the operation of its plant.

In UNL's Safety Report the measures which are taken to fulfil this main objective are described. It contains organizational conditions, safety provisions, safety technical specifications and the safety plan. The risks at UNL have been further identified and evaluated in a risk inventory and evaluation.

In addition, fire risks were further analysed and the results are documented in UNL's Fire Hazards Analysis (FHA). This is described in more detail in the following sections.

2.4.1 *FCF Urenco Types and scope of the fire safety analysis*

The fire safety objectives of the enrichment facility are to ensure the achievement of the main safety functions 'Confinement to protect against internal exposure and chemical hazards , 'Prevention of criticality' and 'Protection against external exposure' by protection the integrity of the safety relevant SSCs through:

- The prevention of fires and/or incidents resulting in fire;
- Controlling incidents that nevertheless occur;
- The prevention of casualties due to fire and fire symptoms, like smouldering or smoke.

The fire safety analyses at UNL contain several studies and analyses following the deterministic Fire Hazard Analysis methodology. In the following sections the results of the studies are described. Additionally, for UNL, a level 3 Probabilistic Safety Assessment is performed, in accordance with the ANVS Guide for Level-3 PSA.

Type of scenarios

Fire scenarios are initially analysed as part of UNL's Safety Report and further developed in several specific studies, as documented in UNL's Fire Analysis Report. For enrichment facilities, the following main hazards related to the main safety functions are identified, and used in the definition of scenarios:

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[37] 'Report of the integrated safety assessment of research reactors (INSARR) to the Hoger Onderwijs Reactor (HOR)', IAEA, December 2021 https://www.autoriteitnvs.nl/documenten/rapporten/2021/12/22/iaea-rapport-insarr-missie-bij-de-hoger-onderwijs-reactor-hor-van-het-reactor-instituut-delft

- The potential release of UF_6;
- A criticality hazard: potentially exists since the concentration of U-235 is higher than 1%;
- External exposure is a concern in the handling of recently emptied cylinders, especially those used as containers for reprocessed uranium, with build-up of U-232.

In line with IAEA SSG-5 Rev.1: ‘Safety of Conversion Facilities and Uranium Enrichment Facilities’, and its guidance on protection against internal and external threats, the following threats related to fire (safety) were considered in the definition of scenarios:

- Internal fire or explosion;
- External fire or (gas cloud) explosion;
- Extreme weather conditions i.e. extremely high temperature and lightning;
- Failure of external electrical power supply;
- Crashing plane.

Additionally, specific possible (fire) scenarios that may lead to heat radiation, overpressure, toxicity and ionizing radiation are further analysed. In the following sections, the most relevant will be described, being:

- *Storage and Transport* and *Process Systems*: where the failure of UF_6 cylinders is analysed;
- *Conventional fires in corridors, electrical systems and diesel rooms*.

Combination of events

Since the installations at UNL are in principle not fire hazardous, most scenarios that may lead to the release of UF_6, which will react with air humidity to form the toxic but not flammable HF, consist of a combination of events. This also applies to the release of HF as a result of a fire in the storage of filters containing sodium fluoride, or the release of a fluoride used at Stable Isotopes. Conventional risks, such as a pool fire resulting from ignition of diesel or fire in a chemical storage, are considered to have no radiological consequences on the environment outside site boundaries according to Dutch regulations, which means individual risks are below 10^{-6}.

Moreover, UNL’s Safety Report describes that safety relevant buildings, constructions and installations are seismically robust against earth movements relevant for Almelo. Flooding is not a considered scenario for UNL since the site is situated above sea level and the buildings are located at higher levels.

2.4.2 FCF Urenco Key assumptions and methodologies

UNL complies with current laws and regulations and applies IAEA guidelines, which are not prescribed by law, as far as reasonably applicable. In addition, industry standards and guidelines are applied, where relevant and applicable, including the ‘Bouwbesluit 2012’, the ATEX and PGS directives.

UNL’s design philosophy focuses on the inherently safe principle, by preventing accidents by technical means and procedures; designs are based on state-of-the-art technology and best practices. Designs are checked according to the 4-eye principle and validated by an independent team of experts and/or representatives of the responsible management.

UNL has all the necessary provisions with regard to fire safety. This concerns structural provisions (fire compartmentation, fire barriers, escape routes), technical provisions (fire alarm and extinguishing systems) and organisational provisions (Emergency Response Plan, emergency response maps, emergency response organisation). This is described in more detail in Chapter 3.

Following the guidance of IAEA SSG-5 on protection against internal and external hazards, the threats related to fire safety are considered, and the safety analysis are performed for UNL, starting with a list of representative postulated initiating events.

The assessment framework for the Fire Hazard Analysis (FHA) is a combination of IAEA Safety Reports Series No. 8, 'Preparation of Fire Hazard Analyses for Nuclear Power Plants', the Graded Approach of IAEA SSG-25 'Periodic Safety Review for Nuclear Power Plants' and the guideline 'Model Integrale Brandveiligheid Bouwwerken' (i.e. 'Model integral fire safety of buildings') based on the 'Bouwbesluit 2012'.

Additionally, scenarios involving the release of radioactive material are included in the environmental dispersion PSA Level 3 safety analyses, performed with probabilistic risk assessment code 'NUDOS2' (in accordance with the ANVS Guide for Level-3 PSA) based on conservative starting and boundary conditions. Two design scenarios lead to a radiological or chemo-toxic emission, i.e.:

1. failure of an UF_6 pipe due to an incorrect or extreme temperature: release of 0,68 kg UO_2F_2 and 1,60 kg HF in 30 minutes or 1,44 kg UO_2F_2 and 3,36 kg HF in 180 minutes;
2. drop of a 48Y cylinder: 0,18 kg UO_2F_2 and 0,41 kg HF in 30 minutes.

For these scenarios, a probabilistic analysis of exposure distribution is calculated. The (95-percentile) maximum inhaled amounts were determined to evaluate chemo-toxic deterministic effects. The results are far below the limit stipulated by acceptance criteria, i.e. the legal requirements. UNL has concluded that scenarios with possible radiological consequences are not fire related.

With respect to the main safety function 'Confinement to protect against internal exposure and chemical hazards', the main systems to be protected against fire are those systems containing UF_6, in any of the steps during the enrichment process. Fire in a building with radiological risks could theoretically lead to the failure of systems containing UF_6. Several barriers are applied to prevent release of UF_6 in general:

- Systems containing UF_6 are completely closed (except for specific situations);
- At least one of the following additional barriers applies:
    - UF_6 is contained at sub-atmospheric pressure, so any leakage will not release UF_6;
    - the system features a second sealed enclosure;
    - the system is located in a room equipped with controlled ventilation at sub atmospheric pressure and detection of air contamination.

Furthermore, the amount of gaseous process medium in the plant is limited, so that only this limited amount may be discharged in case of an event. The system includes pressure gauges and valves that constantly monitor the pressure and, in case of increased pressure, can shut off parts of the plant. The containment functions are guaranteed by tests and controls. These principles also protect the plants in the event of a fire.

Table 3.1 in Chapter 3, Section 3.1 lists the installation components at UNL that contribute to the function 'containment' in the context of fire safety in combination with the function and the DiD safety level of the component.

With respect to the main safety function 'Prevention of criticality events', several aspects are considered. First of all, international experiences demonstrate that criticality incidents are rare and (discarding reactors and critical assemblies) only occur at higher enrichment levels than the ones present at UNL, in the vast majority of cases with plutonium or highly enriched uranium. The occurrence of criticality cannot be caused by fire because an elevated temperature does not have a significant influence on criticality. Temperature is not identified as a parameter influencing criticality, in which all influencing parameters are analysed. This means that at higher temperatures, reactivity decreases. It is very plausible that this holds also for a homogeneous solution of UO_2F_2 in water, used in calculations applicable to UNL.

In the 'Nuclear criticality safety guide for fire protection professions in DOE nuclear facilities'[38] the unsafe accumulation of moderator or reflection materials (e.g. water), which could be used in firefighting, is mentioned. However, Urenco internal report 'Fighting fire in the presence of UF_6 ' (Dutch: 'Bestrijding van brand in aanwezigheid van UF_6') demonstrates that the use of water does not lead to criticality since it is not credible that a thick water layer that might lead to a critical configuration will retain on apparatus, cylinders or installations. Nor will the occurrence of criticality lead to fire because the fire load is very low under all circumstances.

2.4.3 FCF Urenco Fire phenomena analyses: overview of models, data and consequences

The Fire Hazards Analysis is further developed by analysing the fire scenarios described in UNL's Safety Report. These are determined by analysing internal and external threats based on IAEA SSG-5. The fire scenarios were further analysed according to the PGS6 together with the regional fire brigade, by selection of the normative scenarios and determination of the necessary fire extinguishing capacity using regulation based standards.

From UNL's Safety Report, the following fire-related postulated initiating events are described:

6.1 Internal fires or explosions

6.8 Ignition of accumulated hydrogen

7.7 External explosions

7.8 Aircraft crashes

7.9 External fires

7.11 Accidents on transport routes.

Based on the probabilistic safety analyses, only Postulated Initiating Event (PIE) *7.8 Aircraft crashes* derives in a normative scenario. In all aircraft scenarios, the probability of damage to an installation part with large amounts of UF_6 is $< 5x10^{-7}$ per year.

Calculations demonstrate that no radiotoxic deterministic effects will occur. The results show that no deterministic effects due to inhalation of HF will occur outside site boundaries. It further shows that deterministic effects due to inhalation of UO_2F_2 could potentially occur. The calculated individual risks and group risk are well within the legal requirements.

Tested against the PGS6, this scenario is considered non-credible.

In the successive Fire Hazard Analysis, other fire-related scenarios are included. The following threats (based on IAEA SSG-5) were considered:

1. **Internal fire or explosion:** locations with potential fire hazard are:
   a. diesel storage and loading: leakage of diesel with risk of pool fire after ignition;
   b. storage of chemicals and gas cylinders: fire in chemical storage buildings with risk of toxic smoke gas cloud;
   c. ammonia in refrigeration plants: leakage of ammonia with risk of toxic gas cloud and fire;

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[38] Rev.B, 1994

   d. storage of process gas diethylzinc for stable isotopes: leakage of process gases at stable isotopes with risk of toxic gas cloud and fire (not included in TPR);
   e. natural gas purchasing station with UNL's main natural gas connections.

NB: UF_6 is non-combustible and only limited combustible materials have been used in plant construction and are present on the plant.

2. **External fire or (gas cloud) explosion**: locations with potential external fire hazard are:
   a. storage of hazardous substances at neighbour ETC NL company: no immediate explosion hazard and no possibility of a spreading fire due to the distance between the storage and UNL;
   b. main natural gas pipeline: not able to lead to a significant pressure wave in case of an explosion, due to a distance of at least 400 meters and the limited fire load towards UNL;
   c. transport of hazardous substances by road via the N743 and Drienemansweg and via the Almelo-Hengelo railway: a direct explosion or fire during transport will not result in significant damage to the facilities due to a distance of at least 200 meters;
      Note: a major leakage of gas transported by rail could lead to a gas cloud that could drift towards UNL under specific weather conditions; a gas cloud explosion due to UNL's electrical installations has been assessed as not to be credible;
3. **Extreme weather conditions** i.e. extremely high temperature and lightning;
   a. installations and buildings can sufficiently withstand extreme temperatures possible for the site: cooling is not a safety function;
      NB: UF_6 in the cylinders has a triple point of 64 °C, which gives sufficient margin compared to the maximum outdoor air temperatures to be assumed. An extremely low outside air temperature is not relevant in the context of this TPR.
   b. lightning strikes can adversely affect the operation of electrical systems such as UNL's instrumentation and control systems, which is not likely and has never occurred;
      NB: buildings containing safety-relevant systems are equipped with lightning protection connected to earth points, in accordance with the regulations applicable during construction, such as NEN 1014 and/or NEN-EN-IEC 62305;
4. **Failure of external electrical power supply**: UF_6 systems transition to a safe state, centrifuges run down and feed systems shut down which is not always the case since the power supply is automatically taken over by the UPS;
   NB: no electrical power is required for systems to switch to a safe mode, the evacuation of the UF_6 inventory through designated filters to a dump system and to prevent criticality;
5. **Crashing plane**: explained above as postulated initiating event based on UNL's Safety Report.

The analyses of these scenarios demonstrated that the extent of their consequences is limited, that the release of UF_6 and HF is not plausible, and that external safety risks are very low and compliant with the legal requirements.

In addition to the previous list, an analysis of the fire safety level of the buildings on the UNL site was carried out. The results have been compiled into UNL's parent Fire Hazard Analysis report.

Possible (fire) scenarios were further analysed for conventional fire scenarios and fire scenarios for *Storage and Transport* and *Process Systems*. This analysis includes scenarios that may lead to heat radiation, overpressure, toxicity and radioactive radiation.

1. *Storage and transport*: collapse of a cylinder due to fire during transport or storage is not considered relevant due to the limited fire load/fire duration;
2. *Process systems:* failure of a UF_6 cylinder in case of fire can only occur if the cylinder is exposed to an external fire for a long period of time. At a (continuous) fire temperature of 800 °C, a cylinder collapses within 26 – 28 minutes. This follows from the study Radiological consequence analysis in case of fire impact carried out by the German organisation Gesellschaft für Anlagen- und Reaktorsicherheit GRS mbH. It should be noted that a continuous fire temperature of 800 °C is not realistic for the situation in UNL's storage buildings due to the low fire load. Based on the standard fire curve in accordance with NEN 6069, this temperature will only be reached after approximately 25 minutes.
3. *Conventional fire scenarios*: the normative scenario *Fire in a corridor* has been further detailed.

   Fire in a corridor – installation scenario 1: Conventional fire scenarios were developed to better consider the fire risks of UNL. The following scenarios were assessed: fire in a corridor, a switchgear, cable duct, control panel, transformer room, UPS generator, pump installation, luminaires, diesel room.

   The scenario *Fire in a corridor* is a representative example scenario for the Separation Plants, and leads to heat load in the building. Supply valves are closed and the cascades are drawn empty to the dump. Collapse of the dump due to heat load is estimated as not very likely. Upon collapse, the contents of 4 dump filters will be released and react with water vapour in the outside air. The pessimistic assumption is that all UF_6 (60 kg) is converted to HF (15 kg) and UO_2F_2 (53 kg) and has been released in 30 minutes. In this situation the alarm level to warn population in the environment (AGW) can be reached up to 60 metres without LODs and in average weather conditions in the Netherlands (types D5, E5).

2.4.4 FCF Urenco Main results / dominant events (licensee´s experience)

The FHA shows that no scenarios have been identified with significant effects beyond the site boundary or the release of radioactive substances. In fact, there is no scenario where an entire fire compartment could burn down, taking into account the development of fire under unfavourable conditions. This is mainly the result of the extremely low fire load at UNL. No credible PGS 6 scenario is identified at UNL.

A conventional fire in a building with radiological risks could theoretically lead to the failure of systems containing UF_6. As described above, several analyses have shown that this is not a credible scenario. Fire in an area where open UF_6 systems are present could lead to the release of UF_6; however, the quantities of UF_6 present are limited, which means that this scenario could not cause significant effects on the environment.

Only conventional fire hazards, mainly electrical, lead to a possible appearance of the emergency response organization, possibly supplemented by external emergency services.

No scenarios were identified in which a fire in a building that has no radiological risks will lead to consequences for buildings with radiological risks. The main reason is the large distances between these buildings.

Additionally, no credible events with criticality consequence were identified.

2.4.5 FCF Urenco Periodic review and management of changes

Extensions or changes to installations or working methods are subject to requirements. Each proposal for change passes through a determined procedure, in which safety and environmental aspects are explicitly included in the considerations. The change can only be implemented after formal approval and release. Organizational changes are also assessed for their impact on safety before they can be implemented; this includes specific testing for fire safety and possible effects on the Emergency Response Plan and FHA.

The FHA is updated at least once every three years and more frequently if reasonable; at the discretion of the Manager Systems Compliance. This frequency generally applies to written documentation, such as the Emergency Response Plan and Crisis Plan.

2.4.5.1 FCF Urenco Overview of actions

In the current situation, there are no relevant fire safety improvement measures to be implemented based on the FHA. UNL plans to recheck all the FHA's assumptions before the end of 2023. All actions, including restrictions on fire loads, will be implemented in UNL's management systems.

This year, a fire resistant storage will be built in one of the separation plants for the storage of used or contaminated oil and filters. Moreover, UNL is planning new production halls. Programs of Requirements ('PvE', see Glossary) are currently in production; fire protection and preventive measures are incorporated in coordination with the Compliance department.

2.4.5.2 FCF Urenco Implementation status of modifications/changes

Actions and improvement measures arising from the FHA are recorded and monitored in FCF Urenco's ReAct reporting system; there are currently no open actions in the context of fire safety. This FHA will be reviewed every three years and relevant modifications to installations will be recorded as improvement actions in the management system. The planned new buildings will be designed in compliance with applicable regulations and guidelines.

2.4.6 *FCF Urenco Licensee's experience of fire safety analyses*

2.4.6.1 FCF Urenco Overview of strengths and weaknesses identified

UNL has performed several analyses on safety, including fires. UNL has concluded that scenarios with possible radiological consequences are not fire related and fire risks are not caused by UF_6 and the enrichment process. In particular, fire safety has been subjected to a thorough investigation, to get more insight in fire risks at UNL. Fire risks consist mainly of conventional electrical risks due to the electrical installations present.

Fires have been accounted for in different reports, mainly those about the Safety Analyses and Fire Hazard Analysis. These are elaborated following different requirements and guidelines. Analyses of different fire scenarios are described in several reports. These reports have been developed by different experts, and show no obvious connection, since scenarios differ. Moreover not all scenarios mentioned in UNL's Safety Report are considered in the Fire Hazards Analysis report, for instance ignition of accumulated hydrogen.

2.4.6.2 FCF Urenco Lessons learned from events, reviews, fire safety related missions, etc.

Improvement actions are included in the management system based on the periodic review by the FHA, audits by ANVS, insurers and the 10 annual PSR (10EVA). Considered actions based on these reviews are included in the management system and are implemented. Examples are:

- UNL has introduced safety walks and implemented a safety culture program with monthly safety briefings based on the WANO principles.

- A standard specification will be made, in which the use of construction materials will be specified, for new-buildings but also for renovation, including use of isolation materials in order to guide future Design.
- UNL's explosion document is reviewed, resulting in the removal of stored flammable hazardous substances that are no longer used.
- A quarterly report with external incidents is shared across the organisation. External incidents, for example incidents about fire, are collected from news websites and nuclear authorities, including the FINAS-database[39]. Updates on laws, regulations and guidelines are shared in the report as well.

2.4.7 FCF Urenco - Regulator's assessment and conclusions on fire safety analyses

2.4.7.1 FCF Urenco – Overview of strengths and weaknesses identified by the regulator

Operating an enrichment facility, Urenco manages only low level radioactive material. The major risks of UF_6 are mainly related to toxicity due to its chemical effects (chemotoxicity) and not due to the effects of radiation.

One of the strongest points is that a Fire Hazards Analyses and a (PSA level 3) risk assessment have been developed, accounting for internal hazards and external hazards, including fires. This assessment is based on the ANVS PSA level 3 guidelines, and several international guidelines.

The safety functions and related systems to be protected against fire, together with relevant scenarios, have been identified and assessed. This practice of risk assessment for nuclear installations other than reactors is almost exclusive for the Netherlands.

The safety functions and related systems to be protected against fire, together with relevant scenarios, have been identified and assessed.

A strong point is that Urenco has similar installations in different countries, and these installations are all individually subjected to different national regulations and inspections. Experience and design improvements can be gathered and shared between operators of the various installations.

For installations such as those of Urenco, a risk of criticality may arise if using water to extinguish fires. This was assessed and the risk is deemed to be negligible.

As a weakness, it is observed that fire scenarios have been accounted for in two reports: the Safety Analyses and the Fire Hazards Analyses reports, which are elaborated by different experts following different requirements and guidelines. Some differences between the scenarios considered in the Fire Hazards Analyses and the Safety Analyses have been identified by Urenco.

2.4.7.2 FCF Urenco – Lessons learned from inspection and assessment as part of the regulatory oversight

In 2013, a post-Fukushima stress test analysis was carried out ('Complementary Safety Margin Assessment Urenco Netherlands BV'). Relevant for this TPR, it was observed that:

- The risk of an internal fire is very small because the amount of combustible inventory in the facilities with UF_6-systems is insufficient to cause a discharge of UF_6 as a result of the fire. Furthermore, the cylinders containing large amounts of UF_6 have a high heat-resistance.
- The design of the equipment, the characteristics of the installation and the way operations are conducted, have been demonstrated to be adequate for the confinement and subcriticality control

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[39] Fuel Incident Notification and Analysis System (FINAS); IAEA and OECD/NEA database for FCFs.

functions. The emergency response organization is prepared and suitably equipped in case of accident conditions.

Every 10 years, a comprehensive revision of the status of the installation from a safety perspective is performed (PSR / 10EVA). The last 10EVA was carried out in 2017. From this evaluation, based on SSG-5: clauses 4.38-4.40, and 4.43, the following was pointed out:

- Improvements in the screening of the rooms: which rooms are relevant with regard to nuclear safety, the fire load per room and the consequences of fire on the nuclear safety functions. This is needed to substantiate that the scenarios described in the fire analyses are comprehensive. In addition, it is needed to substantiate whether the ignition sources and fire loads can or cannot be minimized further.
- What Urenco does well is that they take into account the existing mitigating measures in the analyses they perform. This becomes clear in the fire brigade scenarios drawn up according to PGS6. A distinction is made between mitigated and unmitigated risks.

2.4.7.3 FCF Urenco – Conclusions drawn on the adequacy of the licensee's fire safety analyses

The information requested by WENRA for the development of this chapter is reflected in the requirements detailed in the individual licence of Urenco. The permit holder is obliged to draw up, maintain and implement a fire prevention, fire detection and fire-fighting programme substantiated with a risk assessment, aligned with all the topics developed in this chapter, as reflected in the example in Appendix C. This programme must be updated at least once every five years and submitted to the ANVS for assessment, or if changes are introduced.

The licence holder is currently compliant to the assessment framework.

2.5 Dedicated Spent Fuel Storage facilities COVRA

2.5.1 SFS COVRA Types and scope of the fire safety analyses

The main principle of nuclear safety is that, under normal operating conditions as well as in the event of malfunctions and accidents, a situation may never arise in which personnel, the local population, the employees of surrounding companies and the environment could be caused damage that is deemed unacceptable.

The fire safety objectives of COVRA are to provide protection against fire risks, taking measures in a number of fields, following the Defence-in-Depth concept:

- to prevent fire from starting, this is achieved by the quality of the design and safe operation,
- to ensure surveillance, detect fire quickly and enable fire-fighting,
- to minimize the consequences of fire in case a fire starts (in spite of fire prevention) by preventing the spread of those fires.

To meet the safety objectives, the safety systems, shall be protected against the consequences of fires so that their safety functions are preserved: to stop the operations in a safe way, to remove residual (decay) heat, to contain radioactive material and to ensure radiological protection.

Fire risk has to be considered when the three following conditions are present :

- inflammable material (fuel),
- combustible agent (air in the area),
- fire initiator with sufficient energy so as to initiate fire.

In order to determine an adequate degree of fire protection in the different areas (fire compartments, fire resistance rating of the fire compartment boundaries, fire extinguishing systems and other necessary features), a fire hazards analysis is performed observing guidance in various IAEA and WENRA documents. Examples are IAEA Safety Standard GSR Part 4[40], IAEA Safety Fundamentals SF-1, WENRA Waste and spent fuel storage safety reference levels report[41], version 2.1, IAEA draft Safety Standard No. D284[42], and IAEA Safety Standards: Specific Safety Guide, SSG-2[43].

A risk evaluation has been developed for the 2015 Safety Report.

Various scenarios have been studied. For example, two scenarios have been considered regarding the gas explosion safety of the HABOG. The first scenario assumes the explosion of an external gas cloud of which the blast wave enters the storage room via the ventilation inlet. The second scenario considers the case in which a flammable mixture enters the storage room via the ventilation system.

Both earthquakes and floodings have been considered in the design basis of the HABOG. In areas with very low seismic activity, the available data are often not sufficient for a probabilistic approach. This applies to the COVRA location. In such cases, reference is often made to the maximum earthquake effect observed in the area of the location and its intensity plus 1 is used as the design basis (as per IAEA and KTA guidance).

The effect of a (military) aircraft fuel fire (fireball) following an aircraft impact event has been analyzed as well.

2.5.2 SFS COVRA Key assumptions and methodologies

An inventory and analysis of the areas with fire loads (room list) has been made and has been recorded in the plant documentation. In order to determine an adequate degree of fire protection, a fire hazards analysis has been performed considering the different areas (fire compartments, fire resistance rating of the fire compartment boundaries, fire extinguishing systems and other necessary features). The analysis can be subdivided into the following steps :

- Identification of items to be protected (redundant or not) present in the area.
- Assessment of fire load density.
- Identification of ignition point.
- Detection system and extinguishing system.
- Compartment characteristics: kind of system ; requirements for fire barrier.
- Ventilation control compartment.
- Personal protective measures.
- Assessment of the fighting provisions for the fire brigade.
- Evaluation of foreseen measures.

Fire protection design depends on fire risk level analysed in the different areas (expressed as fire load density in MJ/m2). According to the Dutch Building Decree, a fire compartment is constituted when the fire load

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[40] IAEA Safety Standards: General Safety Requirement, GSR-part 4, Safety Assessment for facilities and activities. Vienna, 2009.

[41] WENRA Waste and spent fuel storage safety reference levels report, version 2.1, WENRA Working Group on Waste and Decommissioning (WGWD), Stockholm, February 2011

[42] IAEA Safety Standards: draft safety standard series No DS284, The Safety Case and Safety Assessment for Predisposal Management of Radioactive Waste, Vienna, 2011.

[43] IAEA Safety Standards: Specific Safety Guide, SSG-2, Deterministic Safety Analysis for Nuclear Power Plants, Vienna, 2009.

density in the area is higher than 400 MJ/m2. In parallel, as per the Dutch Building Decree, a fire barrier must ensure its integrity for at least 90 minutes.

In the design of the HABOG, the Dutch standards (NEN) relevant for structural design were used as well. In addition, a number of foreign and international codes are used as guidelines. A description of the design requirements together with national and international standards and guidelines applicable to COVRA, is given in section 3.5. This set of documents provides valuable input for the Fire Hazards Analysis.

The fire containment approach, assumes that all combustibles within a fire compartment can be consumed during a fire. After such a fire, the undamaged portions of the plant do not involve unsafe conditions.

As in the facility a mechanical process is implemented, the postulated source of fire arises from electrical fires where there are concentrations of cables or electrical equipment (motors, switchgears, cabinets).

Maintenance work having potential for causing fires, particularly work involving the use of open flames, soldering, welding and flame cutting, requires additional caution and shall be subject to written authorization (permit) and shall be carried out only under controlled conditions with proper consideration given to fire protection. A fire detection system is implemented in areas where maintenance can induce a fire risk.

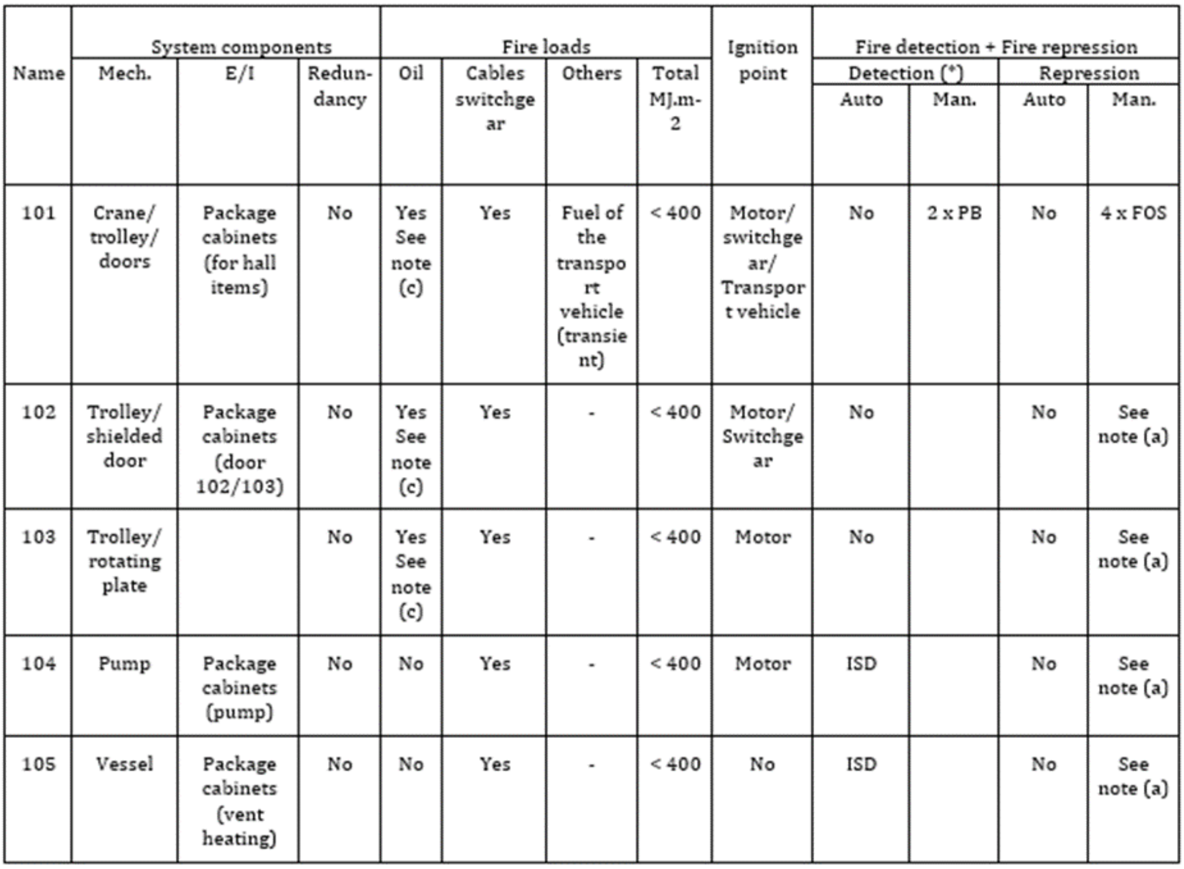
COVRA is not classified as a High Risk installation as per the Brzo. Furthermore, it is not required to have an internal fire brigade by the Safety Region Zeeland, but it is required to have a company emergency response organization (BHV) with limited firefighting capabilities. In case of large fires, regional fire brigades will be alarmed. Further explanation of the organizational arrangements are provided in the corresponding Chapter 3.

2.5.3 *SFS COVRA Fire phenomena analyses: overview of models, data and consequences*

Fire risk has to be considered when the three following conditions are present :

- inflammable material (fuel),
- combustive agent (air in the area),
- fire initiator with sufficient energy so as to initiate fire.

The following Figure 2.1 gives an example of how the data is collected and analyzed, identifying fire loads, ignition points and detection/ suppression systems.



Name	System components			Fire loads				Ignition point	Fire detection + Fire repression			
	Mech.	E/I	Redun-dancy	Oil	Cables switchgear	Others	Total MJ.m-2		Detection (*)		Repression	
									Auto	Man.	Auto	Man.
101	Crane/ trolley/ doors	Package cabinets (for hall items)	No	Yes See note (c)	Yes	Fuel of the transport vehicle (transient)	< 400	Motor/ switchgear/ Transport vehicle	No	2 x PB	No	4 x FOS
102	Trolley/ shielded door	Package cabinets (door 102/103)	No	Yes See note (c)	Yes	-	< 400	Motor/ Switchgear	No		No	See note (a)
103	Trolley/ rotating plate		No	Yes See note (c)	Yes	-	< 400	Motor	No		No	See note (a)
104	Pump	Package cabinets (pump)	No	No	Yes	-	< 400	Motor	ISD		No	See note (a)
105	Vessel	Package cabinets (vent heating)	No	No	Yes	-	< 400	No	ISD		No	See note (a)

Figure 2.1: Example of table from COVRA's data collection and data analysis, identifying fire loads, ignition points and detection/ suppression systems

With regards to Figure 2.1, it is noted that:

- Fire suppression is manual with fire extinguishers from surrounding area;
- The redundant cables for mechanical equipment are protected against fire once going out from the fire compartment if they are routed in the same room, up to the point where they enter the crane room
- Flash Point > 200°C

The process of the Fire Hazard Analyses is illustrated with an example, as follows.

Standard fire loading curve for a fire has no serious detrimental effects in the HABOG building. The cover on the reinforcement is such that the temperature at the reinforcement remains well below critical levels even for fire durations up to 120 min.

The Reception Hall in the HABOG, belongs to the so-called 'controlled area'. The process equipment items constitute a very low fire load density (< 400 MJ/m^2). When transport casks are received in this area, the transport vehicle (such as train, lorry or truck) brings an additional fire load with a potential ignition source. Personnel shall be present in order to ensure transport vehicle and cask unloading. In case of fire due to transport vehicle or process equipment, personnel can use suitable portable or mobile extinguishers present in the reception hall.

Additional prevention and protection measures are adopted as result of the fire hazard analysis, for example:

- A manual fire alarm system is implemented in the reception hall.
- Procedures to be followed are established:
    - no unattended parking of a vehicle inside the reception hall,
    - evacuation of transport vehicle after unloading the cask and before the cask entering in the main building.

The transport casks are designed to maintain an acceptable containment level and an acceptable waste temperature during and after a fire of 30 minutes at 800°C.

The relevant fire related normative scenarios considered are:

- Flue gas cleaning failure during incineration of carcasses in the cadaver incinerator.
- Fire in working stock of solid compressible waste with alpha emitters.
- Fire in buffer stock.

Additionally, studies into the gas explosion safety of the HABOG have been performed and internally documented. As a result from the FHA, two bounding scenarios have been considered.

The first scenario assumes the explosion of an external gas cloud of which the blast wave enters the storage room via the ventilation inlet. The ‘BLAST 3D’ code has been used to calculate the overpressures due to the entering blast wave in the storage room. The results has been used to design the floor of the room as well as the equipment inside the room.

The second scenario considers the case in which a flammable mixture enters the storage room via the ventilation system. Due to an ignition outside the building, the flame front enters the room where it ignites the flammable mixture. The overpressure inside the room due the internal explosion has been calculated. It was concluded that the overpressures would be too high and that preventive measures should be taken to avoid an internal explosion. As preventive measures, the application of igniters to deliberately ignite a flammable mixture outside the HABOG have been installed by a certified company.

The effect of an (military) aircraft fuel fire (fireball) following an aircraft impact event has been analyzed as well. HABOG resists such an impact, the building will remain intact.

Regarding criticality risks related to fires events, it has been concluded that no criticality issues can arise from the presence of water coming from the fire extinguishing systems.

2.5.4 SFS COVRA Main results / dominant events (licensee ’s experience)

The safety systems required to stop the operations in a safe condition, to remove residual heat, to contain radioactive material and to ensure radiological protection, are protected against the consequences of fires, so that their safety functions can still be carried out.

In a handling and storage facility like HABOG, the fire risk mainly results from electric or electronic failure. The objectives, in case of such a failure are:

- In handling areas, storage areas and filter rooms, to ensure that the combustion is localized and limited in time without any intervention so as to prevent that the combustion degenerates into a fire in the whole area and to avoid the attack of radioactive material and radiological shielding by the fire; and to ensure that, after combustion stops, the radioactive sources can be placed in a safe position in order to allow the necessary repair operations to be performed.

- In other areas, to prevent fire spreading from areas where a fire hazard has been identified to areas containing radioactive materials and radiological shielding; and to ascertain that, after fire is extinguished, the radioactive sources can be placed in a safe position in order to allow the necessary repair operations to be performed.

In addition, it shall be ensured that heat removal from the wastes is maintained, in order to keep them at acceptable temperatures. In the HABOG, heat removal of waste is ensured by passive principles:

- by convection and conduction through the walls in the handling areas and in the bunkers, and
- by natural convection in the vaults.

2.5.5 *SFS COVRA Periodic review and management of changes*

A periodic safety review is carried out at least once every 10 years, the most recent one took place in 2020. In this report, COVRA's fire safety measures were evaluated and assessed.

Additionally, the safety analysis is updated whenever a significant modification to the plant is scheduled to be implemented.

2.5.5.1 SFS COVRA Overview of actions

As part of the assessments in the framework of the 10-yearly Periodic Safety Review (10EVA), various assessments were conducted and reported per 'Safety Factor', Guidance for the 10EVA was the IAEA Guide SSG-25 'Periodic Safety Review for Nuclear Power Plants', which was applied observing a graded approach. The 2020 Safety Assessment report on Safety Factor 1 'Design', concluded that the overall fire protection measures at the COVRA site are considered a good practice.

The report was reviewed by the ANVS before finalisation. No further recommendations or suggestions on fire safety were given in this report.

2.5.5.2 SFS COVRA Implementation status of modifications/changes

Implementation of measures mentioned in the 10EVA have been, of are being implemented. With regard to the management of change, this procedure has been improved by harmonizing technical as well as organizational changes.

2.5.6 *SFS COVRA Licensee's experience of fire safety analyses*

2.5.6.1 SFS COVRA Overview of strengths and weaknesses identified

The Fire Safety Analysis documents are part of the Integrated Management System of COVRA, and are reviewed once every maximum two years.

The risk of an internal fire inside the storage areas is very small due to the very low amount of combustible inventory in HABOG. The areas where more combustible material is present are accommodated with fire detection systems. This aspect has been addressed in the Complementary Safety Assessment (CSA) for the HABOG in 2013. Moreover, in the 10EVA measures which COVRA has taken for fire prevention including uncontrollable fire propagation were identified as a good practice.

2.5.6.2 SFS COVRA Lessons learned from events, reviews, fire safety related missions, etc.

To date, during the entire operating life of the HABOG, no incidents have occurred with regard to fire-hazardous situations or circumstances.

The HABOG was designed in the late 1990s and has been in use since 2003. The development of the approach, and the documentation of requirements with regard to fire safety were further developed during that period. It was a common practice for the requirements with regard to the fire alarm system to be part of the standard specifications for tenders. A separate Program of Requirements (‘PvE’) associated with fire safety was later adopted. Each part and/or building has its own approach and solutions.

Following the accident at the Fukushima nuclear power plant in Japan, the European Council declared that “*the safety of all EU nuclear power plants should be reviewed on the basis of a comprehensive and transparent risk assessment (Stress test)*”. In the Netherlands, this review was later expanded to nuclear installations other than nuclear power plants. Based on this, the former Ministry of Economic Affairs, Agriculture and Innovation (EL&I) requested COVRA N.V. to perform an assessment of the safety margins of the HABOG facility. In this complementary Safety margin assessment (NRG 23254/ 13.118712, 06/06/2013, document of public domain), fire safety also is considered. In its summary it was concluded: “*In general, consideration of the ENSREG Stress Test requirements has concluded that there are no credible fault scenarios or cliff-edge effects at the HABOG (COVRA) site for which there are no current adequate provisions*.” In the report there were no recommendations specific to fire safety.

Furthermore, May 1st , 2018 the CCV – a Dutch institute developing certification and inspection guidance - published the CCV Certification Scheme for the Fire Safety Baseline Document (UPD[44]). With this publication, there is more direction and coherence with regard to fire safety.

The Integral Fire Safety Model (IBB[45]) strengthens fire safety through cooperation. By involving all parties and by ensuring good coherence between the various fire safety measures. Due to the structured approach and the clarity and coherence of the measures, this increases the safety of people and limits the damage in the event of a fire. COVRA has applied this model and set it up together with a certified company. The aim of the scheme is to increase the confidence of customers in the quality of UPDs through independent and expert supervision. The scheme thus answers the demand from clients, competent authorities and insurers for expertise and quality assurance when drawing up principles.

2.5.7 *SFS COVRA – Regulator’s assessment and conclusions on fire safety analyses*

2.5.7.1 SFS COVRA Overview of strengths and weaknesses identified by the regulator

COVRA’s HABOG facility is a Spent Fuel Storage, where only limited activities are carried out. The vitrification process of spent fuel is done abroad (in France), and the vitrified waste is then safely stored in HABOG. Spent fuel of research reactors is stored as well. COVRA is classified as a low risk nuclear installation.

One of the strongest points is that a Fire Hazards Analysis and a risk assessment have been developed. This assessment complies with the ANVS PSA level 3 guidelines, and several IAEA / WENRA guidelines. This practice of risk assessment for nuclear installations other than reactors is almost exclusive for the Netherlands.

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[44] UPD is a Dutch acronym for ‘Uitgangspuntendocument brandbeveiliging’, which is a fire safety baseline document which forms the basis for the design of fire safety. The purpose of the document is to clearly lay down agreements on fire safety between the user and the parties defining the frameworks (such as competent authority and insurer).

[45] Dutch: ‘Model Integrale Brandveiligheid’, IBB

The safety functions and related systems to be protected against fire, together with relevant scenarios, have been identified and assessed.

The scenarios analysed cover both internal and external hazards, and plant modifications have been implemented consequently.

2.5.7.2 SFS COVRA Lessons learned from inspection and assessment as part of the regulatory oversight

In the year 2013, following the Fukushima accident, COVRA carried out a Stress Test assessment. In relation to fire safety, the following observations were made:

- "*For HABOG neither a seismic PSA nor an explicit 'Seismic Margin Assessment' has been performed in the past. A qualitative evaluation of the seismic margin [...] comes to the conclusion that due to application of several conservatisms in the seismic design of the SSCs of the HABOG facility, the seismic capacity is (qualitatively) estimated to be (much) more than expressed by the DBE. Exceedance of the DBE may result in small damage to SSCs, but will not threaten the fundamental safety functions. It can be concluded that an extreme earthquake does not lead to cliff-edge effects.*"
- "*So far no PSA has been conducted for the HABOG facility. However, a risk evaluation of HABOG is currently under development as input for the new Safety Report. It should be pointed out to what extent the mentioned 'risk evaluation of HABOG' can compensate for it.*"

The most recent 10EVA was conducted from 2009 to 2018, and in it no specific fire protection related issues were observed.

As part of the recent extension of the HABOG, the safety analysis has been updated and developed accordingly, including considerations toward Fire Hazards.

2.5.7.3 SFS COVRA Regulator's conclusions drawn on the adequacy of the licensee's fire safety analyses

The fire prevention, fire detection and firefighting program as described in this chapter is requested in the licence, even though in less detail than shown in Appendix C.

The information requested by WENRA for the development of this chapter is reflected in the requirements detailed in the individual licence of the COVRA. The licence holder is obliged to draw up, maintain and implement a fire prevention, fire detection and firefighting programme, aligned with all the topics developed in this chapter.

The licence holder is currently compliant with the assessment framework.

2.6 Waste storage facilities on site (WSFs)

Dedicated facilities for storage of waste are in general characterized as quite simple installations where no active processes are required to maintain safety. Such installations are generally inherently robust, and safety is provided by means of passive safety functions. For these installations, fire safety is primarily related to protecting the function Containment of radioactive material, meaning the prevention of radioactive releases from waste involved in a fire.

The fire safety analyses for such installations are not required to be unduly sophisticated unless stored waste / waste packages as such are flammable.

2.6.1 WSFs at NPP Borssele, the KCB

2.6.1.1 WSFs at NPP Borssele – Types and scope of the fire safety analyses

It shall be noted that in the KCB, the spent fuel assemblies are stored underwater in the ‘Fuel Pool’ located inside the containment until transport, and not in a separate building. Therefore, spent fuel as a high level radioactive waste is protected against fire through all the means described in Section 2.1 and Section 3.1.

The low level waste of the plant is temporarily stored in a dedicated building (waste storage building). In that building, in rooms separated from the waste storage, some accident management equipment is stored. This equipment can contain a low amount of diesel or petrol fuel. The equipment and containers with fuel are stored in fire proof cabinets. The nuclear waste is stored in special containers in concrete building parts. The only ignition sources are small electric equipment, cranes and lighting. The fire risk is this building is there for very low.

No specific Fire Hazard Analysis is made for the waste storage facilities (low level waste) at the KCB. The fire safety in the waste storage building is based on engineering judgement. The fire load is very low (mainly steel and concrete) and no significant ignition sources are present in that building. The building is equipped with a fire detection system and manually operated firefighting equipment.

2.6.2 WSFs at site of RR HFR

In the HFR the spent fuel assemblies are stored in the ‘Fuel Pool’ located inside the containment until transport, and not in a separate building. Therefore, spent fuel as a high level radioactive waste is protected against fire through all the means described in Section 2.2 and Section 3.2.

The Waste Storage Facility (WSF) is a building in the western dune valley of the NRG site (Building 26) serving as temporary storage for radioactive waste that was produced at various EHC locations. The WSF is equipped with deep, underground ‘plugs’ for the storage of waste canisters containing ‘legacy’ waste. The underground storage is fitted with pipes. Some of these pipes are sealed with a steel or concrete plug; other pipes are covered by steel beams. In addition, shallow repositories or ‘trenches’ have been excavated for the storage of stable waste in various forms. These are covered with concrete slabs.

The plugs, steel beams and concrete slabs together form the floor of WSF.

2.6.2.1 WSFs at RR HFR – Key assumptions and methodologies

A probabilistic fire analysis was performed for the Waste Storage Facility (WSF) at the Energy Health Campus (EHC, formerly known as OLP). The WSF consists of one hall which is split into three rooms that have been analysed as individual fire cells. All the fire cells are used as storage for radioactive materials which are classified as wastes. This analysis was required to be performed as a result of measures due to the Stress test analyses and along with the WSF, other nuclear installations at the EHC were included in this analysis. However, this section specifically focuses on WSF. The objectives of this internal fire analysis are to:

- Identify internal fire scenarios that could lead to a radioactivity release;
- Calculate the contribution of internal fire scenarios to the total frequency of the unacceptable end effects.

2.6.2.2 WSFs at RR HFR – Types and scope of the fire safety analyses

It should be noted that the probabilistic internal fire analysis for the WSF is based on conservative estimations and assumptions. For instance, the calculated final risk, due to a fire accident, is attributed to the consequence of a full radioactivity release from the building. The fire analysis is performed in four tasks which are listed below.

- *Building Walkdowns*: Preparing an inventory of items/equipment which supports fire ignition or fire propagation;
- *Estimation*: Calculating the total Fire Ignition Frequency (FIF, -/year) and the total fire load per square meter (MJ/m2) for each fire cell, based on some estimates/assumptions in the inventory prepared from building walkdowns;
- *Screening and estimation of the Fire Induced Radioactivity Release Frequency (FIRRF)*: To screen the fire cells based on their total fire load per square meter (MJ/m2), and calculation of the total Fire Induced Radioactivity Release Frequency (FIRRF, -/year) for each building;
- *Results and Insights*: Ranking of the FIRRF (-/year) contribution using the NRG risk matrix (an NRG ranking method for risks) and deriving insights from the study.

To perform the analysis, two main guidelines were used:

- EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities (NUREG/CR-6850), and;
- Protection against Internal Fires and Explosions in the Design of Nuclear Power Plants, IAEA guideline NS-G-1.7, Vienna, 2004.

The assumptions considered in this analysis are as follows.

- Fire ignition or fire propagation to the fire cell containing radioactive sources will directly lead to a full radioactive release from the building to the atmosphere. This is applicable when the fire cell containing the radioactive sources, does not have a complete barrier or has a significant amount of fire load which results in a fire duration that is beyond the fire rating of the barrier. For example, a fire cell with fire-rated doors and walls but the windows or glass on the windows have insignificant or no fire rating.
- The weight (in kilogram, kg) of equipment and materials is estimated purely based on the engineering judgement of the analyst performing the walkdowns. These values are assessed conservatively and the true value might be much lower than estimated.
- Due to the uncertainty in determining the type/quantity/length of cables present in the seven buildings, the non-suppression probability for cable fires has not been considered. The fire ignition frequency and fire load calculations for cables were performed based on the analyst's broad estimations/interpretations of the type/quantity/length of cables present in these buildings.
- Concrete and windows are assumed to have a maximum fire rating of 30 minutes; i.e. concrete walls and glass in windows are fire resistant for 30 minutes only. It is assumed that all the fire cells have, at least, concrete as their fire barrier.
- According to the Dutch reference 'Jaarboek Brandbeveiliging 2002', a combustible fire load of 19 MJ/m^2 corresponds to an approximate duration for fire combustion of 1 minute (i.e., 900 MJ/m2 ≡ 47 minutes; 230 MJ/m^2 ≡ 12 minutes).
- It is assumed that the full radioactivity release due to fire from any of these buildings will lead to a possible deterministic effect of greater than 200mSv dose (to the people on the EHC). This assumption is in coherence with the level-5 consequence used in the NRG Risk Matrix.
- The consequence of >200mSv that is assumed is taken based on the discussions for DWT (Decontamination and Waste Treatment unit) and this is used as a bounding consequence for all the buildings considered in the analysis.
- It should be noted that the FIRRF figure does not completely correlate with this consequence. In reality, the FIRRF results mentioned in this report would correlate to a comparatively lesser consequence.

- The manual fire suppression of a fire event by locally available fire extinguishers is not credited in the analysis.
- Local manual detection (detection made by the personnel and not by the automatic system) is credited for the calculation of the FIRRF.
- The chemicals and radioactive samples stored in the 90 minutes fire-rated self-sealing cabinets are not affected during a fire as these rooms are mainly in laboratories and the total fire load for the labs is generally less than needed for a 60-minute fire.
- The fires originating in the seven buildings under analysis are assumed to be mostly electrical and cable fires. This is due to the large number of office spaces, storage areas and the electronic equipment in use in these buildings. Thus, the fire suppression rate is selected from NUREG/CR- 6850 accordingly.

2.6.2.3 WSFs at RR HFR – Main results / dominant events (licensee's experience)

According to the NRG risk matrix, the results of all the buildings are classified in the yellow zone. There are 3 possible scores: low (green), medium (yellow) and high (red). The classification 'yellow' is mainly due to the conservative approach, refer to section 2.2.2 for a list of the assumptions, employed in this study. Hence, the FIRRF results mentioned in this report are conservative and, in reality, correlate to a lesser risk due to the following factors which also contribute to the conservatism of the final results.

- The FIRRF results presented are at least one order of magnitude lesser than the frequency mentioned in column 'A' (<0,01/Year) of the risk matrix (so smaller than 0,001 /year);
- The consequence assumed in the analysis is conservative due to the assumption of a non-mitigated fire event in a fire cell of the building leading to a full radioactivity release from the whole building;
- For the WSF nearly all the radioactive waste is stored in pipes under concrete. Due to the uncertainty in the amount of radioactive materials which are not stored in this manner, it is assumed that there will be a full radioactive release from this building in case of a fire igniting in or propagating to the radioactive storage areas in this building, which is very unlikely.

The FIRRF is calculated based on the total fire ignition frequency of the fire cell (FIF, -/year) and the fire suppression features and their probability of failure.

The following are general recommendations derived from the Probabilistic Internal Fire Analysis performed for the EHC facilities:

- Automatic suppression systems are not present in any of the buildings considered in the analysis. Installing automatic fire suppression systems can reduce the overall risk through the reduction of failure probability of fire mitigation,
- Efficient storage management and periodic disposal of old equipment/materials (paper, plastic, wood, etc.) from the buildings is recommended.
- The fire rating of doors, walls, ceilings and windows should be verified to be at least 60 minutes to contain a fire in these rooms or prevent fire propagation into the rooms,
- The fire detectors and integrity of the fire barriers have to be tested at regular intervals. It is recommended that the detectors are tested at least three times every year in the buildings handling radioactive materials.

In the WSF, there are no flammable or explosive substances present in quantities that could lead to a fire or explosion of such magnitude that the floor of the WSF could be damaged and lose its shielding and heat-resistant effect.

2.6.3 WSFs on site of RR HOR

It shall be considered that the spent fuel assemblies are stored in the 'Fuel Pool' located inside the containment until transport, and not in a separate building. Therefore, spent fuel as a high level radioactive waste is protected against fire through all the means described in Section 2.3.

2.6.4 WSFs on site of FCF Urenco

Radioactive waste management at UNL is based on separating radioactive waste at source and cleaning all potentially contaminated waste streams as much as possible before disposal. This minimizes the radioactive waste stream and allows cleaned materials to be reused or disposed of regularly.

The ReCycling Center (RCC) building contains a special area for storage of nuclear waste which is a separate fire compartment with a Resistance to fire penetration and flash-over of 60 minutes. The RCC will be extended with an area of about 2,996 m^2.

Cleaning uses abrasive blasting and laser technology. In addition, evaporators and dryers are used to reduce the amount of water in the radioactive waste. The fire risk consists of conventional electrical hazards.

Waste can be stored temporarily pending transport. The packaging complies with ADR transport requirements (e.g. packaging free of contamination and sufficiently low dose rate), but some final handling before transport may still take place (e.g. administration/stickering). This storage room is designed as a separate fire compartment.

Cleaning uses abrasive blasting and laser technology. In addition, evaporators and dryers are used to reduce the amount of water in the radioactive waste. The fire risk consists of conventional electrical hazards. This process is part of the Fire Hazard Analysis (FHA) as described in section 2.4.1, 'FCF Urenco Types and scope of the fire safety analysis'.

The fire risk of techniques and resources used is reduced by using adequate work instructions, monitoring temperature and pressure and the fire detection and alarm system with full monitoring.

2.6.5 WSFs at site of FSF COVRA

The WSFs at the COVRA site are excluded from this report. COVRA is a dedicated above ground waste storage facility, therefore this section is not applicable. Refer to chapter 1 of this report for a substantiation for this decision.

2.6.6 WSFs – Regulator's assessment of the fire safety analysis and conclusions on WSFs on sites

2.6.6.1 WSFs Overview of strengths and weaknesses in the fire safety analysis of WSFs

The risks associated with the WSF on site is directly related to the type of waste they may contain. This section is therefore mostly of interest to sites hosting reactors, where high level radioactive material would be present.

However, at the NPP and the two research reactors in The Netherlands, the spent fuel assemblies (highly radioactive) are stored underwater in a pool inside the containment building, connected to the reactor pool. Spent fuel is not stored in WSF facilities on site. Consequently, the protection of spent fuel assemblies in case of fires is included in the Fire Hazards Analyses of the reactors.

Separate FHA for Waste Storage buildings are considered to one extent or the other, depending on the installation, as described in the next section.

2.6.6.2 WSFs Lessons learnt of inspections and assessments on the implementation of the fire safety analysis as part of its regulatory oversight

No specific Fire Hazard Analysis has been made for the waste storage facilities (low level waste) at the NPP KCB. The fire safety in the waste storage building is based on engineering judgement. The fire load is very low (mainly steel and concrete) and no significant ignition sources are present in that building. The building is equipped with a fire detection system and manually operated firefighting equipment.

In the particular case of the HFR, there is a historical waste storage facility which dates from decades before a proper classification of waste was in place. A waste characterisation plan has been developed as a requirement before bringing the waste from this facility to the COVRA facility. The structures of this storage form a concrete bunker and the waste is stored in metal drums, for which the fire load is deemed to be relatively low. A PSA has been developed for this facility, as described in section 2.6.2.

2.6.6.3 WSFs Regulator's conclusions on the adequacy of the fire safety analyses and their implementation

Waste storage facilities containing nuclear and radioactive materials must be analysed in terms of safety, including fire hazards, according to their associated risks. There have been topics of improvement identified and associated implementation actions are ongoing related to these types of WSFs on the reactor sites.

Waste storage facilities on site in general are relatively simple facilities where no active processes are needed to maintain safety. They generally are robust, and safety is provided by passive safety functions. For these installations fire safety is primarily related to prevention of radioactive releases from waste in case of fire, rather than to protect SSCs from the effects of fire. The safety analyses for these facilities do not need to be unduly sophisticated.

The legal requirements for the waste storage facilities on site are included in each individual licence, and are based on a graded approach.

3. Fire Protection Concept and its implementation

Fire protection consists of several operational and design aspects important to reduce the risk of a fire. To prevent fire from starting, it is important that the potential fire load (burnable material) is as low as possible. This is an aspect important for operational work in the plant, but also for the choice of materials to be used in the design. Another aspect is the limitation of ignition sources. To detect the (beginning) of a fire at an early stage, an adequate detection system is needed so that timely manual or automatic actions can be taken. To prevent a fire to spread through compartments is also important.

The following sections describes the approach from each selected licensee in the Netherlands.

3.1 NPP KCB – Borssele

3.1.1 NPP KCB Fire prevention

3.1.1.1 NPP KCB Design consideration and prevention means

The design of the plant is based on the principle that the equipment itself should not cause a fire. Furthermore, to prevent fire from starting, the fire load of equipment in the plant shall be as low as reasonably possible.

This is relevant when implementing updates or modifications to the systems, where updates and upgrades of fire resistant materials, design or regulations are considered. As an example, existing cables, important for nuclear safety and in the vicinity of redundant systems are protected against fire by a fire retardant coating, whereas new cables in the plant shall be FRNC (Fire Retardant Non Corrosive) according the EN 50575: ‘Power, control and communication cables – Cables for general applications in construction works subject to reaction to fire requirements standards’.

One specific design feature of the Borssele NPP is that the spent fuel pool is situated inside the containment. The Borssele plant has no dry storage of fuel elements; all fuel (new and spent fuel) is covered by borated water. That means that all fire protection equipment (detection and extinguishing) in the containment is also available for the spent fuel handling equipment.

Also, rooms with systems/components that are not used to fulfill the safety functions, but in which there is a large fire load (> 1000 MJ/m^2), are included in the fire safety system (NVR NS-G-1.7, par. 3.8-3.19). As the degree of redundancy of the systems decreases, there is a greater need for protecting these systems (functions) from the effects of fire and explosion (NVR NS-G-1.7, par. 2.18).

There are several means to prevent fires from starting. The sections 4.4-4.9 of NVR NS-G-1.7 provide requirements for minimizing application of combustible material in the plant. There should also be as little combustible material as possible stored on site.

For civil constructions, cabinets or equipment/ components , the use of wood is not allowed.

Packing material shall be removed outside the controlled area. This material shall be disposed in special containers outside the buildings of the plant. Additionally, the disposal containers inside the plant are metallic ones since plastic ones are not allowed.

Furthermore, the power station is protected against natural phenomena that can cause fire (e.g. lightning).

3.1.1.2 NPP KCB Overview of arrangements for management and control of fire load and ignition sources

Fire load in the plant buildings shall be as low as reasonable. For bringing in fire load in the plant, a permit of the internal fire brigade is obliged. The fire team handles the request by applying a fire risk analysis. The analysis results in a permit or prohibition on placing an amount of temporally fire load into that location. On this permit is described the kind of the fire load, the place where it will be stored, possible mitigating actions to lower the risk on fire and the ultimate storage time. To control the temporary fire load in the plant, the fire brigade uses a software tool to hold a total overview of the incoming and outgoing fire load. This tool is developed by using the results of the fire hazards analysis report and the fire PSA.

For hot works, (welding, cutting, etc.) a hot work permit is obliged by internal processes. This is controlled by means of the work order system. In case of hot work, measures like the presence of mobile extinguishers and the supervision of a fireman are common practice. The fire brigade of the plant can also prescribe extra measures in case of a high fire risk. The rules for this kind of activities are described in the Technical Specification of the plant. Examples of these measures are: extra manual extinguishing equipment and extra surveillance by the fire brigade.

3.1.2 NPP KCB Active fire protection

3.1.2.1 NPP KCB NPP Fire detection and alarm provisions

3.1.2.1.1 NPP KCB Design approach

The fire detection system of the plant is used for timely warning of fire and/or smoke in the plant and initiating actions like closing fire dampers, closing fire doors, switch off ventilation, starting the heat and smoke removal system in the roof of the turbine building and starting of automatic extinguishing systems (water mist and gaseous).

To assure that the fire will be detected as soon as possible, the detectors are set to the kind of fire to be detected, and designed according the environmental conditions they would withstand (for example, the detection system in the reactor building can resist the radiological environment there observed).

In addition, the fire detectors are divided into different groups per compartment. In this way, a fire in a particular compartment will not affect the detectors in the redundant compartment.

3.1.2.1.2 NPP KCB Types, main characteristics and performance expectation

Approximately 2.000 automatic detectors are present in the plant buildings. The detection system of KCB is certified according to the Dutch standard NEN 2535:2009+C1:2010 to obtain an optimal and adequate detection all over the plant. Most detectors are of the optical/thermal type.

In the reactor building (crane and cooling equipment), annulus building (radioactive solid waste system), turbine building and electric building (marshalling room), smoke aspiration systems have been installed.

In the charcoal filters of the nuclear ventilation system, temperature detectors have been installed. In the turbine building, flame detectors are also present. Furthermore, a great number of manually activated fire alarm switches have been installed all over the plant buildings. When triggered, they (automatic detectors and manual activators) give an alarm in the control room. Based on this alarm, the control room operator will take measures such as directing the fire brigade to the affected room or call for the off-site fire brigade, if deemed necessary. The alarm consists of two levels: an early warning and an actual alarm.

The control system of the detectors and activators consists of eight fire control cabinets, divided over the plant buildings, and a fire control panel. All these systems communicate over a data network. The notifications of fire and detector failures are communicated to the control room and reserve control room. The fire control panel in the control room is connected with the MM8000 system. This system presents relevant information like the room number in which the alarm is actuated, the component code of the detector/activator, short description of the affected room and a floorplan of the concerned room. The detection system is powered by emergency power busses. Moreover, each of the control cabinets have their own battery backup for at least 24 hours. To prevent failure of the detection system by a cable failure, the detectors are connected in a loop configuration. The cables are of a fire retardant type.

The fire control cabinets are connected with in total 36 automatic extinguishing systems (nine *Inergen* gaseous systems, two CO_2 gaseous systems and 25 water mist systems or subsystems).

The fire detection systems are inspected and tested on a yearly basis.

3.1.2.1.3 NPP KCB Alternative / temporary provisions

To prevent spurious actuation of detectors while hot works are being performed, the local detection system can be temporarily turned off. In that case a fire man will survey the place during the hot work activities. Permission for this operation is given by the internal fire brigade, according to the plants Technical Specifications and procedures.

3.1.2.2 NPP KCB Fire suppression provisions

3.1.2.2.1 NPP KCB Design approach

In the design of the suppression systems, account is taken of:

- the size of the fire to be suppressed and
- the sort of fire load (oil, cables, electric equipment, etc.).

Electric and electronic systems have a gaseous suppression system. The used ‘Inergen’ gas consists of a mixture of nitrogen (52 %), argon (40 %) and carbon dioxide (8%). It has the advantages of not causing chemical damage to the protected equipment and its electric conductivity is very low (not causing short circuits). This is important to minimize the effects of spurious operation.

For cable fires and oil fires, water mists, fine water spray or micro drops, are the most suitable suppression method, and the required water is supplied by the low pressure extinguishing system pumps. Fine water sprays are obtained by adding pressurized air to the water in the spray heads. These systems are very effective because they gives a very large water cooling surface. The water is supplied by the low pressure extinguishing system pumps. Another advantage is that not much water is needed for an effective suppression. In case of spurious operation (inadvertent) of a fine water spray system, the equipment in the room will hardly be damaged as a result of the relatively low water consumption.

In the relatively small rooms with the oil systems of the main coolant pumps, CO_2 gaseous extinguishing systems are built in.

For fighting fires in rooms with nuclear safety equipment, automatic extinguishing systems are used. Also in rooms with no safety systems but with a potential for high fire load, automatic extinguishing systems are applied (as described in Chapter 2 Section 2.1). In other places, manual extinguishing equipment is always available. The rooms with an automatic extinguishing system are also equipped with manual extinguishing systems.

For manual firefighting, a low pressure water extinguishing system is available. This system supplies the hydrants outside the buildings and hoses inside the buildings of the plant. For firefighting inside the plant, a high pressure water extinguishing system is also available.

For firefighting of the main (outside) transformers, a water extinguishing system is available, consisting of a water tank which is kept on pressure by pressurized air. The water supply of this system can switch over to the low pressure extinguishing system when the tank is empty.

All over the plant, small portable extinguishing containers (red bottles) are available for fighting small (starting) fires. In most cases these are filled with carbon dioxide.

3.1.2.2.2 NPP KCB Types, main characteristics and performance expectations

Micro drop systems are used in the following systems/rooms:

- Cable channels in the auxiliary building;
- Gasoil storage tank in the emergency diesel building;
- Diesel generator in the emergency diesel building;
- Cable cellars (three) in the electric building;
- Safety injection pumps (two rooms) in the annulus building.

At KCB, fine water spray systems are used for firefighting in the following systems/rooms:

- Oil supply for the high pressure turbine in the turbine building;
- Oil storage in the turbine building;
- Oil channel in the turbine building;
- Gasoil storage tanks (two rooms) in the emergency diesel building;
- Diesel generators (two rooms) in the emergency diesel building;
- Day tanks for gasoil (two rooms) in the emergency diesel building.

The gaseous extinguishing system for the oil cooling systems of the main coolant pumps is a CO_2 system. *Inergen* gaseous extinguishing systems are used in the following system/rooms:

- Conventional marshalling room in the electric building;
- Relays room in the electric building;
- Switch gear room in the auxiliary building;
- Nuclear marshalling room in the auxiliary building;

- Switch gear room in the auxiliary building;
- Reactor protection room in the electric building;
- Computer room in the electric building;
- Switch gear room in the cooling water intake building;
- Switch gear room in the cooling water intake building.

For manual firefighting, a low pressure water extinguishing system is available. This system supplies the hydrants outside the buildings and hoses inside the buildings of the plant. For firefighting inside the plant, a high pressure water extinguishing system is also available.

The low pressure extinguishing system consists of a water tank, two pumps, one electric and one diesel driven pump including a jockey pump. The water is distributed to the buildings (hoses and automatic systems) and hydrants outside the buildings through underground pipelines in a closed loop configuration. For backup, a fire water pond is available for supplying the low pressure system in case the normal water tank is not available.

The high pressure extinguishing system consists of a water tank, two pumps, both electric and powered by emergency power busses plus a jockey pump. The part of the high pressure system in the nuclear area is seismically qualified. The pumps however (built in in the electric building) are not seismically qualified. Therefore, in case of a seismic incident, a fire truck or a mobile pump can supply water into the high pressure system of the reactor building.

The main coolant pumps and the turbine bearings are protected by a manually activated deluge system, supplied by the high pressure system. The reason for manual activation is that in case of spurious operation the damage on the equipment will be very large. The time between a fire alarm, the confirmation time that there is a real fire and the manual activation is short. After visual verification the buttons can be activated by the operators / fire fighters. The reason for this configuration is to ensure the visual confirmation of the fire. In this way spurious operation, resulting in great damage, will be avoided.

In the turbine building, bunkered building and emergency diesel building, foam (1% AFFF) can be added to the high pressure water to improve the effectiveness of the suppression.

In case of fire in a charcoal filter of the nuclear ventilation system, the high pressure system can manually be coupled to the internal extinguishing system of these filters.

The oil cooled main transformers are located outside the turbine building. The firefighting provisions consist of a water extinguishing system, comprising a water tank which is held on pressure by pressurized air, and a number of spray nozzles around the transformers. This system can be passively or actively activated. A pressurized air hose on top of the transformers will melt by heat in case of a fire causing opening of the valve of the extinguishing system. The system can also be actuated by one or more of the detection sprinklers or manually from the control room. The water supply of this system can be switched over (manually) from the tank (when empty) to the low pressure extinguishing system. Alternatively a firetruck with foam equipment is available on site (foam firetruck).

3.1.2.2.3 NPP KCB Management of harmful effects and consequential hazards

Detrimental effects of unintended operation (or failure) of fire-fighting systems are taken into account in different ways. Some examples were mentioned in the previous section. Furthermore, fire suppression systems are designed with redundant options:

- The low pressure fire extinguishing system is equipped with two pumps and two external supply points.

- The high pressure fire extinguishing system is provided with two pumps and three alternative external supply points.
- Automatic extinguishing systems are equipped with manually activated buttons if systems do not start automatically
- Various extinguishing systems can be fed alternatively if the water supply fails.
- EPZ have a single water tank. It is designed in such a way that a minimum amount 1.200 m^3 (fire extinguish water) of the total 2.500 m^3 of industrial water is always available. The water in the tank is protected against freezing but isn't seismic qualified[46].
- As an alternative (secondary) for the water tank, KCB has a firewater pond containing about 1.600 m^3 water.

Assurance of the reliability of the systems is done by carrying out frequently scheduled inspections and tests by operational staff, maintenance teams and the company fire brigade.

Secondary hazards of activation or breakage of fire suppression systems have been considered as well. For example, certain areas can be blocked in the fire extinguishing water network by means of valves. Furthermore, fire extinguishing water from the high pressure extinguishing system cannot accidentally enter the reactor building. The supply is fitted with a remote-controlled shut-off valve that will only be opened in case there is a real fire in the reactor building. This satisfies the design requirement of preventing unintentional change of the criticality of, for example, the fuel storage pool.

In the nuclear buildings and the conventional buildings, drainage systems are built in to drain leaked water from, for instance, the water extinguishing systems to tanks collecting this leakage water. Since all the fuel assemblies, both fresh and irradiated, are stored underwater in the reactor pools in dedicated racks (neutron adsorbing material), the triggering of the fire-fighting systems does not introduce any criticality risk. Moreover, the valves for supplying water to the extinguishing systems at the floor level of the top of the spent fuel pool are situated on a lower floor level (normally closed) and will be opened by the fire brigade in case of a fire.

3.1.2.2.4 NPP KCB Alternative / temporary provisions

The alternative injection points for the extinguishing pumps (high pressure as well as low pressure) is a fire-truck. This can be the internal fire department's own fire-truck, or a fire-truck of one of the external fire brigades. These trucks can be connected to the high pressure system on three places located on the site. Also, two low pressure mobile pumps are available on site for EPZ's internal 'Flex Support Procedures'. These procedures were implemented based on EPZ's lessons learnt from its Complementary Safety Assessment (CSA), conducted in response to the Fukushima Daiichi accident. In the framework of accident management, Flex Support Procedures provide alternative ways to cope with accident consequences. They have not specifically been developed for accidents involving fire.

Two low pressure fire water system injection points are available on site. These injection points can be used when the two main low pressure fire pumps are out of order. With external equipment from the local fire brigade the fire system can be injected for instance with water from mobile trucks or with seawater.

All over the plant, in all the buildings, there are small manual CO_2 and/or foam extinguishers available depending on the fire risk in the direct surroundings of the location. Everybody may use these manual extinguishers in case of fire.

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[46] The seismic risk in the Southwestern area of the Netherlands (KCB area) is very low.

3.1.2.3 NPP KCB Administrative and organisational fire protection issues

Promoting fire safety and awareness of fire risks among EPZ employees, contractors and suppliers is a daily priority. A fire which can occur by a low fire safety attendance can create a disastrous level of damage, affecting the availability of the plant. This awareness is expressed in the desired behaviours, and enhances the understanding and cooperation for the prevention of fire. The daily focus among all employees to prevent fires contributes to a high fire safety level. The basic strategy is the defence-in-depth principle, which is also considered in the Fire Safety Analysis.

Firefighting strategies are consolidated in written procedures under the fire safety process. Within the process there are four sub-areas, each with its own procedures and instructions. The four sub-areas are: Policy and Strategy, Prevention, Preparation and Suppression. For specific firefighting training, EPZ uses an external institute with its own training centre. Firefighters practice for at least 32 hours annually. In addition to the basic exercises, all six normative scenarios in the plant are practiced annually. Of these 32 hours, one day each year is spent in performing firefighting exercises under realistic conditions. Six turnout drills are held each quarter. There is an annual evaluation from which points for improvement are defined, providing input for new topics within the exercise program the following year.

The shift supervisor is responsible for the operation of the plant. Even in the event of a fire, this position has final responsibility for the process. In the event of a fire, the fire team leader is responsible for firefighting at the scene of the incident. The fire team leader consults with the shift supervisor and determines whether a fire is under control and out. Both leaders have access to operators and firefighters. The shift supervisor and fire team leader discuss which priority is most urgent and deploy operators accordingly.

The fire protection concept is subject to a comprehensive inspection program, from both upkeep and surveillance standpoints. EPZ uses the German KTA guideline (KTA 2101.1, 'Brandschutz in Kernkraftwerken') for this purpose, from which also the frequency is taken for carrying out the inspections. For the certified systems, EPZ depends on the frequency determined by the testing authority.

All available fire-fighting equipment is intended for fire incidents on EPZ's site only. These resources are not made available outside the location. This rule stems from the strict allocation decision and the choice that EPZ fire brigade only meets the need for firefighting on its own site and not outside. The government fire brigade is alerted for incidents outside the site.

If incidents develop and the resources for a proper response from EPZ itself fall short, EPZ can call on the government fire brigade (which can be on site within eight and ten minutes). With their resources, the government fire brigade can seamlessly connect to EPZ's firefighting systems. Where this is not possible, adaptor couplings are available to still be able to make the connection.

There are at least two access options to reach the EPZ site for emergency organizations. Several alternative routes are possible on the site itself. Mitigating measures are taken during works affecting these routes, in order to be able to arrive at an incident location at all times with the available and requested equipment. It should also be noticed, that with flooding, due to the periodicity of the tide, accessibility will be hindered at a maximum of six hours. However, when needed, the ministry of defence has the capability to support EPZ even under flooding conditions.

3.1.2.3.1 NPP KCB Overview of firefighting strategies, administrative arrangements and assurance

According to EPZ's licence under the Dutch Nuclear Energy Act ('Kew'-licence), EPZ is obliged to have adequate fire prevention and fire detection systems, and to implement and maintain a firefighting program. This includes the requirement to ensure that an adequately trained, equipped, practiced and therefore skilled firefighting team is permanently available.

EPZ also has to draw up and maintain the firefighting ' attack plan' that involves the provincial governmental fire brigade (Safety Region Zeeland, ‘VRZ’).

EPZ has a strategy document that describes how the KCB meets the requirements of the licence with respect to fire safety. The document lists the requirements with regard to the fire safety for the buildings on the site of the nuclear power plant. With that, the preconditions for controlling the configuration in the field of fire safety and managing the fire safety tasks are defined. In the strategy document, the following aspects related to managing the fire safety are covered:

- Design;
- Surveillance and Maintenance;
- Firefighting organization.

According to the NVR NS-R-1, the starting point for fire safety is to make sure following primary nuclear safety functions are ensured at all times:

- Reactor shutdown;
- Discharge decay heat;
- Preventing the discharge of radioactive substances.

In addition, working with fire and other forms of heat is conducted in a controlled manner. The KCB also works with a fire load management program. This means that the temporary presence of fire load, such as packaging material or lubricants, will be minimized. This is arranged in the KCB work management system (also see section 3.1.1.2 of the present report).

The detection and extinguishing equipment is up to date, as required in sections 2.12-2.15 of NVR NS-G-1.7. Faulty operation does not negatively affect the safety functions. In the design of the extinguishing systems, single failure criterion and maintenance activities are taken into account. In areas where the influence approach has been implemented, in principle automatic detection and extinguishing are applied (NVR NS-G-1.7, sections 3.15, 3.19).

In areas where the containment approach is applied, in principle measures with regard to detection and extinguishing options are not obliged to be taken. However, in case of a large fire load when using the containment approach, measures are taken to extinguish a possible fire as soon as possible (NVR NS-G-1.7, sections 3.8-3.14).

The capacity and response time of extinguishing systems and personnel follow from the results of the Fire Hazard Analyses Report (FHAR). The KCB’s detection system and the infrastructure of the fire water supply system is certified: its design and operation satisfies the NFPA (National Fire Protection Association) standards. The fire extinguishing system will be certified as required in the individual Kew licence. For these systems too, the NFPA standards are adopted.

In rooms where water-mist extinguishing or gas extinguishing systems are installed, smoke displacement is not allowed because this adversely affects the effective operation of those systems.

3.1.2.3.2 NPP KCB Firefighting capabilities, responsibilities, organisation and documentation onsite and offsite

The Kew-licence states that an adequately trained, equipped, and thus a skilled firefighting team must be permanently available for the KCB. The firefighting organization is based on the risks present in the installation and the applicable regulations and complies with the defense-in-depth principle. The organization has tasks in fire prevention (information, control, permits), in the detection and control, and in the limitation of the consequences (manual extinguishing and/or prevention of expansion). When fighting a starting fire, the design provides, depending on the risks, for a first-line control in the form of automatic fire extinguishers. The fire-fighting organization then forms the second-line control using manual extinguishing agents provided in the design and/or external fire extinguishers. If there is no need for an automatic extinguishing system or an automatic extinguishing system fails, the firefighting organization will fight the fire with the available extinguishing equipment.

The KCB is legally obliged to have its own fire brigade on site. Although a fire truck Is not necessary for firefighting in buildings containing relevant safety systems, the fire brigade has a fire truck for fighting fires on site. The fire brigade consists of a commander, pump operator and two firemen. Furthermore, some other personnel of the plant (volunteers) can be brought into action in case of a fire alarm. In case of a fire alarm in the controlled area, the off-site fire brigade of the villages Borssele or Nieuwdorp will turn out for the KCB. In case of fire in other buildings, the KCB commander will decide whether or not to call for the off-site fire brigade. It has been established by procedures that, when the off-site fire brigade has arrived on site, the commander of the off-site brigade is in charge.

At the KCB there is a firefighting team, as required by the NVR NS-G-2.1 (section. 8.1- 8.7), of three levels:

1. EPZ fire brigade, 24/7 on shift, composed of a fire team leader, shift operators, truck driver and guide (five employees per firefighting team per shift, the first attack team), which makes use of on-site extinguishing equipment, e.g. fixed extinguishing systems, hand extinguishers and hydrants (first attack team);
2. EPZ company fire brigade, volunteer group composed of both day shift and continuous shift employees, who have access to additional emergency aid equipment;
3. External fire service assistance from the governmental local fire service, with their own equipment (off-site fire brigade).

The national Safety Region regulations ('Wet Veiligheidsregio's', see Section 1.2), article 31 requires that the firefighting organization is based on 'normative' fire scenarios. Based on these benchmark scenarios, the size and reaction times of the company fire brigade (first attack crew) are established. Fire scenarios and described task analyses are included in the Industry firefighting report. In KCB, there are six normative fire scenarios that determine the minimum or basic size of the firefighting team (the first attack team) and the reaction times, as described below.

The normative scenarios have been tested for credibility. Three criteria have been distinguished in order to determine that an incident scenario is normative. Normative incident scenarios are fire and/or accident events that:

1. Given the nature of an installation or facility, and taking into account the preventive measures installed therein, can be regarded as realistic and typical.
2. Can lead to damage to buildings or persons in the vicinity of the establishment.
3. Preventive or fire suppression measures can be expected to have a clear effect, so that escalation can be prevented.

Point 2 would not actually apply to the Borssele nuclear power plant because in the vicinity of the KCB, there are no buildings or persons not belonging to the plant. However, these are regarded in the context of events that can lead to the loss of a safety function 'containment of radioactive substances'. An incident scenario is normative if all three points apply. If one of the three does not apply, then that scenario is not normative.

Based on the criteria for normative scenarios, a selection of scenarios has been made:

- Fire at the electrical system and/or fire with feeding emergency diesel generator;
- Fire due to oil leakage or electricity from main and/or emergency feed water pumps;
- Fire caused by electricity from the nuclear intercooling system;
- Fire caused by oil leakage or electricity from the core inundation and cooling system;

- Fire due to oil leakage of the lubricating oil from the main coolant pumps;
- Fire caused by electricity in or near cable duct between the bunkered and reactor building.

These six normative incident scenarios are enveloping all other scenarios. In other words, if these normative scenarios are manageable, other scenarios that may occur that do not pose any damage or threat to the population and buildings outside the facility, can also be controlled. These are scenarios that would have adverse consequences for continuity and thus direct economic consequences for business operations, such as process failure due to indirect damage as a result of a fire (smoke, temperature and water damage).

The corresponding task analyses have been worked out for these six normative scenarios, describing the effects and associated deployment strategies of the company fire service. The aspects of effects, organization, team size, training, equipment, resources, turnout times, communication, protective equipment and accessibility must be described. In accordance with the working method, the normative incident scenarios are assessed on the following three aspects: personnel, equipment and time.

- *Staff:* How many educated and trained employees must the company fire brigade minimum consist of to be able to control the credible incident scenarios mentioned?
- *Equipment*: What resources must the company fire brigade have immediately available to be able to carry out the incident response task in order to prevent the incident from escalating?
- *Time factor*: The time factor is related one to one to the fire curve. The strength of a company fire brigade is to be able to act effectively in a very short time in order to control the development of a fire that is progressing exponentially at an early stage. This limits the collateral damage and the effects on the environment (discharge of ionizing substances) of a fire. The time factor is therefore an important determining factor in determining the task analyses to arrive at the normative incident scenarios.

The updated view on (indoor) firefighting has been added to this. Each normative scenario has been tested against the updated view on (indoor) firefighting. The updated view of indoor fire suppression is focused on matching the fire load versus the available churning capacity of the available extinguishing agents.

The six normative scenarios are described below.

3.1.2.3.2.1 Firefighting at the emergency electrical system and / or fire with feeding emergency diesel generator

This concerns the emergency power supply for various components. The system is redundant. Both of these redundancies are installed separately from each other in an earthquake resistant and flood-protected building. Even if one of the redundancies is lost, the overall installation will still be compliant with the safety concept. A possible cause (LOC – loss of containment) for the loss of one of the two redundancies, which eliminates a barrier to a potential radioactive release, is fire due to a gasket leak. As a result, lubricating oil or fuel can leak onto hot parts of an emergency power generator that is in operation. Criterion for approaching the location for incident response in the event of a fire is 3 – 10 kW/m^2, assuming an indoor (in the fire cell) oil pool fire of approximately 10m^2. The facility boundary is not immediately exceeded but the failure of these emergency power generators (loss of the emergency power network II) may lead to an increased threat of radioactive discharge. Domino effect due to fire is not applicable due to the redundant arrangement of both emergency power generators. If both emergency power generators are not available due to any influence whatsoever, a mobile emergency power generator is available (LOD – loss of defense).

For incident control in the event of a fire, it is important that the company fire brigade goes to the scene as quickly as possible and initially uses the available extinguishing agents. The deployment must be aimed at extinguishing and control (cooling environment and nearby installations to prevent further expansion). Incident management is aimed at a rapid response (keeping fire within the fire cell, preventing expansion and extinguishing) using the extinguishing options available in the building. The incident responders have protective clothing, manual gas detection, a thermal imaging camera and the necessary breathing protection equipment.

3.1.2.3.2.2 Fire due to oil leakage or electrical motors from main and/or emergency feed water pumps.

This concerns the main and emergency feed water pumps for supplying secondary water to the steam generators, so that heat can be removed from the primary system via heat exchange. The process is performed redundantly by three main feed water pumps and three emergency feed water pumps. The main and emergency turbine driven pump have a large amount of lubricating oil. There is a fire-resistant separation between the main and emergency feed water pumps. A possible cause (LOC) for the loss of one or more of the pumps, which removes a barrier to possible discharge of radioactivity, is lubricating oil leakage resulting in fire. There are 800 l of lubricating oil, which are circulated around at 160 l/min under pressure of 2,5 bar. Criterion for approaching the location for incident response in the event of a fire is 1 – 3 kW/m^2, assuming a lubricating oil pool fire of approximately 12m^2. An additional point of attention is the electric motors driven by high voltage (6 kV) (ignition source). Domino effect due to fire applies because the three main feed water pumps are next to each other without a mutual fire-resistant separation. Since July 2017 there is a semi-automatic fire deluge system for extinguish a fire with one or more of the main feed water pumps. For incident control in the event of a fire, it is important that the company fire brigade goes to the scene as quickly as possible to confirm an actual fire on the basis of a rapid reconnaissance and activate the deluge system (cooling capacity) installed.

Other available extinguishing agents are small extinguishing agents (foam), high-pressure foam (two units) from the high-pressure fire extinguishing network in the building, low-pressure foam and water in the building. Incident management is aimed at a rapid response (fire development of hydrocarbons) using the extinguishing options available in the building. A possible back-up for extinguishing agents can be built up with the aid of a fire service vehicle that comes to assist later. The first attack team has additional mobile fire extinguishers and equipment available. The building is included in the attack plan and has an accessibility map. The incident responders have protective clothing, manual gas detection, a thermal imaging camera and the necessary breathing protection equipment.

3.1.2.3.2.3 Fire caused by electricity from the nuclear intercooling system

Concerns the engines of the nuclear intercooling system which provides cooling for the nuclear auxiliary systems. The process is performed redundantly by distributing four pumps over two lines. The pumps are electrically driven. The four pumps are situated in one compartment but redundantly separated from each other by means of fire partitions and fire-resistant coating on the supply cables. One possible cause (LOC) for the loss of one or more of the pumps, which removes a barrier to a possible discharge, is a short circuit with an arc flash or an overload that could ignite a supply cable. The pumps and electric motors do not contain any lubricants or flammable materials. The only source of fire is the electrical cables.

Criterion for approaching the location for incident response in the event of a fire is 1 kW/m^2, assuming a plastic fire (cables). An additional point of attention is the electric motors driven by high voltage (6 kV). The facility boundary is not immediately exceeded due to an assumed scenario (fire), but the failure of these motors to drive the intercooling system may lead to an increased threat of a radioactive discharge (failure of a barrier). Domino effect due to fire applies because the four intercooling pumps are next to each other and are only separated by a fire-resistant bulkhead and are not separated from each other by means of a separate compartment. If all intercooling pumps become unavailable due to fire, the intercooling system can be cooled via well pumps (VE).

For incident control in the event of a fire, it is important that the company fire brigade goes to the scene as quickly as possible and initially uses the existing extinguishing agents (high-pressure extinguishing water and K10 CO_2 extinguisher). The deployment must be aimed at extinguishing and control (cooling environment / nearby installations to prevent further expansion).

Available extinguishing agents are small extinguishing agents (CO_2), high pressure (one unit) from the high pressure fire extinguishing network in the building. Incident management is aimed at a rapid response (fire development, cable fire) using the extinguishing options available in the building. The building is included in the plan of approach to fire and has an accessibility map. The incident responders have protective clothing, manual gas detection, a thermal imaging camera and the necessary breathing protection equipment.

3.1.2.3.2.4 Fire caused by oil leakage or electricity from the core inundation and cooling system.

Concerns core inundation and support cooling pumps for dissipating heat by injecting water. The process is performed redundantly by four high pressure core inundation and support cooling pumps distributed over two lines / redundancies. All pumps are electrically driven and have an amount of lubricating oil due to the high pressure pump.

The pumps are individually equipped with a fire resistant separation, in pairs. The space they are in is separated by a fire resistant partition. In the compartment, each pump is equipped with a permanently installed automatic sprinkler system. A possible cause (LOC) for the loss of one or more of the pumps, which removes a barrier to possible discharge, is lubricating oil leakage resulting in fire. As a result, lubricating oil can leak onto hot parts of an operating TJ pump or be released in highly atomized form. The pumps are on standby during normal operation and are not running. Lubricating oil quantity provides a criterion for approaching the location for incident response in the event of a fire of 1 – 3 kW/m^2, assuming a lubricating oil mist or pool fire of approximately 5 m^2.

An additional point of attention is the electric motors driven by high voltage (6 kV). The facility boundary is not immediately exceeded due to an assumed scenario (fire), but failure of these pumps may lead to an increased threat of radioactive discharge (failure of a barrier). Domino effect due to fire only applies within a compartment because two pumps are next to each other. However, they are all equipped with automatic extinguishing. The pumps come into operation at a LOCA, which releases contaminated primary water. This must be taken into account when fighting a possible fire. If all feed water pumps become unavailable due to fire, the primary system can be fed by the TW system or, if there is sufficient pressure drop, by the low pressure core inundation and support cooling pumps (LOD). The latter are incidentally located in an adjacent fire compartment next to the high pressure TJ pumps.

Incident management is aimed at a rapid response (fire development) using the extinguishing options available in the building. The building is included in the plan of approach of fire and has an accessibility map. The incident responders have protective clothing, manual gas detection, a thermal image camera and the necessary respiratory protection equipment.

3.1.2.3.2.5 Fire due to oil leakage of the lubricating oil from the main coolant pumps

Concerns the main coolant pumps which, as one of the important systems, are directly part of the primary system. The primary system includes two main coolant pumps, both located in one compartment. Domino effect between the two pumps is not or hardly possible. One possible cause (LOC) for the loss of one of the two redundancies, which removes a barrier to a possible discharge, is fire due to a leak from a seal in the lubricating oil system of the pumps. This can cause lubricating oil to leak onto hot parts of the primary system, vaporize and the oil vapor to catch fire.

Criterion for approaching the location for incident response in the event of a fire is 3 kW/m^2, assuming an oil pool fire of approximately 12 m^2 and process ambient temperatures. The facility boundary is not immediately exceeded due to an assumed scenario (fire), but failure of these pump(s) means there is an increased threat of a primary leak resulting in a possible radioactive discharge.

A sprinkler system that can be activated manually is provided for incident control in the event of a fire at one of the two main coolant pumps. Because this extinguishing has to be activated manually, it is important that the company fire brigade goes to the scene as quickly as possible. The extinguishing does not have to be activated by the fire brigade, but can also be activated by engineers at two locations. Both pumps have camera surveillance. The effort must be aimed at initially activating the extinguishing by means of a fire extinguisher. Sprinkler, after which the company fire brigade checks the effect of the extinguishing. To enter the room, the reactor must be switched off because of the otherwise high neutron radiation.

Available extinguishing agents are the sprinkler installation, small extinguishing agents (CO_2) and one high pressure fire hose reel with water and a Fire Express mobile unit. Incident management is aimed at a rapid response (fire development). A possible back-up for extinguishing agents is provided by supplying additional mobile extinguishing agents (foam). The building is included in the attack plan and has an accessibility map. The incident responders have protective clothing, manual gas detection, a thermal imaging camera and the necessary respiratory protection equipment.

3.1.2.3.2.6 Fire caused by electricity in or near cable duct between the bunkered and reactor building

Concerns the electrical cables that are fed from one building to the other. These cables partly supply the systems with voltage and function as control cables of safety-relevant systems. Before these cables leave one building, they are spatially separated from each other. After the implementation they come together, so that an influence approach can occur if one of these cables were to overheat due to overload and catch fire. During normal operation, most of these cables are not live. Because the chance of these cables igniting is very small and because they are of the difficult-to-combustible type, the chance of a fire starting with smoke damage and nuclear safety relevant consequences will be very small.

A possible cause (LOC) for the loss of the power and control cables, which removes a barrier to a possible discharge, is a short circuit with an arc flash or an overload that could cause a supply cable to catch fire. The combustible materials are limited to the hardly combustible cables, which give rise to smoke in the event of a fire. The cables are of the flame retardant type. Despite these preventive circumstances, it is and remains necessary to intervene when a fire starts.

Criterion for approaching the location for incident response in the event of a fire is 1 kW/m^2, assuming a plastic fire (cables). An additional point of attention is the possibility of available electricity. As a result of the failure of these cables due to fire, from two hours after the start of a fire, a barrier for the drive and control of safety systems can be lost. Domino effect due to fire applies because the cables are not redundantly separated from each other.

An automatic extinguishing system to quickly extinguish a possible incipient fire was provided, but due to the outcome of the review (chance of occurrence, effects and function retention in the event of a fire) this modification plan is cancelled. In the event of a fire, fighting an incipient fire by means of manual deployment by the first company fire service suppression team is considered sufficient. For the purpose of incident control in the event of a fire, this must be aimed at extinguishing and control (cooling of the environment / nearby installations to prevent further expansion).

Available extinguishing agents are small extinguishing agents (CO_2), high pressure (one unit) from the high pressure fire extinguishing network in the building. The building is included in the plan of approach of fire and has an accessibility map. The incident responders have protective clothing, manual gas detection, a thermal imaging camera and the necessary breathing protection equipment.

3.1.2.3.3 NPP KCB Specific provisions, e.g. loss of access

The NPP Borssele’s Technical Specifications specify the requirements that the operational occupancy must comply with in connection with fire-fighting capabilities. The responsibility for firefighting has been coordinated with the off-site fire brigade and is procedurally established. In the event of a starting fire, the shift supervisor is ultimately responsible, while the fire brigade commander is in command of the deployment of the fire brigade (first attack suppression team and volunteer group). After the arrival of the governmental fire brigade, the commander / Officer of the local fire services (OvD-B[47]) of this fire brigade officially takes over the responsibility for the fire-fighting from the shift supervisor.

In the event that the main gate to the Borssele site is blocked, a second gate at the other side of the site is available for the off-site fire brigade and other emergency assistance personnel and equipment.

3.1.3 NPP KCB Passive fire protection

3.1.3.1 NPP KCB Prevention of fire spreading (barriers)

3.1.3.1.1 NPP KCB Design approach

The nuclear safety aspects must be guaranteed and protected against the effects of fire, with observance of the 'single-failure' criterion. To meet this requirement, the redundant divisions of the systems are physically separated from each other to prevent mutual influence from fire effects. Preferably, the redundant divisions are in their own fire compartment (minimum requirement: F60) (containment approach) but at least in fire cells (influence approach).

The Dutch Safety Rule NVR NS-G-1.7 identifies two configurations for use in the fire protection analyses of redundant safety systems equipment that is identified as part of a safety function, Containment approach and Influence approach, as described in the Glossary:

- Containment approach: A fire compartment of the KCB has a fire resistance of at least 60 minutes (F60) which is complies with the rules of the Buildings Decree ('Bouwbesluit'). In practice (as built) the resistance is higher. Fire doors have a real resistance of at least 90 minutes. The same for fire dampers in ventilation systems.
- Influence approach: A fire cell has a lower fire resistance than F60. In this case, extra fire measures are required ((automatic) extinguishing equipment, detection, etc.). A fire cell can consist of a wall or door etc. with a lower resistance than 60 minutes, of a greater distance between the redundancies, of cable coating or of special screens.

3.1.3.1.2 NPP KCB Description of fire compartments and/or cells design and key features

The fire doors between the compartments of the emergency diesel generators in the building where they are located have a resistance of 180 minutes.

Redundant fire extinguishing and detection systems and supporting equipment such as ventilation, drainage and smoke extraction are mutually independent.

Redundant cables in the same compartment (influence approach) that are at a distance of 1.5 m or less, are separated from each other by means of a fire-resistant coating. Cable penetrations through walls are of the type Bratberg.

Over the lifetime of the KCB, several improvements are made for the compartmentation. During the large outage of 1997, a great number of modifications were made (extra fire dampers, screens between redundancies, extra fire doors and renewal of existing fire doors, fire retardant coating on cables, etc). In the years after the outage of 1997 more fire dampers were placed or replaced.

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[47] Dutch: 'Officier van Dienst – Brandweer', OvD-B

3.1.3.1.3 NPP KCB Performance assurance through lifetime

The condition of the fire barrier walls, fire doors and cable and pipes fire resistant penetrations of all fire compartments are annually visually inspected by an external, independent supplier specialized in fire prevention. Fire doors of fire compartments and cells can be visually identified by a mark in their corners (red triangle).

A point of interest in case of plant modifications is the passive fire protection. In the checklist added to the plant modification procedure, there is special notice for the fire resistance when extra fire load is added as result of the modification (outcome from the ANVS/GRS inspection in 2017).

3.1.3.2 NPP KCB Ventilation systems

3.1.3.2.1 NPP KCB Ventilation system design: segregation and isolation provisions

In the ventilation systems (nuclear as well as conventional) the segregation/isolation between fire compartments is made by automatic operating fire dampers (controlled by an automatic fire detecting system) with a fire resistance of at least 60 minutes. This is to prevent spreading of smoke from the affected room to another room / compartment through the ventilation ducts. The dampers are built in in the ventilation ducts directly on the compartmentation walls. In situations where this configuration is not possible the ventilation ducts are cladded with fire resistant material between the fire damper and the wall.

In case of a fire in stair cases, smoke can be removed by the ventilation systems to prevent enough visual sight for members of the fire brigade to reach the affected room.

In the roof of the turbine building a heat and smoke removal system is installed. This system consists of 12 ventilation hatches. These hatches are actuated by the fire detection system. Furthermore, each hatch can be opened by a thermal activated device (temperature is 72 °C). The purpose of this ventilation system is to protect the roof construction against collapsing by heath and to guarantee access for the members of the fire brigade to reach the fire.

3.1.3.2.2 NPP KCB Performance and management requirements under fire conditions

Fire dampers in the ventilation systems are tested every year. In case of fire in a charcoal filter of the nuclear ventilation system the high pressure extinguishing system can be manually coupled to the filter for extinguishing the fire.

3.1.4 NPP KCB Licensee's experience of the implementation of the fire protection concept

3.1.4.1 Overview of strengths and weaknesses by Licensee EPZ

With respect to Fire prevention, a strength for limiting the fire load in the plant is the use of the internal procedure for bringing fire loads into the plant with the involvement of the internal fire brigade, as described above. A fire permit is required in case of work with a certain fire risk to be executed.

A great number of control rounds by various departments of the plant (Fire brigade, control room operators and engineers of the technical department, management and staff) is aimed at contributing to fire prevention.

A potential weakness can be a lack of discipline to carry out these rounds by the operating personnel.

With respect to Active Fire protection, it is worth to mention that the fire safety department and its organization have been recently (2021) fully updated. The fire safety department is now an integral part of the fire safety process which have been implemented into the management system of EPZ. The results of these updates are improvements of the organization, management and responsibility structures. The strength of this upgrade-project is that fire safety has become an more important subject in relation to the nuclear safety. The organization and responsibilities have been updated and are now more clear and easier to understand.

Investments will have to be made in order to maintain the current standards and, where necessary, to improve them further. For example, all non-qualified fire resistant doors (F60) are currently being replaced and some fire dampers will have to be replaced in the near future. For improving the 'Inergen' extinguishing performance in the marshalling room of the electric building, the cable penetrations in the floor will be repaired.

In relation to the Kew-licence conditions, EPZ is obliged to have the fire detection installation and the permanently installed automatic fire extinguishing installations certified. When the fire detection system was replaced in the period 2014 – 2016, the new installation was certified by the independent KIWA / R2B inspection organization in accordance with the KIWA CCV regulations.

EPZ is still in the process of getting its permanently installed automatic fire extinguishing installations certified. These systems employ water, inert gas and water fog. Because of the earlier design from the 1970s and 1980s, for several automatic extinguishing systems it is difficult to demonstrate that these earlier designs comply with the current design requirements and regulations. Nevertheless, EPZ expects that before 2026, the permanent automatic fire extinguishing installations will have been certified. If certification turns out not to be possible (for practical reasons) this shall be described in a report.

3.1.4.2 Lessons learned from events, reviews, fire safety related missions, et cetera

In the past years, fire prevention lessons have been learned from reviews and fire related missions. Examples are:

- Replacing plastic waste containers by metallic ones (source: ANVS/GRS inspection);
- Replacing wooden panels by Trespa (non-combustible) panels (source: inspection insurance company);
- The fire load procedures mentioned in paragraph 3.1.1.2 (source: WANO peer review).

The fire safety organization of EPZ has recently (2022) become a member of the WANO Fire Protection & Safety industrial working group (FP-IWG). In May 2022 a delegation of the EPZ fire safety team participated in the first international meeting on Fire Safety of this group. The FP IWG is a newly formed international group, approved by CNO's from across the world at the Virtual Global CNO Forum held in June 2021.

From time to time fire safety specialists and fire safety colleagues are sent out on WANO / OSART missions around the world (peer review and MSM). Participation in these international missions provides a broad view on fire safety and it forms a platform for building up experience and exchange of information about fire safety.

Also, the international fire event reports, the internal reports, experiences and low level events are analyzed and the lessons learned are included within the company's firefighting organization to improve where necessary. Participating and organizing exchange programs and benchmarks is also very instructive to broaden knowledge and thereby improve the level of fire safety.

An important result of the WANO mission of 2014 was the improvement of the quality management system of the equipment of the fire brigade. This has resulted in better instructions and procedures for maintenance and surveillance of this equipment.

As result of several inspections conducted by the 'Veiligheidsregio', the communication equipment of the fire brigade has been renewed to improve the communication in the plant, especially in the controlled area. Also, inspections by the regional Veiligheidsregio Zeeland (VRZ) and the ANVS in most cases resulted in some recommendations related to the operation of the onsite fire brigade, currently being implemented.

Additionally, significant reviews on fire safety are those of the insurance companies (EMANI and the Nuclear Insurance Pool). Insurance companies inspects to reduce the risk related to the coverage of the insurance, with an impact on the related costs. Inspections are based in plant walk walkdowns. The inspectors of the insurance companies made a number of suggestions that helped the KCB in improving the fire safety. The main already implemented modifications related to this are:

- Heat and smoke removal system in the roof of the turbine building;
- Semi-automatic sprinkler systems for the turbine bearings;
- Semi-automatic sprinkler systems for the main feed water pumps;
- Extinguishing systems for the charcoal filters in the nuclear ventilation system.

Most of these modifications were carried out as part of the 10-yearly evaluations. On the scale of 1-100 of EMANI (European Mutual Association for Nuclear Insurance), the KCB is scored on level 93.3 (the average of 75 other plants insured by EMANI is 74.1).

3.1.4.3 Overview of actions and implementation status

Regarding Fire Prevention, it was noted that the hydrogen seal oil pumps can unintendedly be supplied by gravity with oil from the lube oil tank in case the turbine is not running. That will cause a high fire load in the area with hydrogen. This should be prevented in situations when the turbine is not running, and a modification program is currently ongoing. A hardware solution (automatic valve) and a procedural solution are being considered.

Additionally, regarding active Fire Protection measures, the most important actions and projects which are planned, are in progress or have already been implemented, are:

- Certification of all permanently automatic fire extinguishing installations (in progress);
- Renewing fire resistant doors (2022 – 2024);
- Renewing fire dampers in the electric building (2024);
- Renewing high pressure (40 bar) fire water pumps (2023);
- Improvement of the water mist systems (in progress);
- Preventing oil to flow to the hydrogen seals of the turbine system when the turbine is not running (in progress);
- Study on effectiveness of an Inergen extinguishing system for the exciter (in progress);
- Improvement by placing of additional nozzles around the conservators of the yard transformers (in progress);
- Renewing alternative high pressure fire water injection points (ready 2022);
- 10EVA23 (ten yearly safety evaluation / safety factor SF7) (in progress);
- Renewing personally protected clothing of all the fire brigade members (2022);
- Renewing PFAS containing foaming agent (2023);
- Renewing foam fire truck (progress 2023 – 2025).

3.1.5 *NPP KCB Regulator's assessment of the fire protection concept and conclusions*

3.1.5.1 Overviews of strengths and weaknesses in the fire protection concept

One of the strengths of the Fire protection concept and its implementation is the fact that the installation is subjected to several inspections by national and international organisations.

On the national level inspections are performed by among others, the ANVS and the regional Safety Region (VR) fire brigade and the insurance company (EMANI). On the international level, this is done through e.g. IAEA, WANO.

The Safety Region Zeeland designated the licensee as needing to have an internal company fire brigade. The KCB internal fire brigade has an active role in Fire Protection. They report on internal audits performed, walkdowns and analyses performed, trainings, and checks performed on portable extinguishers. Safety Region Zeeland and KCB carry out trainings and simulations yearly for normative scenarios.

There are regular meetings to discuss the status of Fire Safety with the Safety Region. The ANVS is regularly invited to participate in these inspection rounds.

The internal procedures for maintenance, temporary works or special activities include a fire check by the internal fire brigade through a work permit system, and the company fire brigade performs checks on the workplace prior and during the work. The company internal fire brigade is involved in reviewing modifications that might impact fire safety.

The KCB has developed procedures for the maintenance and improvement of all related fire protection aspects, covering from design modifications, to organization, and the certification of systems. All these measures are substantiated by the results of the Fire Safety Analyses.

Systems, structures and components are updated or upgraded to comply with current regulations, where possible. The licensee has a certified fire detection system, based on the Dutch standard NEN 2535:2009+C1:2010, and required by the licence. The maintenance of these systems is based on NEN standards and certified as well. The licensee is in the process of certifying the fixed extinguishing systems, based on NEN and required by licence. Another example is the use of FRNC cables where convenient.

However, given the operational lifetime of the KCB, one of the weaknesses is that not all the systems can be easily modified to accommodate the findings from the Fire Safety Analysis, inspections, lessons learned or the newest standards. To remedy this, a systematic approach is taken to ensure a sufficient level of protection.

3.1.5.2 Lessons learnt from inspection and assessment on the implementation of the fire protection concept as part of its regulatory oversight

Every 10 years, a comprehensive evaluation of the status of the installation and the Safety Analyses is performed (PSR/ 10EVA). Many modifications have been initiated and implemented in different fire protection aspects.

In 2011, a Post Fukushima stress test analysis[48] was done by the nuclear inspectorate of those days, the KFD, one of the entities that was later merged into the current ANVS. The following was observed related to fire-safety:

- "*In the report it is noted that the fire-fighting systems in buildings 01, 02 and 35 are not designed for operability after a DBE. This is listed as a weakness and therefore as a possible modification. [...]. To enhance the protection against internal fire these systems should be qualified for the DBE.*"

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[48] vi-2011-125-post-fukushima-stresstest-nuclear-power-plant-in-the-netherlands-tcm334-326358.pdf

- "*The quality of the water of the fire-fighting pond of the CCB 1.600 m*^{3} *is poor. It is doubtful whether it can be used as cooling water. The risk of blocking the equipment of the fire-fighting is unknown. KFD recommends further investigation of the actual usefulness of this cooling water*." This particular comment does not impact directly the firefighting capabilities, but the use of water as a coolant in emergencies.
- "*No specific attention is given to internal fire cause by electric powered equipment. In general, these kind of fires will lead to specific threats because of the nature of these fire. Effects as fire in cable ducts, short-circuits and availability of instrumentation should be taken into account*."

In the years after the stress test, these actions have been attended to and have been completed.

In 2017, the ANVS conducted an inspection on Fire safety and Fire Protection concepts, together with the German TSO GRS, where several topics were observed. A follow-up inspection was carried out in 2019 and in 2023. Some of the observations and their current status are:

- One general observation was that EPZ as licensee of the Borssele NPP was very well prepared for the Fire Safety Audit conducted commonly by ANVS and GRS. The audit with the plant walk-through and the detailed discussions were very informative. A variety of documents had been provided in advance; more documents needed were available during the audit. Furthermore, the Borssele NPP staff members involved in fire safety are highly knowledgeable, open minded and competent.
- The plant management showed high interest in the Fire Safety Audit and joined the summarising discussion at the end of every day.
- One general observation was that the fire load minimization principle was in general followed by EPZ, however could be further improved. In several plant areas temporary (transient) fire loads were observed, either openly available or in non-qualified enclosures (e.g. closets). Partly, these fire loads were present because of some work was ongoing in the corresponding area; however, wrapping material for transport should be directly removed. Several actions were taken by EPZ to reduce the fire load, from awareness campaigns to removal of temporary fire loads.
- It is suggested to use non-combustible (trash) containers instead of a plastic ones in order to protect (enclose) the fire load inside them and to reduce the fire load of the container itself. The plastic containers were consequently replaced by steel containers.
- The replacement/renewal of fire doors in some areas. This is an ongoing activity.
- Consider the HEAF (High Energy Arcing Fault) scenario, in particular for electrical rooms with medium or high voltage electrical cabinets. Any HEAF event may create extreme temperatures and a blast probably opening the fire door representing the weakest element of the fire barrier as boundary between the two fire compartments for the two redundant safety trains. This activity is ongoing.

An IAEA OSART[49] mission was organized in January – February 2023, thus at the time of writing of this report. Some findings are:

- Leadership for safety: Fire doors were not always closed by plant personnel, as required.
- Qualification and training of personnel: the plant self-identified that currently the fire detection alarms were not simulated in the control room simulator.
- Organization and functions: "[…] *appointed actions from [internal] system health reports identified in 2018 for fire suppression system were still open* [in 2023] […]"

Additionally, the ANVS participates in the OECD – NEA Fire Safety database activities and introduces this experience in the inspection activities at the Borssele NPP.

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[49] https://english.autoriteitnvs.nl/documents/report/2023/07/03/iaea-report-osart-review-borssele-nuclear-power-plant-2023

3.1.6 NPP KCB Regulator's Conclusions on the adequacy of the fire protection concept and its implementation

The licence contains several explicit requirements related to the Fire Safety Analysis and Fire protection concept similar to the example shown in Appendix C. The information requested by WENRA for the development of this chapter is reflected in the requirements detailed in the individual licence of the KCB. The licence holder is obliged to draw up, maintain and implement a fire prevention, fire detection and fire-fighting programme, aligned with all the topics developed in this chapter.

In the year 2016, a revision of the operating permit was issued to EPZ, based on the outcome of the (post Fukushima) Stress test (2011-2012) and the previous 10-yearly evaluation (2012-2013).

Based on the information developed in the previous section, together with the information presented in the corresponding section in Chapter 2, EPZ has proven compliance to the assessment framework.

The licensee has shown a continuous commitment to the improvement of safety related aspects, including fire related topics.

3.2 RR HFR Fire Protection Concept and implementation

The HFR reactor is located on the Energy and Health Campus (EHC) in Petten, formally also known as the research location Petten, in Dutch 'Onderzoekslocatie Petten' or OLP. A description of the facilities located on the Petten site is given in Chapter 1. Apart from the nuclear facilities operated by NRG, there are radiological facilities operated by pharmaceutical company Curium, non-nuclear research facilities of various organisations as well as office buildings. The buildings have usage permits in accordance with the applicable regulations.

3.2.1 RR HFR Fire prevention

Various safety and environmental assessments have been carried out for the (fire) safe use of rooms and the large testing facilities. For places where there is a risk of explosion due to the release of flammable gases or vapors, safety documents have been drawn up within the framework of the European ATEX (Atmosphères Explosibles) directive. In addition, a number of preventive measures have been taken, which are described in more detail in the sections below.

3.2.1.1 RR HFR Design consideration and prevention means

The HFR was designed in the 1950s, according to the then existing standards. Since then, its design has been repeatedly and systematically evaluated against the newest regulations. A main point for the HFR and all buildings on the EHC is that they currently comply with the Building decree of 2012, and that the requirements of the current building code and building regulations are met as much as reasonably possible.

The fire prevention policy at the HFR, or any other building/facility on the EHC, is based on minimizing the use of combustible materials and minimizing sources of ignition. For example, outside the use of natural gas for heating, the supply of flammable gases is not permitted, unless under special conditions, in consultation with the internal fire brigade. The regulations also apply to the use of flammable liquids, unless other conditions have been laid down in consultation with the Quick Response Team, QRT.

The design of the buildings and systems takes into account the fire load of materials.

To minimize the amount of flammable material in the HFR reactor building, the HFR storage building for non-radioactive and non-contaminated materials and goods is located on the west side of the reactor complex.

This building provides storage space for e.g. the historical archive, which is essential for the operation of the HFR, but forms too great a fire load to house it in the reactor building or the reactor outbuilding (RBG, 'ReactorBijGebouw', i.e. auxiliary building).

3.2.1.2 RR HFR Overview of arrangements for management and control of fire load and ignition sources

The EHC is situated in a dune area. To reduce the chance of fires in the dunes due to human activity, smoking is prohibited both inside and outside the buildings, with the exception of a number of designated smoking areas, each equipped with the necessary fire extinguishers.

Open flames are prohibited in the HFR and on all NRG facilities. An exception applies to workshops and laboratories under the following conditions:

- The use of fire must be related to regular operations within that space;
- Work with open fire must be included in the risk inventory and evaluation of the room / department;
- Preventive measures must have been taken so that these activities can be considered low/normal risk;
- An escalation scenario for these activities must be included in the local emergency procedure of the building / department;
- The presence of burners et cetera must be included in the attack plan of NRG's Quick Response Team (QRT) on site.

For non-regular work that requires working with open flames (such as maintenance work), a work permit and task risk analysis must be prepared, according to the applicable implementation regulation. High-risk work is understood to mean in any case:

- work with a fire and / or explosion hazard;
- work on detection equipment or fire extinguishing equipment;
- work in which detection equipment or fire extinguishing equipment is temporarily taken out of service.

After and outside office hours, the QRT carries out fire safety rounds in the EHC. During these rounds, fire alarm systems are checked for malfunctions or disconnected groups. In addition, all areas in which transport movements may take place are checked for (fire) unsafe situations.

A Reactor Shift Crew (Dutch: 'ReactorBedrijfsWacht', RBW) is present on the reactor site of HFR on continuous duty. The RBW is primarily responsible for fire prevention measures in the reactor, and provides a daily inspection, which includes fire safety checks. The reactor site is therefore not part of the QRT's daily fire safety round.

The fire alarm and fire detection system must be managed, monitored and maintained in accordance with Dutch norm NEN 2654.

3.2.2 *RR HFR Active fire protection*

3.2.2.1 RR HFR Fire detection and alarm provisions

The fire detection system of the HFR is used for timely warning of fire and/or smoke in the plant and initiating actions. Within NRG's facilities, the HFR and all buildings or building sections are equipped with automatic fire and smoke detection systems which are connected to a fire alarm system (Dutch: BMI, 'Brandmeldinstallatie').

Fire alarms are reported immediately, without delay, to the Company Alarm Center (Dutch: 'BedrijfsAlarmCentrale', BAC). Fault reports are also reported and followed up by the QRT for first-line fault response. The role of the BAC and its interaction with other parts of NRG’s firefighting organization is described in section ‘Overview of firefighting strategies, administrative arrangements and assurance’, section 3.2.2.3.1.

3.2.2.1.1 RR HFR Design approach

Within NRG’s facilities, the HFR and all buildings or building sections are equipped with automatic fire and smoke detection systems (Siemens Advanced Signal Analysis, ASA), which are connected to a fire alarm system (BMI). Where necessary, these are fitted with an auxiliary panel.

The HFR is equipped with both automatic and manual alarms that signal to the central company’s alarm station (BAC). In case one of the fire detectors or alarms is activated, the signals will be relayed to the reactor control room, the security lodge and the QRT. Every employee is allowed and able to initiate a fire alarm.

To prevent a fire from spreading quickly, a number of doors in the reactor auxiliary building will automatically close when a signal is triggered; even though they can still be used. Also, manual actions are taken aimed at controlled shut down of the reactor if necessary, additionally from automated actions.

The fire detectors are fed by an emergency power supply. Evacuation alarms are being activated manually.

On the HFR site, full fire surveillance is used in accordance with NEN 2535. With full surveillance, in addition to the necessary manual call points, all rooms are equipped with automatic detectors.

The cabling (from the alarms) is installed where necessary to maintain its function for at least 30 minutes in case of fire complying with NEN NPR 2576 (Circuit integrity under fire conditions – Guideline for transmission paths).

3.2.2.1.2 RR HFR Types, main characteristics and performance expectation

Full monitoring is applied to buildings where, among other things, fissile and radioactive materials are handled; in this case, fire detection systems are present in all rooms. Partial monitoring is applied to the remaining buildings, with the exception of some individual units of outside firms and buildings such as the gas reducing station and the clean water cellar.

Gas detection systems have been installed in areas where hazardous gases are handled. The gas detection systems are managed by NRG’s facility management department and are inspected and maintained once a year through a maintenance contract by certified experts. These inspections are also recorded in logbooks.

When activated, the gas detection systems within the HFR and NRG’s other facilities produce a signal to the BAC. Other locations on the EHC also have detection systems, in part, with only local signaling to users.

Since almost all buildings are equipped with fire alarm systems, the design, the quality requirements and project guidelines from NEN 2535 (Fire safety of buildings – Fire detection installations – System and quality requirements and guidelines for detector siting) are taken into account.

Management and maintenance take place in accordance with NEN 2654 (Management, control and maintenance of fire safety systems) and are recorded in logbooks. The QRT performs the management of these maintenance activities which are carried out by a BBMI (‘Beheerder Brandmeldinstallatie’) certified employee. Maintenance of the installations is carried out by external experts, according to the CCV inspection schedule.

The notifications and malfunctions are recorded and reported internally. Both the notifications and the reports are available for inspection by the VR-NHN and the competent authority.

In the event of a fire alarm, the QRT is present in any location on site within six minutes.

3.2.2.1.3 RR HFR Alternative / temporary provisions

To prevent spurious actuation of detectors in case of hot work to be performed, the local detection system can be turned off during the time that the work is performed. In that case alternative actions are taken. In most cases a fire man will survey the place where the hot work is performed.

Permission for this operation procedure is given by the internal fire brigade (QRT), according to the plant's Technical Specifications.

3.2.2.2 RR HFR NPP Fire suppression provisions

The EHC site is equipped with its own firefighting water supply. Throughout the EHC, above-ground fire hydrants on a potable water supply system with a capacity of 2,000 litres per minute have been installed as a primary supply.

The fire hydrants are inspected and monitored annually for operation by NRG's facility management department. The QRT inspects the hydrants for accessibility and operability. The hydrants are kept accessible in regular site maintenance at the EHC.

3.2.2.2.1 RR HFR Design approach

In the HFR, a fixed manually operated firefighting system is available; no automatic firefighting system is used. The fixed firefighting system is limited to the installation of fire hoses and plugs that are supplied by a low and high pressure system. The original location of fire reels was determined by the branching of the fire water supply system within the HFR. Subsequently, adjustments were made over the years in consultation with the company fire brigade to ensure that reels are available at all relevant locations.

All buildings are equipped with portable fire extinguishers tailored to the fire classes relevant to the building. These extinguishers can be used to fight small (starting) fires. In most cases these are filled with CO_2.

Modifications in the installation are conducted following a standardized procedure. As part of this procedure, a Hazard Identification (HAZID) analysis is performed in which, among others, fire hazards are analyzed and addressed if necessary.

3.2.2.2.2 RR HFR Types, main characteristics and performance expectations

The HFR and its buildings feature in total several types of fire suppression provisions, such as portable fire extinguishers (at least one per workplace) and fire extinguishing systems including hydrants (outside) and hoses (inside buildings).

For manual firefighting in the HFR, a fixed low pressure water extinguishing system is available. This system supplies the hydrants outside the buildings and hoses inside the buildings of the plant. A high pressure water extinguishing system is available as well.

Both systems are fed from a water storage facility in a separate building on the EHC site. Water is pumped from this facility to the HFR. In case no power is available to run the pumps (and no mobile pump is available to take over the function of the installed pumps), water can be transported via a downpipe by gravity from the water storage facility located in a separate building at a short distance to the HFR. In this storage facility, a fixed amount of water is reserved for emergency core cooling, the remaining part is used for daily consumption and firefighting purposes if necessary. Since this storage is in a separate building, it does not introduce a risk of spurious flooding.

The fire extinguishing systems are not designed to withstand an earthquake.

Once a year, maintenance is carried out on the portable fire extinguishers following NEN 2559 by the QRT employees, certified in accordance with the Regulations for Recognition of Maintenance of Extinguishers

(REOB). All fire reels are also subject to this inspection. The fire hydrants are kept accessible during the regular site maintenance of the EHC. A REOB manual has been drawn up for the procedure.

3.2.2.2.3 RR HFR Management of harmful effects and consequential hazards

Inadvertent operation and system reliability

Since there is no automatic firefighting system in the HFR, there are no problems with spurious or inadvertent operation. In addition, manual CO2 and powder extinguishers are present in the building suitable for suppression of the potential fire loads (fuel, oil and electric equipment).

The use of the hydrants is automatically monitored by means of the building management system. If a predetermined quantity of water is used, NRG's technical service will receive a notification.

3.2.2.2.4 RR HFR Alternative/temporary provisions

The alternative injection sources for the extinguishing pumps (high pressure as well as low pressure) is a fire truck. This can be a QRT fire truck or a fire truck of one of the external fire brigades. These trucks can be connected to the high pressure system at three places located on the site.

Also, two low pressure mobile pumps are available on site for the Severe Accident Management Guidelines (SAMGs) implemented after the Fukushima disaster. These procedures allows the QRT to supply an extra water supply. Two low pressure fire water system injection points are available on site. These injection points can be used when the two main low pressure fire pumps are out of order. With external equipment from the local fire brigade the fire system can be injected for instance with water from mobile trucks or with seawater.

All over the plant in all the buildings there are small manual CO_2 and/or foam extinguishers available depending on the fire risk in the direct surroundings of the location. Everybody may use these manual extinguishers in case of fire. Fire hazards are also considered in the Hazard Identification study (HAZID) that takes place during the design of experiments and production facilities.

In case of maintenance works, if for example a hydrant is temporarily switched off, a bypass is created. The QRT has the necessary spare fire hoses for this purpose.

In addition, there are two secondary water extraction sites, in the form of fire ponds that are considered 'open water' supplies. These are used when a lot of water is needed; in the event of a fire or, in exceptional cases, when it is decided to replenish the cooling water of the reactor using these ponds. Ponds are primarily intended as a fire extinguishing water supply; the QRT possibly in cooperation with the Regional Fire Brigade (of the VR-NHN) can then extract water from it by means of pumps with available resources.

The Regional fire brigade (VR-NHN) also has resources to fetch water from the North Holland Canal, for example; transporting over that somewhat larger distance is called Large Water Transport.

The procedures described above are rehearsed on a regular basis.

3.2.2.3 RR HFR Administrative and organisational fire protection issues

Within the HFR, a substantial part of the personnel are trained members of Corporate Assistance (BHV, 'BedrijfsHulpVerlening') or 'BHV+' in which case personnel are also trained to use breathing air equipment. In addition, the so-called 'nuclear professional' training that all NRG staff receive, contributes to safety awareness within NRG.

The operators perform a daily general fire safety round and perform inspections every 6 months, the main aim of which is to check the presence and condition of the extinguishing equipment and safety equipment. The walking routes associated with the oversight of the fire alarm systems are drawn up by and checked on the initiative of the QRT.

Via the emergency number, preprogrammed on each landline telephone, direct connection is obtained with the BAC. In each room there are signs, on which the emergency number is mentioned and on which is indicated (in Dutch and where necessary English) how to act in case of certain emergencies.

The BAC has direct lines to NRG's QRT and can always remotely alert the shift on duty. Alerting and scaling up is done according to the specified procedures[50], identifying roles and responsibilities, the way of escalation and the conditions for escalation . The BAC will, depending on the nature of the report and the method of alerting, forward the alert to the regional Safety Region, the VR-NHN. Both the BAC and QRT have access to so-called 'C2000'[51] communications equipment. This enables communication with the government emergency services.

Every two years, a request is made to the Fire Department of the VR-NHN to express an opinion on the quality of fire prevention, fire detection and firefighting. Within three months, following an external inspection, a summary report is provided for internal and external accountability.

3.2.2.3.1 Overview of firefighting strategies, administrative arrangements and assurance

NRG's firefighting organization consists of the Emergency Response Team (BNO) , the company alarm center (BAC) and the Quick Response Team (QRT). Via the aforementioned entities, NRG can when needed, request support from various external emergency response services that resort under the local Safety Region 'Veiligheidsregio Noord-Holland-Noord, the VR-NHN. During the first phase of an incident, the response is initiated by the BNO and the QRT. Different incidents require different approaches, therefore external emergency services can be alerted by NRG in various ways:

- Request ambulance by oral request via the BAC;
- The QRT team leader may decide to scale up in consultation with the fire brigade of the Safety Region, VR-NHN. The QRT team leader then is in direct contact with the Joint Control Room (GMK, 'Gemeenschappelijke Meldkamer') of the VR-NHN;
- In incidents where severity has reached a certain level, NRG calls in its emergency coordinator, who then takes the lead. This person is called in Dutch the CaCoN ('Calamiteiten Coördinator NRG'). If alerted the CaCoN may decide to alert the VR-NHN. This is done via the BAC, which connects the CaCoN to the GMK. The GMK will put the CaCoN in contact with the leader of a local emergency response team of the VR-NHN, the so-called CoPI/OL ('Coördinatieteam Plaats Incident / Operationeel Leider'). Leader CoPI/OL ultimately decides whether or not to scale up;
- The Plant Security Manager (PSM) can decide to alert the police for security reasons. If he does, he will inform the CaCoN about this.

The various entities of a Safety Region act according to a certain procedure, the Coordinated Regional Incident Response procedure, Dutch acronym 'GRIP' ('Gecoördineerde Regionale Incidentbestrijdingsprocedure').The GRIP describes how the management of incident and effect control is in the hands of the Safety Region, by means of entities like a CoPI, ROT (Regional Operational Team), GBT (Municipal Policy Team, Dutch: 'Gemeentelijk Beleidsteam') and/or a RBT (Regional policy team, Dutch: 'Regionaal Beleids Team').

The BNO and its operation is described in NRG's company emergency plan, which is included in NRG's integrated management system. The BNO includes the experts and the company emergency responders. Together with the BAC and company security, these experts have a supporting role in responding to an

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[50] There's also an 'Alarm role' which is a flow chart document that describes the alerting process; who, how and when to alert.

[51] C2000 is a digital communication system for emergency services. It is used by the police, fire brigade, ambulance services, the Ministry of Defence and various partner organisations.

emergency.

The QRT consists of a unit of 5 people with a tanker truck with automatic pumping system and is on standby 24/7 for emergency response. The QRT must be able to be at any NRG facility on site within 6 minutes. The range of tasks of the QRT includes not only acting as a firefighting team as mentioned in the Kew permit, but it has also other response tasks in case of fire, nuclear emergencies and other incidents.

For the entire EHC site, the QRT provides basic firefighting services on behalf of the Safety Region VR-NHN. For this purpose, a cooperation agreement has been concluded with the Safety Region and Service Level Agreements (SLAs) have been concluded with the other companies on the EHC in Petten.

Upon receipt of a report, the BAC alarms the QRT and/or other services or officers according to the alarm roles established for each type of incident. Once the QRT has arrived, the QRT team leader takes over operational control of an incident. The building's local emergency plan (LNP) and attack plan contain any specifics or additional instructions regarding this handover.

From the moment of handover, the local emergency organization (BHV, administrator, radiation experts, etc.) operates at the service of the QRT. The QRT team leader may request a meeting of the BNO level 3 and 4 [52] if (the development of) the incident warrants it.

If an incident develops such that the capacity of the QRT proves inadequate, the QRT will scale up. A list of scaling-up criteria has been drawn up for this purpose. In the event of an actual fire, the safety region will always be alerted immediately.

If scaling up occurs, the QRT will act as a unit under the operational chain of command of the governmental fire department, and its officer on duty. To ensure effective and safe operational deployment during emergencies, the QRT is involved in operational preparedness activities.

3.2.2.3.2 RR HFR Firefighting capabilities, responsibilities, organisation and documentation onsite and offsite

Emergency Preparedness & Response (EPR) is a responsibility of the QHSE (Quality, Health, Safety and Environment) staff group within NRG. EPR has two focus areas namely NRG's Company Emergency Response Organization (BNO) and the Quick Response Team (QRT). Under the Dutch Working Conditions Act (see Section 1.2), every company in the Netherlands has to have a so-called BHV organisation, which consists a number of employees who can provide expert assistance at the workplace with small and larger incidents. At NRG, the BHV organization is fully embedded in the BNO. Plant expertise is also insured in the BNO.

The Manager EPR is responsible for daily managing of the teams (no incident situation). The Coordinator of Training, Education and Exercise is responsible for the coordination of keeping the EPR Organization competent.

There are four QRT team leaders and the QRT employees work on a roster so that a Quick Response Team is present 24/7 consisting of 5 people, namely a QRT team leader and 4 QRT employees.

The QRT has a tanker truck at its disposal with automatic pumping system. As a result, the QRT is capable of performing virtually all basic firefighting tasks. The QRT is not only competent and equipped to fight fires, but also has the knowledge, skills and equipment to deal with accidents in and around (nuclear) facilities. In addition, the QRT can be deployed for emergency assistance in the broad sense and accidents involving hazardous substances, as part of NRG's operational company emergency organization. The NRG QRT is thus maximally capable of acting both as a basic firefighting emergency unit but can operate effectively and at a

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[52] Four levels are defined; level 1: performing operational tasks, level 2: providing leadership over individual relief teams, level 3: providing coordination of multiple relief teams, level 4: crisis management.

high level of quality through additional education and training combined with specific equipment to suppress nuclear and radiation incidents. The QRT personnel know the locations, processes and risks and regularly work with the local emergency organization in both incident and normal (non- incident) situations.

The responsibility for firefighting by QRT has been coordinated with the off-site fire brigade of the VR-NHN and is subject to established procedures. In the event of a starting fire, the shift supervisor is ultimately responsible, while the Team leader QRT is in command of the deployment of the fire brigade.

After the arrival of the fire brigade of the VR-NHN, the commander / Officer of the local fire services (OVD-B, ‘Officier Van Dienst – Brandweer’) of this fire brigade officially takes over the responsibility for the firefighting from the shift supervisor.

Personnel of the QRT are trained in accordance with the Personnel Safety Regions Decree and all hold the diplomas required therein. In addition, personnel hold other diplomas necessary for their positions or additional roles. For example, QRT team leaders hold the diploma TMS-VRS-D (formerly known as radiation protection expertise level 5).

NRG has a company-wide Professional Competence Policy Plan. As derivative of this plan, for QRT-tasks there is a dedicated plan in order to make sure staff has all the required knowledge and experience to perform its tasks. This includes an annual exercise plan.

The QRT staff exercises on the basis of a pre-established exercise plan which is based on industry guidelines and guidance documents, such as the exercise guideline of the Dutch Institute for Safety (‘Instituut Fysieke Veiligheid’). The exercise program is geared to the risks and possible scenarios on the EHC site. Education and training activities also follow from the findings of the compulsory Risk Inventory & Evaluations, RI&E, that have to be conducted for all activities within Dutch companies. RI&Es are there to guarantee healthy and safe working conditions. Company-specific exercises form an important part of the total exercise package.

The exercises include evacuation, topical deployment and emergency response in a facility as well as table-top exercises related to policy aspects. In addition, QRT members also perform cold EPR tasks in the areas of Fire Prevention and Fire Detection.

The implementation of the exercise program is recorded individually in the professional competence management system. The exercises are also evaluated and the results are used as input for a follow-up exercise or for adjusting plans and procedures. Relevant internal officials (radiation experts), the BHV and services at the EHC are involved in the exercises.

All the QRT’s activities – operational preparation, the skills program, incident response and additional services – are recorded in the integrated management system. On the basis of this registration, periodic reports on performance are made. This involves both internal QHSE and NRG reports and reports to the other companies on the EHC on the activities according to the Service Level Agreements.

Emergency procedures and guidelines for the BHV are described in the Site Emergency Plan (LNP, ‘Locatie NoodPlan’). The LNP is to be followed immediately in the event of disruptions and incidents at the locations (building, installation, object, facility) concerned. This action is aimed at securing the business processes, carrying out the emergency response tasks and initiating management and control actions and thus possibly preventing escalation and limiting the effects on the environment.

Regarding the cooperation with VR-NHN and other chain partners, efforts are made to maximize effective cooperation and preventive coordination. To this end, joint exercises are organized annually and there is structural consultation and coordination between the various parties.

Cooperation in the area of professional skills takes place with neighboring fire stations. This is geared to knowledge exchange about the EHC and the associated relevant risks and scenarios (e.g. those involving radiation protection aspects). It also aids cooperation with officers and teams within the scaling-up structure of the Safety Region, the VR-NHN.

Once every four years the regional disaster response plan is revised and exercises are also organized in the framework of that plan.

Implementation of the fire prevention and detection program is assured through NRG's certified integrated management system. The QRT's local management system is a part of that overarching system. This also ensures that improvements are carried out, guaranteed by certification according to ISO 9001.

All activities of the QRT are evaluated to close the Plan Do Check Act (PDCA) cycle and achieve continuous improvement. These evaluations take place at the executive level in the form of after-action reviews after deployments and post-exercise reviews. In addition, program evaluations take place periodically at the EPR policy level. Where relevant, the performance and evaluations of the QRT are also part of the periodic reports to the Authority for Nuclear Safety and Radiation Protection, the ANVS.

3.2.2.3.3 RR HFR Specific provisions, e.g. loss of access

In case the main gate to the EHC is blocked, a second gate at the north side (entrance JRC) of the site is available for the off-site fire brigade and other emergency assistance personnel and equipment.

Routes to HFR and other facilities like WSF on the EHC

To ensure that the Quick Response Team and other emergency services (e.g. ambulance) can provide assistance as quickly as possible, it is the task of the emergency response team to provide guidance: leading the emergency services from the gate of the facility to the incident location. The BAC will inform the shift supervisor of the arrival of the Quick Response Team (QRT) and other emergency responders. The emergency response team leader ensures that the emergency services are met. He provides guidance in the offices, the shift supervisor provides guidance in the installation.

3.2.3 RR HFR Passive fire protection

3.2.3.1 RR HFR Prevention of fire spreading (barriers)

3.2.3.1.1 RR HFR Design approach

The general design approach for HFR and WSF regarding fire prevention is based on minimizing the amount of flammable material at locations important in connection with nuclear safety. Secondly, the use of fire compartment or cells to localize effects of starting fires is applied. These are described in the next section. In the original design of the HFR, fire compartments were not defined as such. In later fire safety studies, these were defined as in the glossary.

3.2.3.1.2 RR HFR Description of fire compartments and/or cells design and key features

The HFR and its supporting systems are contained in several buildings, each of which is divided into separate rooms, or fire cells. The specific features per building are described below.

HFR reactor building (RB)

The reactor building (RB) consists of five fire compartments, which are:

- the reactor hall, which is considered to consist of seven fire cells:
    - the ground floor;
    - four platforms;

    - the steel walkway (basement);
    - the remainder of the basement.
- the basement, consisting of two fire cells:
    - the steel walkway;
    - the remainder of the basement.
- the sub-pile room;
- the pipe corridor;
- the off-gas filter station.

From the control room of the HFR, the operators have a view of the reactor through a window. This window is made of fire resistant glass to prevent fire spread from the reactor hall to the control room.

To prevent a fire from spreading quickly, a number of doors in the reactor auxiliary building will automatically close when an alarm signal is triggered; even though they can still be used.

Reactor outbuilding (RBG)

The reactor outbuilding (RBG, 'ReactorBijGebouw') consists of two fire compartments:

- Compartment A; defined as the RBG basement and all rooms above this part of the basement on the ground floor;
- Compartment B; defined as the remainder of the RBG - which contains offices and workshops.

Fire compartment A and fire compartment B are separated from each other by a thick wall and fire doors with a 60-minute fire resistance. The possibility of a fire spread from fire cells within fire compartment B to fire compartment A has been investigated. Other than that, as fire compartment B does not contain safe shutdown equipment nor equipment which failure could cause a plant trip (plant trip initiators), fire compartment B is not further analyzed. Fire cells within the RBG are defined in accordance with the RBG floor plans.

Primary pump building (PPG)

The primary pump building (PPG, Primair PompGebouw) consists of five fire compartments:

- The four transformer rooms in the PPG form four separate fire compartments;
- The remainder of the PPG forms one fire compartment.

The PPG contains concrete cells in which the primary pumps, decay heat removal pumps, heat exchangers, basin and primary cleaning systems and basin pumps are installed; thick concrete doors close the entrances to each cell. However, as primary and secondary piping and cabling runs from the basement of the PPG through holes in the cell floors, these cells cannot be considered to be individual fire compartments.

Fire cells within the PPG are defined in accordance with the PPG floor plan.

Secondary pump building (SPG)

The secondary pump building (SPG, Secundair PompGebouw) consists of three fire compartments:

- The two high-voltage transformer/distribution rooms in the SPG form two separate fire compartments;
- The remainder of the SPG forms one fire compartment.

Fire cells within the SPG are defined in accordance with the SPG floor plan

Ventilation building (LBG)

The ventilation building (LBG, LuchtBehandelingsGebouw) forms one fire compartment. Fire cells within the LBG are defined in accordance with the LBG floor plan.

Emergency Diesel Building (EDB)

In the Emergency Diesel Building (EDB, also called 'noodstroomcentrale'), a fire resistant separation exists between various areas for the generators. The cable transits and the cabling between these areas are fire-retardant. The aim is to guarantee the power supply for the HFR for as long as possible in the event of a fire in one room, via the unaffected generator(s).

All rooms and buildings on the HFR site that do not belong to any of the above buildings, are combined into one group of 'other buildings'. By definition, the other buildings:

- do not contain any equipment related to reactor safety;
- do not share a common boundary with buildings that do contain such equipment.

3.2.3.1.3 RR HFR Performance assurance through lifetime

Ensuring fire resistance and stability of barriers

The HFR periodically assesses the fire resistance and stability values of the fire cells and compartments and, if necessary, calls in external expertise. In these assessments, the Building Decree is taken as a starting point. The types of periodic review and the actions taken based on the outcomes are further described in section 3.2.4.3.

3.2.3.2 RR HFR Ventilation systems

3.2.3.2.1 RR HFR Ventilation system design: segregation and isolation provisions

In the ventilation systems (nuclear as well as conventional), the segregation/isolation between fire compartments is made by fire dampers with a fire resistance of at least 60 minutes. These dampers are built in the ventilation ducts directly on the compartmentation walls. In situations where this configuration is not possible, the ventilation ducts are cladded with fire resistant material between the fire damper and the wall.

The ventilation installation of the reactor auxiliary buildings, predominantly for the office spaces, has a supply fan, with discharge occurring via several fans on the roof. A separate supply fan is installed for the server room, the portal monitor room and adjacent rooms, with discharge via separate fan units.

In case smoke is moving into the direction of the HFR control room, the smoke will be detected in the inlet and the control room ventilation system will switch to recirculation mode (with an emergency filter installation).

3.2.3.2.2 RR HFR Performance and management requirements under fire conditions

Fire dampers in the ventilation systems are tested every year. In case of fire in a charcoal filter of the nuclear ventilation system the high pressure extinguishing system can be manually coupled to the filter for extinguishing the fire.

The supply fans are shut down in case of a fire by an interface contact with the fire emergency system. In case of an assumed fire, the relevant valves of the ventilation system for separation of the buildings may be closed manually according to the controlled shut down procedure.

3.2.4 RR HFR Licensee's experience of the implementation of the fire protection concept

3.2.4.1 Overview of strengths and weaknesses

Strengths

All activities of the QRT, both operational preparation, the professional skills program, incident response and additional services are registered in the integrated management system. Based on this registration, periodic reports are made on the performance delivered. This involves both internal QHSE and NRG reports and reports to other companies on the activities according to the SLAs.

All activities of the QRT are evaluated to close the PDCA cycle and achieve continuous improvement.

These evaluations take place at the executive level in the form of after action reviews after deployments and post exercise reviews. In addition, program evaluations take place periodically at the EPR policy level. Where relevant, the performance and evaluations of the QRT are also part of the periodic reports to the ANVS.

Once a year, a fire inspection tour is conducted for each building by a QRT employee with additional fire prevention training or a trained Secondary Safety Technician. This involves assessing the presence of fire extinguishers, emergency exits, fire hazards, free passage of internal routes for the fire services, escape routes, etc. Specifically, the storage of chemicals is also considered. Reports are made of these inspections. By means of re-inspections, the settlement of the identified points for improvement is monitored.

In addition, the shift crew periodically checks the presence and placement of fire extinguishers and checks the emergency exits for the HFR. The reports are submitted to the relevant plant managers. A copy is also submitted to the QHSE department and NRG's emergency organization and fire safety policy officer.

Weaknesses

The location of the available fire-fighting equipment is currently not described in the LNP (Site Emergency Plan). Instead, this is included in other, unreferenced documents. It is foreseen to include a reference to these documents in the LNP, so that it is clear where the fire-fighting equipment is located.

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

Stress test following Fukushima

Following the accident at the Fukushima Dai-ichi Nuclear Power Plant (NPP) in 2011, a Complementary Safety Margin Assessment (CSA) or 'stress test' has been conducted for the HFR. As part of this assessment, fire hazards have been evaluated and measures which can be envisaged to increase robustness of the nuclear facilities on the EHC were drafted:

- The effects of an explosion/fire originating from the natural gas pressure reducing station located on the EHC have been analysed probabilistically (S19);
- The fire analysis of the HFR has been updated (S20).
- A communication protocol from the regional fire brigades to the EHC in case of fire or other external hazards has been established (P15).

Based on the findings of the stress test, the Emergency Response Organization (BNO) was founded in 2016 and a cooperation agreement and the exercise program with the Safety region VR NHN was drafted.

Training and competence program

NRG has a cooperative agreement with VR NHN for the coverage of the basic fire service on the EHC. Under this agreement, the QRT provides training in the field of radiation hygiene to the surrounding stations outside the EHC.

In addition, exercises are held with the region within the Competence program. These exercises are also organized within the installations. Thus, the entire deployment is practiced by all involved. An example of an exercise series is the series of exercises organized within the HFR in October 2022 in which the various (external) emergency services practice. The ANVS was also present at one of these exercise moments. All deployments are evaluated by the QRT and VR NHN and secured in the organization according to the PDCA cycle.

3.2.4.3 Overview of actions and implementation status

From 10-year evaluations, various improvement with regard to fire safety have been implemented, such as:

- Installation of automatic fire detection in the HFR reactor building and various other buildings;
- Application of a fire proof sealant to all penetrations through the HFR control room floor from the cellars, to prevent smoke transport and fire propagation to the control room(s) in case of a fire in one of the cellars;
- Replacement of non-fire retardant signal cables to the reactor protection (interlock) system by fire retardant ones;
- installation of a fire door between the two cooling water pumps;
- Separation of decay heat removal pumps by a fireproof door (type F60, NEN 6069);
- Implementation of a procedure to scram the reactor immediately after an automatic fire alarm in one of the cellars of the reactor outbuilding or in case of fire in the PPG.

In addition to these 10 year evaluations, the QRT audits fire safety of the HFR and WSF every year in which it produces a list of suggested improvements. Typical subjects of investigation are usability of escape routes, condition and accessibility of fire extinguishers, fire hazard situations, etc.

Actions and projects which are planned, in progress or ready to be implemented are:

- Replacement vehicle QRT (2023 procurement);
- External Audit EPR (included QRT) (2023);
- Intensification exercise program HFR – QRT (2023) ;
- Intensification BNO exercises HFR – BNO level 3 (2023);
- Implementation replacement fire alarm systems EHC wide NRG (2023);
- Preparing/Cooperation Fire Safety/Firefighting Pallas;
- SLA Pallas implementation (Jan 1, 2023);
- Update of the LNP (as described in section 3.2.4.1.

3.2.5 *RR HFR Regulator's assessment of the fire protection concept and conclusions*

3.2.5.1 Overview of the strengths and weaknesses in the fire protection concept

One of the strengths of the Fire protection concept and its implementations is the fact that the installation is subjected to several inspections by national and international organisations.

On the national level this is done through e.g. the ANVS and the regional Safety Region's (VR) fire brigade.

The HFR organises regular meetings to discuss the status of Fire Safety together with the Safety Region. There are joint exercises organized periodically, to which the ANVS is invited to participate.

On the international level, this is done through e.g. the nuclear insurance pool company, and periodic international missions like IAEA – INSARR.

The strengths of the fire protection concept are:

- The safety of the HFR in case of fire is not dependent on a the presence of a fire-fighting squad, but nonetheless one is present 24/7.
- This firefighting squad (BNO) plays an active role in fire protection and is involved and reports on several related activities, such as internal audits, safety walkdowns, training given and checks performed on portable extinguishers.
- There are many walk downs that pay attention to fire safety.
- The licensee has a work permit system which pays attention to fire safety. The firefighting squad performs checks on the work place prior and during the work.
- The firefighting squad is involved in reviewing modifications that might impact fire safety.
- The licensee has a certified fire detection system, based on NEN norms and required by the licence. The licensee has contracted a certified company to perform maintenance on fire detection systems, based on NEN and required by licence.

One weaknesses of the fire protection concept is that the reactor is not fully divided into fire compartments as a fire protection strategy. However, with the use of fire cells, an adequate level of protection is achieved.

3.2.5.2 Lessons learned from inspection and assessment on the implementation of the fire protection concept as part of its regulatory oversight

Following the accident at the Fukushima Daiichi Nuclear Power Plant (NPP) in 2011, a Complementary Safety Margin Assessment (CSA) or ‘stress test’ has been conducted for the HFR, with the findings as explained previously in the licensee section.

In the year 2016, with a follow-up in 2019, an IAEA INSARR mission was carried out. The following recommendations were given; and they were solved and closed by the follow-up in 2019:

- Procedures should be established for the operator’s response to the anticipated operational occurrences and incident situation. The procedures should cover all the anticipated operational occurrences and incidents postulated by the design, including the loss of off-site power supply, fire inside the reactor building, and external events. The procedures should be simple, clear and include step-by-step instructions aimed at achieving the basic safety functions in all conditions.
- In the area of Emergency Planning a suggestion was provided: “*It is suggested to proceed with the implementation of the revised emergency plan as soon as possible, including the conduct of emergency drills involving the participation of internal and external emergency teams.*”

Every 10 years, a comprehensive evaluation of the status of the installation and the Safety Analyses is performed (10EVA). Many modifications have been initiated and implemented in different fire protection aspects, as explained previously in the licensee section. The last 10 EVA was finished in the year 2021, with the following remark:

- It was observed that the documentation related to the Site Emergency Plan need to be updated to show where the firefighting equipment is located.

3.2.6 RR HFR Regulator's Conclusions on the adequacy of the fire protection concept and its implementation

The licence contains several explicit requirements related to the Fire Safety Analysis and Fire protection concept similar to the example shown in Appendix C. The fire prevention, fire detection and firefighting program is requested in the licence, and must be updated at least once every five years and submitted to the ANVS for consideration. Changes to the fire prevention, fire detection and firefighting program must be submitted to the regulator for assessment at least six weeks in advance.

The information requested by WENRA for the development of this chapter Is reflected in the requirements detailed in the individual licence of the HFR, following the example in Appendix C. The licence holder is obliged to draw up, maintain and implement a fire prevention, fire detection and firefighting programme, aligned with all the topics developed in this chapter.

Based on the information developed in the previous section, together with the information presented in the corresponding section in Chapter 2, HFR has proven compliance to the assessment framework.

The licensee has shown a continuous commitment to the improvement of safety related aspects, including fire related topics.

3.3 RR HOR Fire Protection Concept and implementation

3.3.1 RR HOR Fire prevention

3.3.1.1 RR HOR Design consideration and prevention means

Fire safety is covered in the design of the reactor building by choice of materials[53], layout, compartmentalization and zoning of spaces according to their use, and passive forms of protection such as insulation, separation, fire barriers and application of fire retardants.

In addition legal guidelines and standards apply, that have stricter requirements for some aspects of fire protection than described in the Building Decree. These requirements must always be met. Some examples of this are the PGS15 guideline ''Storage of hazardous substance'' and the ATEX 153 guideline 'Explosion safety'.

For minimizing the risk of an internal fire inside the containment, combustible inventory is kept at a minimum. Inventory check is part of daily inspections and is also included in maintenance planning, and all areas inside and outside the reactor building are equipped with fire detection systems.

As an example, since the containment wall represents a fire barrier, aluminium pallets are used instead of wooden pallets, for works inside it.

With respect to safety relevant instrumentation, cable connections of redundant machinery are run through the building as much as possible via partitioned floor plans. Moreover, spatial partitioning is employed as much as possible.

At various places where more concentrated cable bundles over a longer pathway is unavoidable – for example, vertically from the basement level to the control room level – compartmentalization by means of fire barriers is applied to suppress stack effects through cable ducts. In the cable closet of the control room, specialized fire alarm devices have been installed.

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[53] One of the applicable standards is Dutch industrial norm NEN 6069 'Testing and classification of fire resistance of materials'. There are various standards for fire prevention, prescribed in the Building Decree.

Another example is the Hydrogen gas, which is stored outside, with a 60-minute fire-resistant separation between the building and the storage. The distance to the opposite building part is more than 10 meters. Degassing always takes place before cylinders are connected to prevent explosive mixtures.

3.3.1.2 RR HOR Overview of arrangements for management and control of fire load and ignition sources

Within the HOR and connected buildings, several inspection rounds for fire safety are performed. These inspection rounds take place on a daily basis for basic aspects like amount of combustible materials, ignition sources, blockage of extinguishing systems etc. Once a month, a more detailed inspection takes place (functioning of alarms, fire doors etc).

These activities are coupled to employees and incorporated in service contracts, and are not specifically incorporated in procedures within the HOR management system because the Delft Campus Real Estate (CRE) is responsible for these contracts, the activities to be performed and the related requirements to these activities.

For specific activities within the HOR, like works with open fire, a work permit has to be submitted to and approved by the HOR Management. In this work permit, fire aspects like disabling fire detection systems, use of chemicals, welding, grinding etc. are taken into account.

Chemicals and gasses are stored in special closets (satisfying the PGS15 rule) with limited capacity. Stocks are stored as much as possible outside of the buildings.

In another example, for the new Cold Neutron Facility, hydrogen is used within the process. Several measures, based on fire/explosion prevention requirements, are taken. For instance, prevention of potential ignition sources within the defined danger zones. The following topics are considered:

- Hot sources, e.g. vehicles are prohibited.
- Flames and hot gases, e.g. welding work only with work permit (meeting ATEX requirements).
- Mechanically generated sparks, e.g. the electric motors, pumps and fans in the defined danger zones are explosion-proof and suitable for the relevant zone class.
- Electrical materials, e.g. electrical equipment. The electrical installation in areas with a risk of explosion are inspected periodically in accordance with NEN3140 and NEN-EN-IEC 60079-17 ‘Explosive atmospheres – Part 17’.
- Stray currents and cathodic protection.
- Static electricity , e.g. the gas bottles are always connected by an employee of TU Delft’s special gas team.
- Lightning , e.g. the CNS building is equipped with a lightning protection installation, so that the discharge currents are diverted via the outside of the building in a controlled manner.

3.3.2 *RR HOR Active fire protection*

With respect to fire prevention, detection and firefighting and the provisions made in this regard, the following objectives are used as a point of departure:

- Ensure that in case of fire, the reactor can be shut down under all circumstances and the reactor core can be sufficiently cooled, ensuring a safe shutdown state.
- Ensure that in case of fire, the isolation function of the containment system remains intact, so that any leaking of gases, vapours or liquids (water used for firefighting) which could possibly contain radioactive material under all circumstances is limited and remains controllable.
- Ensure that workers safety is not at risk in case of fire.

3.3.2.1 RR HOR Fire detection and alarm provisions

3.3.2.1.1 RR HOR Design approach

HOR has a Framework Document Fire Safety. Following this document, full fire detection in the reactor and adjacent laboratories is applied.

Fire compartments and fire cells in the HOR are equipped with fire detection systems, generating an alarm in the Control Room of the Technical University of Delft (CRTUD) when a fire or smoke is detected. The CRTUD services the TU Delft Campus. The routing of the alarming follows the NEN 2535 standard, and is tailored to the Reactor Institute Delft (RID) which operates the HOR.

A fire alarm is generated by a manual or automatic detector and initiates the fire alarm system. All controls, except the evacuation, take place automatically. This means, among other things: pagers for the emergency responders (BHV) and forwarding to the regional fire brigade (VRH-b[54], with a delay time). The regional alarm centre (RAC) of the Safety Region also receives the fire notification and waits for permission from the team leader from RID, to start the evacuation. The controls and specific actions are stated in the Program of Requirements of the Fire Alarm System (BMI) and the Evacuation Alarm.

To ensure the functioning of the detection systems in the case of loss of offsite power (LOOP), the non-interruptible battery power (located in the control room) is activated to feed instrumentation (monitoring, control, detection etc.) for the period needed to activate the onsite power by the diesel generator. For the HOR, loss of power has no influence on nuclear safety by design. The HOR diesel generator is installed in a separate building outside the HOR building. The diesel operation time in case of LOOP is at least 6 hours. Two oil tanks are available, a day tank containing 0.65 m^3 of fuel and a supply tank with a capacity of 1 m^3.

In the cable closet of the control room, specialized fire alarm devices have been installed.

Fire detection and evacuation systems meet the Dutch Standard NEN 2535 and 2575. In the NEN standard requirements are given concerning the use/type of systems, duration for non-interruptible power supply, space dimensions, covering distances etc. The CRE is responsible for these systems (purchase, maintenance, inspection etc.).

3.3.2.1.2 RR HOR Types, main characteristics and performance expectation

There are requirements that include specifications/limits for lay-out, materials, dimensions etc. They stem from the mandatory use of certain standards like applicable industrial standards NEN (e.g. NEN 2535, NEN 2575), ISO, PGS (Dutch guides on hazardous substances). Some Ministerial Regulations also apply.

For the design and reliability of operation of the fire detection and alarm provisions, the prescriptions of the Building Decree are followed. For instance, the following mandatory activities are performed once a year:

- Check extinguisher status.
- Maintenance of detection-, alarm[55]- and evacuation systems.

The results have to be approved to finish the activities. In the approval process the Campus and Real Estate, the HOR technical services and the safety region (VRH) are involved. The safety region (VRH) is the most important party for the RID/HOR in this. Leading and prescriptive documents with respect to alarm settings/sequences/initiators etc. are the RID contingency plan (‘Rampbestrijdingsplan RID’]) and the company emergency plan (‘Bedrijfsnoodplan RID’).

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[54] Fire brigade of the Safety Region Haaglanden, Dutch: ‘Veiligheidsregio Haaglanden – brandweer’, VRH-b.

[55] Optical and thermal smoke detectors are used. But also multi-sensor detectors, which can be set to detect both smoke and temperature or a combination thereof.

3.3.2.1.3 RR HOR Alternative / temporary provisions

When fire detection systems are temporary disabled due to work activities, a fire safety check will be performed and alternative solutions, according to internal procedures via de BHV work permit system, will be implemented to guarantee fire safety, if needed. Information about this temporary situation is shared with the HOR organisation.

3.3.2.2 RR HOR NPP Fire suppression provisions

3.3.2.2.1 RR HOR Design approach

The positioning, in terms of the location, of hydrants and the type of used extinguishing systems in the buildings is laid down according to the Dutch Building Decree. For the selection of an extinguishing system, a base document must be elaborated (the UPD, see glossary) describing necessary functions and boundary conditions. This document is used to determine what legislation and standards must be applied. If no legislation is applicable, the user will determine the system. This process is carried out within a multi-disciplinary cooperation like health and safety, environment and regional fire brigade. The base document (UPD) is not a general document; the document is specifically written for the objectives related to the extinguishing system.

The following standards are among others applied and stem from the Building Decree:

- Larger fire compartments:
    - NEN 6060 (based on amount of fire load).
    - NEN 6079 (based on amount of radiant heat).
- Sprinkler: NEN-EN-12845 and NEN 1073
    - CEA 4001 (European standard)
    - NFPA and FM Global (US Standards)
- Fire resistance:
    - NEN 6068 (determination of resistance to fire penetration and fire spread)
    - NEN 6069 (test and classification of fire resistance materials)

For installations, rooms (including rooms with safety related SSCs) and buildings, the TU Delft Framework Document Fire Safety is used to determine fire suppression provisions, a.o. based on the Dutch Building Decree, and Dutch standards (see also former section).

The Building Decree contains regulations for measures that must be taken for fire prevention and fire safety for industrial premises including fighting fires with extinguishing agents such as fire hose reels and fire extinguishers.

Legal guidelines and standards apply, which require a higher level than described in the Building Decree. These requirements must always be met. Some examples of this are the PGS15 guideline ‘Storage of hazardous substance’ and the ATEX 153 guideline ‘Explosion safety’.

3.3.2.2.2 RR HOR Types, main characteristics and performance expectations

The necessary small fire extinguishers are present at strategically chosen places in the building complex. There are 5 hydrants on the RID outside area.

Large mobile equipment is not available on site, it becomes available when the regional fire brigade from the VRH arrives.

The mentioned equipment is periodically inspected and maintained.

All existing extinguishing systems in the HOR are manually operated. For hydrants, an availability within 40 meters of a possible fire brigade position is required.

For high or deep buildings, firefighting water pipes must be installed also within the range of 40 meters of the brigade position to connect the hydrants to these pipes.

As an example, an automatic HALON system (gas extinguisher) will not be used in the control room due to the presence of operators. In this case, fire detectors, in combination with manual powder extinguishers, are judged to be sufficient as provision for fire suppression.

For experimental assemblies (used by research reactors), no specific extinguisher equipment would be needed due to the type and design of the installations. The design of these experiments y are within the scope of the present provisions installed in the fire compartments/cells.

3.3.2.2.3 RR HOR Management of harmful effects and consequential hazards

All existing extinguishing systems in the HOR are manually operated. Harmful effects to safety relevant SSCs due to rupture, spurious or inadvertent operation, are very unlikely due to the large distances to these SSCs, capacity/type of the extinguisher and the robust design of the HOR structures. To prevent dysfunction or failure of extinguishing systems, tests/ inspections/ maintenance are carried out at least once a year (like flow measurement of hydrants). These activities are ensured by service level agreements made by the TU Delft, Campus Real Estate organisation, CRE.

Scenarios with radiological releases due to this event are screened out. In case of accident situations, internal and external response organisations are available.

The fresh fuel storage is designed considering accidental flooding. This means that criticality is not reached when the safe is in contact with water.

3.3.2.2.4 RR HOR Alternative/temporary provisions

For deviating activities with the risk of radiological release, safety evaluations are done, to be approved by the Reactor Safety Committee and possibly (depending on the type of modification) the Regulator Body. For fire safety, the HOR organisation and the safety region (VRH) are involved in the decision making process concerning the use of extra fire safety provisions.

As an example, at the moment, the installation of a new Cold Neutron Source (OYSTER project) in the HOR takes place, with the aim of increasing the accuracy and scope of the reactor. This new facility will meet the Dutch and European legislation concerning explosion- and fire safety, for instance the European Directives 1999/92/EU (ATEX 153) and 2014/34/EU (ATEX 114). The fire-and explosion evaluation of the new facility resulted in design requirements for this new facility.

3.3.2.3 RR HOR Administrative and organisational fire protection issues

3.3.2.3.1 Overview of firefighting strategies, administrative arrangements and assurance

The TU Delft Framework Document Fire Safety describes all legal and additional fire safety measures required by the TU Delft and the way access and escape is managed and organised in relation to the fire safety measures.

Some guidelines and standards apply, that contain stricter requirements than the Building Decree. These requirements must always be met. Some examples of these are the PGS15 guideline ‘Storage of hazardous substances’ and the ATEX 153 guideline ‘Explosion safety’.

For the RID/HOR, it is mandatory to have a firefighting crew available, as stated in the RID permit.

Fighting of fires will initially be done by the internal emergency response fire service (called BHV-b), until the arrival of the regional fire brigade of the Safety Region (VRH-b, external). The BHV-b carries out evacuation actions and guides the colleagues of the VRH-b. The brigade makes use of existing plans, the Company Emergency Plan and the RID Contingency Plan. The firefighting plans are customized for each building; e.g. positioning and approach routes are fixed. In principle the fire strategy is determined on a case by case basis in cooperation with experts from HOR, RID and the Safety Region. In case of fire within the containment of the HOR, specific strategies are applied and periodically exercised. One of the strategies is isolation of the containment without extinguishing the fire. Due to the low amount of combustible materials the fire will fade away without significantly harming safety related SSCs and buildup of possible contaminated extinguisher water. For typical situations like this, the emergency responders (BHV staff) have special breathing equipment for which they are trained to use.

Training for internal emergency responders (BHV) is given for several situations and for the use of firefighting equipment like the use of breathing masks. The training and education plans for personnel incorporates periodic fire instructions; exercises are carried out on a regular schedule to ensure preparedness and capability in the use and application of the provisions.

Part of the BHV staff responsibilities is the ‘on call service’ (Dutch: ‘consignatiedienst’) to ensure that the regional fire brigade can be assisted within the HOR during the evening or weekends.

The plans and provisions of the Company Emergency Plan and the RID Contingency Plan are periodically exercised. The periodicity is determined within the Building Decree and legislation applicable to the safety regions. The measures and provisions are yearly evaluated by the safety region and the internal fire safety consultant on adequacy.

Fire provisions/safety inspections take place every day, week or month, depending on the type of inspection. The daily inspection concerns simple inspections on fire loads, blockages of escape routes etc. More extended inspections are written in specific instructions, and follows the topic list below:

1. the extinguishers on the basis of the flight plans;
2. escape routes are marked and clear;
3. fire and emergency doors are clear and properly closed;
4. whether the (manual) fire alarms are accessible and functional;
5. whether the stairs are non-slippery and handrails are present/in good condition;
6. that emergency lighting is present and lit;
7. that there are no loose wiring;
8. whether gas bottles are fixed/secured;
9. whether labels are present on liquids, bottles, etc.;
10. fall and trip hazards;
11. flammable material, such as pallets, flammable liquids, boxes, etc.;
12. loose garbage bags and other waste;
13. allow the eyewash to flush for 15 seconds;
14. removal of items where possible.

Fire inspections are also performed by the insurance company (‘Nederlandse Atoompool’) every 5 years. The fire expert of the insurance company provides feedback to the TU-Delft RID/HOR. Recommendations can be used to improve fire safety. The insurance company’s requirements must be met. The last inspection by ‘Nederlandse Atoompool’ has been carried out in 2022.

A fire safety audit for the TU Delft takes place every 5 year. This is carried out by a consultant on behalf of Campus Real Estate organization (CRE), department Facility Management (CRE-FM). The consultant has received training aimed at fire safety and is (at least) qualified as a 'Fire Prevention Expert 2'.

3.3.2.3.2 RR HOR Firefighting capabilities, responsibilities, organisation and documentation onsite and offsite

The internal emergency response organisation is called 'BHVO'. It ensures coordinated handling of incidents within the RID/HOR and consists of the following entities:

1. Policy team (BT)
2. Emergency responders (BHV)
3. Radiation Protection Service (SBD)
4. HOR-Technical Services and Campus Real Estate (HOR-TD and CRE)
5. Security staff
6. In case of HOR: reactor staff

The internal organization is described in the Company Emergency Plan ('Bedrijfsnoodplan RID' . More specificaly, for emergency situations for the HOR the instruction document HOR Emergency Situations ('HOR Noodsituaties') is used. In this document, relevant emergency situations are addressed (including fire scenario's). For the distinguished situations a checklist/instruction is given (and referred), to be carried out by HOR employees.

The fire scenario's include the following locations: Fire in the Reactor Building, Fire in the Control Room and Fire in adjacent Buildings.

The activities in case of fire concerns signaling and securing, determining the cause, mitigate the impact.

Policy Team (BT)

Main tasks of the policy team (BT) are:

- General coordination (contact with mayor, fire chief and press);
- Interpretation of the situation in the building and/or with the reactor, assesses what measures must be taken and which higher authorities may need to be notified of the calamity;
- Decides whether the building must be evacuated;
- Instructs individual BT members or groups of BT members to make more detailed calculations, develop scenarios, etc.;
- If required by the municipal emergency services, takes a seat on the Municipal Crisis Staff.

Emergency Responders (BHV)

The Emergency Responders (BHV) consists of the following units: the Emergency Response Fire Service (BHV-b); the BHV Emergency responders First aid; the BHV-HOR Emergency responders personnel and the General emergency response.

Determination of the needed capacity for the different functions of the BHV have been performed on the basis of normative scenarios, for which fire is one of the scenarios. This resulted in the needed capacity for basic emergency responders, breathing air carriers (fire) and team leaders. For every situation (day or night) the BHV team is composed with the minimum of needed functions.

The SBD, HOR-TD, CRE, HOR operations/reactor staff and security provide in expertise, services and relevant information. Experts of these groups are involved in the decision making process, led by the policy team BT.

The Emergency Response Fire Service (BHV-b) consists of a team and one or more team leaders. Fighting (starting) fires, until the arrival of the (external) regional fire brigade (VRH-b) and carrying out evacuation actions and perform a guiding function for the regional fire brigade.

A specific instruction determines what activities have to be carried out by an operator of the reactor. The instruction topics are:

- Administrating activities (such as reporting);
- Signalling and Securing, during and outside office hours;
- Cause and effect limitation;
- Activities during fire in the Control Room;
- Activities during fire in the Reactor Building;
- Activities during fire in other Buildings.

Within the BHV-b, people have completed the training to become a team leader. Each reactor shift has a BHV-b firefighter in the team. They have at least the following certificates:

- Personal protection;
- Life-saving actions;
- Suppression.

The following equipment is available for the BHV-b:

- Fireman’s clothing;
- Breathing equipment;
- Hand extinguishers – mobile;
- Hand held extinguishers – stationary;
- Walkie-talkies;
- First aid bags;
- Fire alarm panel – including manual panels and smoke detectors.

The necessary small fire extinguishers are present at strategically chosen places in the building complex. There are 5 hydrants on the RID outside area. Large mobile equipment is not available (available when the regional fire brigade from the VRH arrives). The mentioned equipment is periodically inspected and maintained.

The BHV-b of the HOR works closely with the external fire brigade of the Safety Region Haaglanden (VRH-b). In practice the VRH-b will be informed about any fire situation which could potentially increase to a more severe level. The BHV-b performs a guiding function for the VRH-b when it arrives on site.

The VRH-b performs periodical inspections at the RID/HOR, coordinate emergency plans and takes initiatives to obtain/provide information (or training of personnel) relevant for fire (emergency).

As long as the national response organization has not yet been scaled up, regional strategic, tactical and operational decision-making will be based on the RID contingency plan ('Rampbestrijdingsplan RID'), the information from the RID and the information from the emergency services on site.

As a licensee, TU Delft/RID is obliged to report an accident to the Authorities (Nuclear Regulator, ANVS, and the Mayor). Activation of the national crisis organisation is initiated by the authorities, depending on the classification and severity of the (threatening) radiation accident.

Radiological Measurements

In the event of a (fire) calamity, an uncontrolled amount of radioactivity might be released inside the building(s), then activity (dose rate) will be measured by the equipment present and an estimate can be made of the possible emission into the environment.

Measurement equipment is installed all over the RID at fixed monitoring points as well as manual equipment. This measurement equipment is used to monitor the activity levels (from a radiation protection safety standpoint) of all those present and measures radioactivity at several monitoring points round the clock. In addition, the HOR operators have their own equipment in the control room to monitor and guarantee the safety of the HOR. This equipment is connected to a back-up power network so, in the event of loss of power, this equipment continues to work. The equipment can be read locally, as well as in an external crisis centre.

Several hand held monitors, which can measure alfa, beta, gamma and/or neutron radiation can be used. These monitors are contamination and dose rate monitors. They are kept at TU Delft/RID and checked regularly. In addition, the auxiliary services also own and use contamination and dose rate monitors. A special team from the fire department is trained to use this equipment for measurements.

As soon as an anomaly occurs in the measurement results, this is registered by the Radiation Protection Service (SBD) and/or the HOR operators. Depending on the degree of the anomaly in the measurement result, this is automatically followed by an alert to SBD and/or HOR. The SBD resp. HOR will, depending on the situation, on the basis of internal safety procedures, decide to continue operation of the reactor or take appropriate measures such as, for instance, shutting down the reactor.

3.3.2.3.3 RR HOR Specific provisions, e.g. loss of access

In case of loss of access routes, the fire strategy will be determined on a case by case basis in cooperation with experts from HOR, RID and the Safety Region. No specific provisions are provided.

The reactor hall has three entrances. There is one door for trucks; opening of this door is only allowed during reactor shut down (RSA protected). And there are two air locks for personnel entrance; one is situated on the ground floor and one at 10.5m above the floor level. The fire brigade can use all three entrances.

3.3.3 RR HOR Passive fire protection

3.3.3.1 RR HOR Prevention of fire spreading (barriers)

3.3.3.1.1 RR HOR Design approach

For all buildings of the TU Delft, a business continuity plan is established, taking into account safety and asset protection. From that viewpoint, measures are defined to protect SSCs by making structural adjustments, installing or adapting installations, or taking organisational measures. The technical design approach for prevention of fire spreading is laid down in the Building Decree. The principles and policies used by the Campus Real Estate organisation (CRE) has been derived from the legal framework and is expanded with extra/specific fire policies for the TU Delft buildings.

Within the HOR, safety relevant rooms/buildings are constructed with fire resistant walls/material (fire barriers) and equipped with fire detection systems. In all rooms, a minimum of combustible materials and ignition sources are maintained. The fire delay time of the rooms/buildings depends on the applied standard for the construction. For the Reactor Building, the outside material ensures a fire delay time of 60 minutes. Requirements are derived from the Dutch Building Decree.

With respect to the results of the HOR-PSA fire analysis (refer to section 2.3), it is considered not necessary to set up a specific design for passive fire protection, other than the rules and regulations following from the Building Decree. In the PSA fire analysis fire compartments and fire cells are defined and selected based on several criteria. Fire cells are determined in the reactor building, the control room complex, pump building and the RID main building. These cells/building-walls are safety relevant.

Compartmentalization by means of fire barriers is applied to suppress stack effects through cable ducts in case cable bundles are placed over a longer pathway.

In the Framework Document Fire Safety, the following principles are applied:

- For the installation, control and maintenance of fire dampers, the provisions of the policy memorandum ‘Fire dampers TU Delft’ must be observed, where applicable.
- Resistance to fire penetration and fire spread of 60 minutes in front of the outer wall of the reactor.

3.3.3.1.2 RR HOR Description of fire compartments and/or cells design and key features

The next rooms or buildings are designated as fire compartments and/or fire cells:

Reactor building

The reactor building forms one fire compartment. The reactor building is considered to consist of four fire cells, which are the ground floor, the first platform, the second platform and the old control room.

Control room complex and RID main building

The control room complex forms one fire compartment (together with the RID main building). The control room complex consists of several fire cells. The entire RID main building forms one fire compartment (together with the control room complex). The pipe basement is considered as part of the RID main building. The RID main building consists of several fire cells.

The fire cells are screened on several aspects, like HOR components, safe shutdown equipment, plant trip initiators, fire inventory, ignition sources, propagation potential etc. The nuclear laboratories, storage of radiations sources etc. of the RID are also located in the main building and are also screened for this aspects (if applicable).

Pump building

The pump building forms one fire compartment and consists of a single fire cell.

Generator building

The (diesel)generator building forms one fire compartment and consists of several fire cells.

Experiment hall

The experiment hall forms one fire compartment. This building is connected to the reactor building and separated from the other buildings; the penetrations are equipped with isolation valves to isolate from the Reactor Building. The experimental hall is considered to form a single fire cell.

Other buildings

All rooms and buildings that do not belong to any of the above buildings. By definition, the other buildings:

- do not contain any equipment related to reactor safety;
- do not share a common boundary with buildings that do contain such equipment.

These buildings are for example office buildings and other working places. For the purpose of the fire analysis, all other buildings are combined into one (hypothetical) fire cell.

3.3.3.1.3 RR HOR Performance assurance through lifetime

The Campus Real Estate organisation (CRE) is responsible for compliance with the TU Delft fire safety policy and the management of activities following from the policy. The responsibility of the CRE with respect to performance assurance can be described with the following activity topics:

- (Periodic) Inspection, internal and external, of fire safety (related) provisions;
- Management of obsolete/outdated provisions;
- Periodic fire safety evaluation with stakeholders;
- Management of follow-up activities as a result of evaluations/reviews.

Also the Safety Region Haaglanden (VRH) has some responsibility for assurance of the fire prevention provisions (like barriers). Fire safety inspections by the VRH (provisions, training programmes, attack plans, etc) are periodically performed.

In the Building Decree (related standards) inspection periods with respect to fire safety related provisions are stated.

3.3.3.2 RR HOR Ventilation systems

3.3.3.2.1 RR HOR Ventilation system design: segregation and isolation provisions

The ventilation system forms a part of the reactor containment system. The reactor containment system is gas-tight and is usually in open, filtered connection with the environment via the intake and outlet of the ventilation system (described in the Safety Analysis Report of the HOR).

The ventilation system has two isolation valves (no separate fire-dampers are installed) in series in the inlet duct and two isolation valves in series in the outlet duct. These are controlled valves with an electrically fail safe configuration which provide gas-tight isolation. If the limit value settings of a number of process variables (such as off-gas activity) are exceeded, the open connection with the environment and containment penetrations are closed by means of isolation valves.

Within the air ducts of the ventilation system, sensitive fire detectors are installed generating fire alarm signals in the Control Room of the TU Delft, the CRTUD.

3.3.3.2.2 RR HOR Performance and management requirements under fire conditions

In case of a serious fire within the Reactor Building, the reactor is scrammed and the containment is isolated by closing of the isolation valves . The seriousness of the fire is judged by the safety region VRH. The VRH determines whether scaling up is required and whether measures need to be taken.

In case radioactive material is released within the isolated Reactor Building, the ventilation system can operate in recirculation mode. In this mode radioactive parts are filtered via the internal loop, reducing radioactive particles in the containment air.

3.3.4 RR HOR Licensee's experience of the implementation of the fire protection concept

3.3.4.1 Overview of strengths and weaknesses

Fire safety is regularly subject to both internal and external inspections, nuclear risk evaluation, generic fire safety measures, external auditing and control by CRE and RID/HOR. Any areas for improvement are addressed in this way.

A remark can be made about the limited fire safety knowledge exchange between (relevant) nuclear facilities. Attention to fire safety should not become less due to the lack of fire events (at the HOR no large fire occurred within 60 years).

3.3.4.2 Lessons learnt from events, reviews fire safety related missions etc.

Audit by the Regional Safety Region

As a result of fire audits, general fire knowledge of the VRH is transferred to the HOR/RID organisation.

INSARR mission

From the IAEA INSARR mission, September 2021, none of the comments addressed fire safety related topics.

Post Fukushima stress test

In 2013, a Complementary Safety margin Assessment of the HOR was performed in response to the accident in Fukushima, Japan. The findings concerning fire (related) safety were:

- If practically achievable, connect the containment ventilation system to the Diesel Generator in order to maintain filtering capabilities after loss of off-site power.
- Investigate/determine the fire resistance of the synthetic plate material at the inside of the containment; perform a fire analysis from the viewpoint of nuclear risks.
- Make an inventory of equipment of Fire Brigade Haaglanden and adjust plans for possible emergency provisions.
- Both procedures in 'Bedrijfsnoodprocedures' (Emergency Operating Procedures) and the 'Aanvalsplan' (plan of approach) for containment pressure relief should be checked on consistency (1 kPa versus approaching 10 kPa) and effectiveness.
- Add the instruction that consultation of Radiation Protection Service (SBD) is needed about internal recirculation over the filters in order to reduce release fractions before pressure relief.

For all findings measures were defined and implemented or carried out.

Inspections by insurance company

Fire inspections are also performed by the insurance company ('Nederlandse Atoompool') every 5 year. The fire expert of the insurance company provides feedback to the TU-Delft RID/HOR. Recommendations can be used to improve fire safety; requirements of the insurance company are to be met. The last inspection was carried out in 2022.

Recommendations and improvements for fire safety concerned the relocation of power equipment and removal of combustible material from the control room. One separation wall did not meet fire safety requirements and shall be modified/replaced.

3.3.5 RR HOR Regulator's assessment of the fire protection concept and conclusions

3.3.5.1 Overview of strengths and weaknesses in the fire protection concept

One of the strengths of the Fire protection concept and its implementations is the fact that the installation is subjected to several inspections by national and international organisations.

On the national level this is done by e.g. the ANVS and the regional Safety Region (VR) fire brigade. There are regular meetings to discuss the status of Fire Safety together with the Safety Region, and there are joint exercises that are organized periodically. The company emergency plan was aligned and approved by the 'Haaglanden' Safety Region in 2023.

On the international level, inspections are done through visits by e.g. IAEA or the nuclear insurance pool company. In a separate contractual framework, the company insuring the licensee's installation audits the installation and provides advice on the improvement of the fire protection systems.

All the relevant action plans, procedures and organizational arrangements are reported in specific documentation, and comply to several decrees, guidelines and standards.

One weakness identified is that the last full revision of the licence was done in the year 1996, and the explicit requirements for fire safety were not developed in much detail.

3.3.5.2 Lessons learned from inspection and assessment on the implementation of the fire protection concept as part of its regulatory oversight

In 2013, a post- Fukushima stress test analysis was carried out, with a follow-up inspection in 2015. Some observations from this activity were:

- Proposals for the overall improvement of fire safety in fire cells or fire compartments, considering risks of fires and explosions;
- Analyze potential fire loads;
- Verify the capacities of the fire brigade to counter the effects of calamities.

These actions have already been considered and implemented at the HOR.

Every 10 years the regulator carries out a comprehensive review of the status of the installation from a safety perspective. Modifications have been initiated and implemented in different fire protection aspects. The most recent one was carried out in 2021.

In recent years, a project for technology improvement at the HOR has been implemented (OYSTER project), including the installation of a Cold Neutron Source next to the reactor core. A safety analysis has been updated and developed accordingly, including the added fire and explosion hazards. This project is now in the commissioning phase. Several preventive measures, based on fire/explosion requirements, are taken into account in the design and implementation.

IAEA conducted an INSARR mission[56] on the HOR in the year 2021, where several recommendations were given to improve the organization structure and arrangements, but no specific issue related to fire protection was identified.

In 2023, the ANVS together with the TSO Bel V carried out an inspection based on an Explosion Protection Document, related to the activities carried out in the OYSTER project. A HAZOP analysis covering the hydrogen system of the Cold Neutron Source has been developed, considering the use of flammable or explosive materials. This activity is ongoing.

3.3.6 RR HOR Regulator's Conclusions on the adequacy of the fire protection concept and its implementation

The information requested by WENRA for the development of this chapter is reflected in the previous sections. At the moment, the requirements detailed in the individual licence of the HOR with respect to fires are rather general. The licence holder is obliged to draw up, maintain and implement a fire prevention, fire detection and firefighting programme, aligned with all the topics developed in this chapter.

Based on the information developed in the previous section, together with the information presented in the corresponding section in Chapter 2, HOR has proven compliance to the assessment framework.

3.4 FCF Urenco Fire Protection Concept and Implementation

3.4.1 FCF Urenco Fire prevention

3.4.1.1 FCF Urenco Design considerations and prevention means

At UNL installations and buildings are designed in an inherently safe way which includes fire safety, i.e. minimizing the likelihood of fire. Combustible materials are avoided and radioactive materials are only present in fire compartments; specifications are recorded in Programs of Requirements which are checked and validated by an independent team. In the following section UNL's fire prevention principles are explained.

The fire safety concept applied follows the legal requirements of the 'Bouwbesluit 2012' and the requirements that follow from the 'Kew licence'. All buildings have been assessed against the 'Bouwbesluit 2012', and UNL's buildings comply with it in terms of fire resistance, fire compartmentation and escape requirements. To this end, the equivalence principle (article 1.3 'Bouwbesluit 2012' [57]) was applied for several buildings, based on the low fire load in these buildings. In addition, UNL has taken some measures beyond regulatory requirements.

For the buildings with radiological risks and safety-relevant systems, this means that fire compartmentation

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[56] IAEA-rapport INSARR-missie bij de Hoger Onderwijs Reactor (HOR) van het Reactor Instituut Delft, December 2021, https://www.autoriteitnvs.nl/documenten/rapporten/2021/12/22/iaea-rapport-insarr-missie-bij-de-hoger-onderwijs-reactor-hor-van-het-reactor-instituut-delft

[57] The same degree of safety, health protection, usability, energy efficiency and protection of the environment is provided by other means but at least at the same level as is intended by relevant regulations.

is in place with adequate fire resistance, which is 30, 60 or 90 minutes (according to the currently valid 'Bouwbesluit 2012'), self-closing doors and wall penetrations provided with automatically closing valves. All buildings are provided with fire detection and alarm systems.

As part of the design, the principle of 'Defence-in-Depth' (DiD) is used on the different levels of fire safety. Here, the activities that play a role with regard to fire safety take place at several distinguishable levels. Any loss of measures or facilities is compensated or corrected by measures or facilities at another level. The distinguishable fire safety levels are:

1. *Fire safety level 1: Prevention of fire*
   Prevention of fire through quality of design and manufacture combined with careful operation with good availability, inspection and maintenance.
2. *Fire safety level 2: Fire detection and control*
   Systems and measures to detect fire and control disturbances so that fire cannot develop.
3. *Fire safety level 3: Fire control*
   Design installations and buildings so that fire is controlled and no consequential damage occurs, such as fire compartmentation and safe escape.
4. *Fire safety level 4: Minimize probability of fire*
   Minimize fire risks by organizational measures like limiting fire load and ignition sources.
5. *Fire Safety level 5: Minimize the consequences of fire*
   Minimize the consequences of fire on the surrounding area through the availability of the Emergency Response Plan (including first aid) and Disaster Response Plan containing adequate alarm response accommodations, resources, procedures for taking adequate on- and off-site measures.

Table 3.1 lists the installation components at UNL that contribute to the function 'containment' in the context of fire safety in combination with the function and the DiD safety level of the component.

Table 3.1 Overview of installation components contributing to the fire safety function 'containment'

Installation component	Function in relation to containment
Cylinders	Containment normal operation Containment in transport accident
Plant control system: alarm control room	Preventing failure of containment in normal operation
No Break units for detecting process conditions and controlling valves	Support detection and control
Fire detection and alarm system	Preventing failure of containment
Battery packs for fire detection and alarm system	Support fire detection
Temperature limitation cylinder by capillary switch	Preventing loss of containment when warming up cylinder
Pressure measurement for insulation UF_6 systems	Leakage detection
Monitoring HF and air dust activity (α/β)	Leakage detection

Isolation valves UF_6 systems	Containment leakage
Leak-tightness of spaces at sub-atmospheric pressure in buildings	Limiting release
Ventilation system	Limiting release
Evacuation and dumping systems	Limiting release
Ventilation system/air cleaning (maintaining sub atmospheric pressure, switching air cleaning, filters)	Limiting release
UPS diesels	Support ventilation, plant control, monitoring

UNL's FHA describes fire prevention means in buildings in more detail. Moreover, fire compartmentation is included in all drawings including emergency response maps.

As the fire risks are mainly electrical in nature, the fire class of cables used is by default higher than required by NEN-8012 and cable trays are oversized. Cables have a *minimum* fire classification of D_{ca}, s3, d2, a3 based upon NEN-8012, unless circumstances require another classification. At new construction works the cable ways shall provide a minimum spare space of 20%. The cableway mounting construction shall take into account the max number of cables and power load on the cables (including future cable in spare space). Thermographic cameras are regularly used to examine for scalding.

Based on conservative assumptions, specific design and maintenance requirements apply that are structurally met. Naturally, systems in use comply with applicable laws and regulations.

Penetrations through fire compartments subject to a fire resistance requirement, are adequately checked and repaired after the installation of a cable, pipe or other penetration. This is part of UNL's maintenance programme.

UF_6 cylinders

Installations and storage of UF_6 cylinders at UNL are located in buildings with fire compartmentation. Some UF_6 cylinders are stored temporarily in shipping containers.

UF_6 cylinders meet standards for mechanical strength, among other things, which ensure that a cylinder can only collapse if the cylinder is exposed to fire for a prolonged period of time. At a (continuous) fire temperature of 800 °C, a cylinder collapses within 26 – 28 minutes. In this period emergency response is provided and the heated cylinder will be cooled with water.

Limiting the amount of UF_6

In case of loss of containment, only a limited amount of UF_6 can be released from the installation. Containment functions are guaranteed by tests and controls. In addition, UF_6 is only present at sub-atmospheric conditions and if not a secondary containment is applied.

Temperature and pressure measurement and Plant Control System

All temperature and pressure measurements are directly connected to the corresponding LCC (local control centre). During warming up a UF_6 cylinder in a plant, the temperature is limited and thus the system pressure is limited. The temperature limitation has three levels:

1. a software limiter: the heat supply stops when a setpoint is reached;
2. a hardware limiter, adjusted to a higher set point;

3. a capillary (on a mechanical principle) makes contact with a switch that de-energizes the heat supply system.

Temperature and pressure in the plants are continuously monitored through the Plant Control System in the Control Room. In addition, various process parameters are monitored.

Storage of chemicals and ATEX

Chemicals are stored in compartmented buildings according to PGS15 guideline. In these buildings, no radioactive materials are stored. Compartmentation prevents escalation in case of fire and limits fire. Locally, chemicals are stored in certified chemical cabinets.

At Uninterrupted Power Supply Generators in production buildings, diesel fuel is present in tanks with a size of up to 0.5 m^3 in a separate fire compartment. Only when the UPS is in operation there is a potential fire risk. To this end, protection systems are present on the plant, fire detection is in place in the room and the fire load is limited. UPSs are always tested in the presence of persons.

On locations where (highly) flammable substances are present on site, the electrical equipment present is suitable for safe use in a potentially explosive atmosphere, according to ATEX guidelines.

All areas at Urenco including areas where flammable material (such as oil and chemicals) may be present are equipped with fire detection systems. Uranium compounds are not present in those areas or only to a minor extent. The spread of any fire to areas with radiological risks is prevented by compartmentation, detection and automatic suppression in case of the server area in the CSF.

Working instructions for switchgear cabinets

Switchgear cabinets are closed during normal operation and are equipped with circuit breakers: in case of overload, voltage is automatically switched off with notification to the Control Room. In that case, it is possible to switch to a redundant system to allow sufficient time for investigation.

When working in opened switchgear cabinets, 30 kg CO_2 extinguishers are available. The worker holds a certificate to operate them. Switch boxes are closed in the event of temporary absence. This is regulated in work instructions.

Safety behaviour

Safety is paramount at UNL; employees are alert to safety and working safely. This is supported by management and the department Compliance, among other things by conducting safety walks, inspections and audits. UNL has a safety behaviour program which describes goals and frequency of inspections and actions.

3.4.1.2 FCF Urenco Overview of the arrangements for management and control of fire load and ignition sources

In accordance with the fire analyses, the following procedures for management and control of fire load and ignition sources are implemented.

Limited fire load

At UNL little use is made of combustible materials, thus the fire load is very limited. If the maximum fire compartment size is exceeded in a building in accordance with the 'Bouwbesluit 2012', the method Beheersbaarheid van Brand (BvB 2007, previous to NEN 6060) is used to demonstrate that an equivalent fire safety level can be achieved (article 1.3 'Bouwbesluit 2012'). This is partly realised by limiting the fire load. For these buildings, the maximum fire load has been calculated and defined. For example, in the CRDB and CRDC buildings flammable materials may be stored in a maximum space of 30 m^3 and the minimum distance between storage areas is 3.5 metres.

The insurance company requires that only non-combustible or fire-retardant plastic sheeting may be used on UNL's premises, from a prevention perspective, provided that it fits within the allowable fire load. For instance, the use of halogenated plastics should be avoided as much as possible.

Ignition sources

Smoking and open flames are prohibited on the UNL site.

A special fire permit is required to carry out hot work; this is additional to the work permit and describes, among other things, the precautions to be taken, extinguishing equipment to be used and the supervision required. Installations can be de-energised from outside. A competent person is available to do this.

All transformers are installed in a separate fire compartment. All transformers are equipped with two-stage thermal protection systems: a pre-alarm at 130 °C and automatic shutdown at 150 °C. A transformer is automatically switched off in the event of a short circuit.

Maintenance

All systems, procedures and instructions described in the previous sections are recorded in the management system. UNL is under contract with certified parties for the mandatory maintenance of the systems. In addition, the in-house department Maintenance provides management, control and maintenance of all buildings and systems on the UNL site. Regular inspections, checks and audits are carried out by UNL-personnel (internal) according to UNL's maintenance programme. In addition, inspections and audits are carried out by ANVS and insurance companies.

Limited accessibility -Security

The site is completely enclosed by a double-layered fence and is not freely accessible. The main gate is located on Drienemansweg and access to the site is only possible with an access pass. Own personnel and permanent contractor personnel have access to the site via a badge system. Visitors and contractors (without a permanent pass) are registered at the Security Building (LOGE) and announced by a host from UNL. Setting fires by unauthorized people is therefore non-credible.

Most of UNL's buildings are equipped with a fire service entrance. This is mandatory for buildings intended for the accommodation of persons based on the 'Bouwbesluit 2012'.

3.4.2 *FCF Urenco Active Fire protection*

Detecting and extinguishing quickly those fires which do start, thus limiting damage, is the second level of defence in depth. The most prominent fire safety means at UNL are fire detection and alarm systems and illuminated escape routes in all buildings, regardless the use of the buildings and the presence of people in the buildings. In the following section UNL's fire safety principles are explained.

3.4.2.1 FCF Urenco Fire detection and alarm provisions

Given the low fire risks at UNL, the 'Bouwbesluit 2012' forms the basis for fire safety. This has been supplemented with requirements from the 'Kew licence' and technical facilities that contribute to fire safety. All fire safety installations are designed and constructed on the basis of a Program of Requirements approved by the demanding authorities.

At UNL, systems are not in a ‘hazardous environment’. Therefore, the impact of such an environment was not considered.

3.4.2.1.1 FCF Urenco Design approach

A fire detection and alarm system with full monitoring in accordance with NEN 2535 is present in all buildings. The fire detection systems consist of detectors, evacuation alarms and escape route signs. All transformer rooms and production buildings are equipped with an Aspiration Smoke Detection system (ASD, also known as VESDA). This is a highly sensitive system that aspirates air and checks it optically. A deviation, e.g. due to smoke, is detected very quickly and triggers a fire alarm.

In buildings with radiological risks, safety-relevant battery packs are available for supplying power to the fire detection and alarm system (the fire detection and alarm system as well as the battery pack are included in the safety analyses).

Besides the failure of electrical power supply and the failure of process systems, a fire alarm leads to switching to a safe mode in which the UF_6 inventory is evacuated through designated filters and shelters.

Rooms where above-atmospheric UF_6 systems are present or operations with open sources take place are equipped with room monitoring for detecting radioactive substances. In the return air ducts, the air is monitored with HF detectors and/or activity meters. These will be activated upon release of these substances leading to evacuation of the UF_6 system(s) to the dump and evacuation of the building. These measures are equal if the origin of the release is a fire.

A fire alarm is notified at a separate fire panel in the Control Room and at the Security Building (LOGE), next to the fire panel at the main entrance of the concerning building. The panel notifies exactly which detector has been activated in which room. Successively, first responders are alerted via their DECT phones and the external fire brigade is notified via the Regional Fire Service Alarm Centre. Only in the server area in the Central Storage Facility (CSF), an automatic extinguishing action is triggered. In all cases doors in fire barrier elements are automatically closed.

All buildings accommodating persons are equipped with an evacuation system type B in accordance with NEN 2575; this means that the evacuation alarm is given by slow-whoop signal generators. All buildings have escape route signs.

A separate emergency number is available to report incidents. This number can be called by anyone. The alarm alerts Security, which then alerts emergency response.

3.4.2.1.2 FCF Urenco Types, main characteristics and performance expectations

Fire alarm and evacuation systems comply with NEN 2535 and NEN 2575 respectively, have an inspection certificate and are inspected annually by an accredited inspection body (in accordance with NEN 2654 1 and NEN 2654 2). The Programs of Requirements takes fire compartment into account. Ventilation systems that cross a fire barrier are provided by fire dampers with a fire resistance that is equal (or better) than the fire barrier. The fire dampers close on fire detection, automatically or by melting of a fuse.

Fire alarms are immediately reported to the Regional Fire Service Alarm Centre. Management takes place in accordance with NEN 2654 (regulations A.10 – A.11 ‘KEW licence’). Escape route signs comply with NEN 3011 or NEN 6088 and the visibility requirements in articles 5.2 to 5.6 of NEN EN 1838. Other installations are installed and maintained in accordance with the accompanying Program of Requirements (e.g. the smoke curtain in CRDC, automatic gas extinguishing system containing 50% argon and 50% nitrogen in CSF).

3.4.2.1.3 FCF Urenco Alternative / temporary provisions

In case of work activities, a fire permit is required for switching off part of the fire detection and alarm system in addition to the work permit. This describes, among other things, the precautions to be taken, extinguishing agents to be applied and the supervision required; this is determined on the basis of the risks of the activity to be performed given the circumstances.

3.4.2.2 FCF Urenco Fire suppression provisions

The following section describes the fire suppression provisions available at UNL. Any fire at UNL will be extinguished manually, except a fire in the server room in the CSF. Water is also used as an extinguishing agent since it is non-credible that a fire will lead to criticality. Moreover will water prevent HF from spreading to the environment.

3.4.2.2.1 FCF Urenco Design approach

Since all UNL's buildings are provided with full fire detection and the fire load is very low, there is no need for special fire extinguishing installations. Only the server area is provided with an automatic fire extinguishing installation from a business continuity perspective. The following section describes the available fire extinguishers.

All buildings are equipped with fire extinguishers, such as fire hose reels and portable or mobile extinguishers. These are placed in visible and accessible locations in the buildings and contain water, carbon dioxide and spray foam as extinguishing agents. The use of fire extinguishers prevents any starting fire from spreading and leading to large-scale damage to the buildings and systems, which could result in the release of UF_6 to the surrounding area.

Due to the mainly electrical fire risks, additional 30 kg CO_2 extinguishers are present on carts in easily accessible places; these carts are placed on marked locations. The emergency response organization is trained in extinguishing fires with these extinguishers. After initial extinguishing with CO2 and switching off the installation, water can be applied as extinguishing agent. The type and quantity of extinguishing agent to be present have been coordinated with the regional fire service and local authorities. Maintenance is performed on basis of a contract for management, control and annual check-up (regulation A.14 – A.15 'KEW licence'). The evacuation plans and emergency response maps in the buildings show the location of the extinguishing agents.

The CSF server room is equipped with an automatic gas extinguishing system (containing 50% argon and 50% nitrogen). Maintenance, monitoring and management is done in accordance with the supplier's maintenance requirements, as prescribed in the UPD and required by the certificate.

SP5 and the UOB are equipped with a dry fire line.

The air bridge connecting the Cylinder Receipt and Dispatch Building CRDB and Cylinder Receipt and Dispatch Center (CRDC) is equipped with a smoke control system to prevent fire from spreading through the air bridge. The mandatory inspection certificate is present (article 23 'Bouwbesluit 2012'). Management, inspection and maintenance is performed based on a maintenance contract. The Program of Requirements describes the design specifications.

3.4.2.2.2 FCF Urenco Types, main characteristics and performance expectations

Fire hose reels, small fire extinguishers and the gas extinguishing system are inspected annually according to the maintenance contracts with certified parties. The accessibility and fire water supply is checked annually by UNL's department Maintenance.

UNL's buildings rely on an on-site fire-fighting water network. The looped pipeline is supplied by water company ‘Vitens’ through a hydrant network. Water is supplied from the buildings SUB and UOB[58], resulting in a redundant system. This primary water supply fulfils the requirement for the buildings present on the UNL site. The main entrance of most buildings on the UNL site is located more than 40 metres away from the public road; in those cases there is a hydrant, connected to the looped pipeline, within approximately 40 metres of the main entrance. If necessary, additional fire-fighting water is available in the ‘Weezebeek’. UNL is not dependent on parties other than ‘Vitens’ for the supply of fire-fighting water.

3.4.2.2.3 FCF Urenco Management of harmful effects and consequential hazards

Water sprinkler systems are not applied at UNL. It is therefore unlikely that large quantities of extinguishing water will lead to secondary effects. There are no situations known where the use of extinguishing water could lead to criticality because uranium compounds are only used in closed systems and failure of containment systems in combination with fire is unlikely. The opposite is valid, i.e. water is recommended as an extinguishing agent because of its cooling capacity and the capacity to reduce the spreading of HF.

3.4.2.2.4 FCF Urenco Alternative / temporary provisions

There are no temporary provisions applied. Fires will be extinguished manually except in the server area in the Central Storage Facility CSF. All areas are accessible for UNL’s first responders.

Hot work will be carried out according to the hot work procedure, which means that a so-called fire permit is necessary. In this fire permit measures to prevent fire and to extinguish a fire quickly are described. Examples are: a fire extinguisher present, a fire watch, stop charging batteries within 10 metres.

3.4.2.3 FCF Urenco Administrative and organisational fire protection issues

The following section describes the firefighting strategies, written procedures defining responsibility and actions and administrative measures.

3.4.2.3.1 FCF Urenco Overview of firefighting strategies, administrative arrangements and assurance

UNL has an emergency response organization to limit the consequences of fire, environmental incidents and accidents. Emergency response focuses on the risks as described in the risk inventory and evaluation and the incident scenarios that can reasonably occur within the company; the emergency response organization complies with legal requirements.

The emergency response organization consists of first responders, a first aid team, evacuation team(s) an alarm centre with continuous staffing, a crisis management team and a site emergency director (SED). Operating personnel working in continuous operation also perform the role of first responder and they are well-trained for this job. A fire alarm is immediately reported to the external Regional Fire Service Alarm Centre. After an alarm, an emergency response officer will immediately investigate the location of alarm, thus an emergency response officer is always present at the incident within a few minutes. This is followed by a team of at least 2 persons with protective equipment. The head of emergency response (Shift Manager or deputy) has access to a C2000[59] portable radio that allows direct contact with the governmental fire service.

The first responders are trained in firefighting, wearing and working with breathing protection, acting In the event of a chemical release (in a gas suit), life-saving actions and CPR. An important aspect of the training is informing and guiding external emergency services. The first responders are examined annually for health and fitness; they practice every five weeks, except during the holiday period. A separate first aid team is available for first aid incidents that are not related to fire or hazardous substances. The emergency response organization maintains contacts with the governmental and other emergency services. If necessary, incidents

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[58] SUB: site Utility Building, UOB: Urenco Office Building

[59] C2000 is a communication network with access restricted to mostly governmental emergency response and security services.

are reported to the relevant authorities.

First responders are available 24/7 on site and have access to all buildings and installations. An official on-site fire brigade is not available (or required); the governmental fire brigade can be present in less than 6 minutes.

UNL has various emergency response tools such as fire-fighting equipment, auxiliary tools, emergency showers and various personal protective equipment. For the situation that a UF_6 cylinder or its valve is damaged, UF_6 emergency kits for sealing are available. These materials are inspected, maintained and tested according to UNL's maintenance program and inspection requirements (e.g. NEN) to ensure the operability of the fire protection measures over the lifetime of the installation.

Firefighting strategies and written procedures clearly defining responsibility and actions of staff in responding to any fire in the installation are included in the Emergency Response Plan (see next section). All emergency response personnel is trained 8 times a year according to the training schedule and program. Training is performed mainly on site in real scenarios; firefighting training is performed at a training centre. Heads of emergency response get extra training on leading and coordination of emergency response.

3.4.2.3.2 FCF Urenco Firefighting capabilities, responsibilities, organisation and documentation onsite and offsite

Emergency planning for an incident at UNL, is documented in:

1. the Emergency Response Plan including first aid: applicable to incidents of limited scale, occurring within the boundaries of the UNL site;
2. the Crisis Plan: applicable to incidents where larger personal or property damage may occur, in conjunction with the Emergency Response Plan;
3. the Disaster Response Plan Urenco of the Safety Region Twente (Dutch: 'Veiligheidsregio Twente'): this describes the role of governmental emergency services and local authorities.

The UNL emergency organization acts immediately after an incident until governmental emergency services are on site. Thereafter, the UNL emergency organization assists and informs the external emergency services. These are well informed on the UNL site by means of the Emergency Response Plan, among other things. Moreover, the regional fire service periodically performs exercises on site together with the emergency response organization. The board of the 'Veiligheidsregio Twente' has concluded that UNL is not obliged to establish a company fire service (article 31 'Wet Veiligheidsregio's'). Persons who have a role in managing incidents are educated and trained appropriate to this role; a registration of professional competences is available if required.

Human Factors during incidents are covered by automation of process control and automatic activation of safety systems, provision of good tools, clear guidelines on how to act in incident situations and regular practice and training.

Emergency Response Plan

The Emergency Response Plan is a description of the organization, procedures and measures UNL has taken to minimize the scope and consequences of an incident/calamity; it indicates how UNL has organized the requirements of all valid legislation. This involves the relevant foreseeable incidents and radiological emergencies that could reasonably occur on the UNL site in accordance with the 'Besluit basisveiligheidsnormen stralingsbescherming' (article 6.7).

The Emergency Response Plan is adapted to the governmental emergency organization as described in the 'Nationaal Crisis Plan Stralingsincidenten', the emergency response plans and the Disaster Response Plan Urenco of the 'Veiligheidsregio Twente'. Managing an incident starts with the Emergency Response Plan and can be elevated to the Crisis Management Team. The Emergency Response Plan has been approved by the

Director ANVS and the ‘Veiligheidsregio Twente’. The plan is regularly practiced, as required by regulation A.8a of the ‘Kew licence’.

The emergency response organization, working arrangements, action lists, maintenance,142rganizag and exercises and emergency response maps are documented in the Emergency Response Plan. The emergency response map for each building is also available and included in the document holder Emergency Response Plan at the entrance of the building. Building-specific maps of all company buildings are available at the fire service.

Crisis Plan

At UNL, the Crisis Management Team (CMT) will be convened when a situation arises in which major personal or property damage occurs or is likely to occur. For these situations, a Site Emergency Director (SED) is 24/7 available. The SED is authorized to start the CMT and acts as the president. On behalf of UNL, the CMT will try to prevent a crisis or deal with its consequences effectively. The CMT will also organize cooperation with government departments. The Crisis Plan serves to guide the members of the CMT in their actions. The Crisis Plan is additional to the Emergency Response Plan and includes the scenario *Fire*. A crisis centre equipped with the necessary tools has been set up for the benefit of the CMT. The Crisis Plan is practiced at least once a year.

Disaster Response Plan

‘Veiligheidsregio Twente’ has compiled a Disaster Response Plan for UNL describing how tasks, competences and plans of the various authorities, emergency services and organizations involved in the disaster response, converge in a structural manner. The CMT will cooperate with the relevant organizations, such as hospitals, ambulance service, fire brigade, police, the municipality and ETC NL. The Disaster Response Plan is based on the scenario crash of an aircraft on the SP4 where autoclaves including cylinders collapse.

Available documentation

The following documentation is available in all buildings:

- Emergency Response Plan;
- Emergency response map per floor;
- logbook, design (on drawing) and operating instructions for fire detection and alarm system;
- Material Safety Data Sheets of hazardous substances present in quantities of >100 kg.

3.4.2.3.3 FCF Urenco Specific provisions, e.g. loss of access

The UNL site is accessible via two independent routes and is spacious; this ensures sufficient accessibility. UNL’s installations are accessible via different, independent routes. Loss of access is therefore, not an identified as a risk, even when weather conditions are extreme or in case of flooding.

UNL is accessible via the public road. To provide access for the fire service, the following gates have been designated (regulation A.7 ‘KEW licence’):

- main entrance near the Security Building (LOGE);
- entrance gate near building SIB (Stable Isotopes Building).

At the main gate, emergency services are met by Security, provided with UNL’s emergency response map and escorted to the incident site. The UNL site is spacious and the buildings can be approached from several directions. This is regulated in the Emergency Response Plan.

Most of UNL’s buildings are equipped with a fire service entrance. This is mandatory for buildings intended for the accommodation of persons based on the ‘Bouwbesluit 2012’. Specifications regarding the fire service entrance are included in the Program of Requirements for fire alarm and evacuation systems for the specific building and are coordinated with the fire service. A so-called fire elevator is not required for any of the buildings on the UNL site.

3.4.3 FCF Urenco Passive fire protection

Preventing the spread of those fires which have not been extinguished, thus minimizing their effects on essential plant functions is the third level of the defence concept.

3.4.3.1 FCF Urenco Prevention of fire spreading (barriers)

3.4.3.1.1 FCF Urenco Design approach

For all buildings at UNL, a business continuity plan has been established, taking into account safety and asset protection. From that point of view, measures are defined to protect SSCs by making structural adjustments, installing or adapting installations, or taking organisational measures. The technical design approach for prevention of fire is described in the 'Bouwbesluit 2012'. The principles and policies are derived from the legal framework and are expanded with extra/specific fire policies for UNL. With respect to the FHA it is considered not to be necessary to set up a specific design for passive fire protection, other than the rules and regulations following from the 'Bouwbesluit 2012'.

All installations at UNL are located indoors. All rooms/building are constructed with fire resistant walls/material (fire barrier) and equipped with fire detection. In all rooms a minimum of combustible materials and ignition sources are maintained. A maximum fire compartment size of 1,000 m^2 applies to areas with offices and the Control Room, since more fire load is present in these areas. Fire barriers and their fire delay time are defined based on the 'Bouwbesluit 2012' and documented in UNL's Emergency Response Plan. Fire compartments and fire cells are selected based on several criteria in the FHA. Fire barriers are part of UNL's maintenance program and are inspected periodically.

3.4.3.1.2 FCF Urenco Description of fire compartments and/or cells design and key features

Fire compartments or fire cells are defined as in the Glossary.

Where necessary, buildings are subdivided into fire compartments or in case the size of a fire compartment exceeds the limit value of the 'Bouwbesluit 2012' it has been demonstrated that an equivalent level of safety has been achieved (article 1.3).

Maps per floor of all buildings are available with the fire-resistant compartments available. All buildings are documented in UNL's FHA.

The next rooms or buildings are designated as fire compartments and/or fire cells:

Table 3.2 Data of fire compartments in UNL's buildings

Building	Fire compartment	Function
Separation Plant SP4	SP4 forms one fire compartment in which separate fire cells are present for: - Diesel generator and storage; - UPS; - Utility rooms; - Escape routes including elevator.	enrichment plant for UF_6 and production support activities

Separation Plant SP5	SP5 consists of 4 fire compartments, and separate fire cells for: - Control room / offices; - Take-off; - High/low voltage rooms; - Diesel generator and storage; - UPS; - Escape routes including elevator.	Enrichment plant for UF_6 and production support activities
CSB: Central Services Building	CSB consists of 5 fire compartments: - Offices; - Technical rooms including laboratory; - Storage; - Blending; - Low voltage room.	Production support activities such as analysis, cylinder cleaning, waste water treatment
RCC: ReCycling Centre + to be built RCC-B	RCC consists of 5 fire compartments: - Production hall; - Offices and canteen; - High/low voltage rooms; - Diesel generator and storage; - COVRA storage. RCC-B is still under construction.	Decontamination of materials and equipment
CRDB: Container Receipt and Dispatch Building	CRDB forms one fire compartment.	Receiving, handling and storage of UF_6 U_3 O_8 cylinders
CRDC: Container Receipt and Dispatch C	CRDC forms one fire compartment.	Storage of UF_6 and U_3 O_8 cylinders
CSF: Central Storage Facility	CSF forms one fire compartment, in which the server room forms a separate fire cell.	Storage of decommissioned centrifuges, materials, parts and packaging material

3.4.3.1.3 FCF Urenco Performance assurance through lifetime

Preventive and corrective maintenance, inspection and periodic functional testing ensure that physical assets remain capable of performing their intended functions and that the reliability and availability of process, process-related installations, building and building-related installations is maintained. The maintenance philosophy and principles for UNL are set out in a Urenco Group Procedure. The method of working for UNL is described in the 'Procedure Installatiebeheer'.

Most of UNL's buildings are equipped with a fire service entrance. Access routes are wide and fulfil the requirements of the 'Bouwbesluit 2012'. Fire compartments and penetrations are periodically inspected and, if necessary, repaired by a certified party. Moreover, fire compartments are present on all UNL's drawing which means that anyone consulting a drawing, e.g. in case of a project, is aware of the fire barrier elements. In case of changes, the process management of chance will be followed and the department Compliance will be consulted.

3.4.3.2 FCF Urenco Ventilation systems

3.4.3.2.1 FCF Urenco Ventilation system design: segregation and isolation provisions

Room ventilation systems are present in all buildings with radiological risks. The buildings support the function of ventilation systems and air purification. In buildings where above-atmospheric UF_6 systems occur or operations with open sources take place, at least the following safety measures are in place:

- the air ventilation system maintains a slight sub atmospheric pressure;
- ventilation air is continuously monitored and contaminated air is automatically led to an air purification unit;
- the room is provided by a separate wastewater collection system which is completely separated from the public sewage network.

Furthermore, the separation plants and CSB have an air extraction system (Gaseous Effluent Vent System – GEVS) that extracts any vapours released when opening equipment and disconnecting pipes. By default extracted air from the vacuum pumps is discharged through the GEVS. The exhaust air from this system is routed through a continuously operating air purification system. All passages of the ventilation systems through fire-resistant compartments are provided with automatically operating fire valves. The fire valves have at least the same fire-resistant capacity as the fire compartment.

3.4.3.2.2 FCF Urenco Performance and management requirements under fire conditions

In case of fire, fire valves in the ventilation systems are automatically closed so that fire compartmentation remains intact. No supplementary provisions are needed.

3.4.4 FCF Urenco Licensee's experience of the implementation of the fire protection

3.4.4.1 Overview of strengths and weaknesses

Regarding Fire Prevention, it can be mentioned that UNL is regularly audited by the fire insurance 'Atoompool'. These audits are carried out by experts familiar with the nuclear industry. In addition, periodical safety reviews are carried out every 10 years by independent experts with nuclear backgrounds as part of the Periodical Safety Review, 10 EVA. Recommendations and improvements are incorporated into the UNL management system which ensures follow-up of the actions. The same holds true for internal inspections.

Moreover, it is unlikely that a fire in rooms with UF_6 systems will lead to a discharge of UF_6, due to the presence of a fire detection system and the limited fire load present. As a result, in case of a starting fire, rapid detection and response will occur and the fire will be controlled. Any relevant incidents are reported to UNL's personnel, for example at our lunch meeting called 'Broodje info' or in a bulletin or report.

UNL is in close contact with the regional fire department which means that fire risks and new plans are discussed, exercises are organised at the UNL site, and documents at the fire brigades are up-to-date.

Regarding Active Fire protection, it is observed that UNL has a rapid intervention at its disposal by the emergency response team. As a result, in case of a starting fire, rapid escalation will not occur and the fire will be controlled. This team is well-trained and equipped. However, due to the fact that UNL has several fire stations on site with personal equipment, team members are not provided with their own equipment. Equipment is available in different sizes. Occasionally, team members are not provided with their own size.

Due to the large buildings, most built up in concrete, walky-talky contact can be difficult. Tests are executed in cooperation with the regional fire brigade to find an alternative way for communication by relay.

3.4.4.2 Lessons learnt from events, reviews, fire-safety-related missions, etc.

In the past six years, there have been nine true fire alarms. Those are reported in the **Fout! Verwijzingsbron niet gevonden.** below.

Seven of these true fire alarms were caused by an electrical hazard and two by human activity. The number of fire alarms decreased from 12 in 2017 to 4 in 2022. The majority of fire alarms were classified as *unwanted* or *false*. Fire alarms are investigated and relevant actions or improvements are defined. These are incorporated into the UNL management system which ensures follow-up of the actions. However, the number of alarms is very low which makes valuable statistics impossible.

Table 3.3: Summary of reports of true fire alarms since 2017

Date	Building	Cause / reason
14-11-2022	NSC	Smoke development during testing from broken housing emergency power diesel
13-1-2022	SP4	Blow of capacitor
12-7-2020	SP5	Defect transformer
16-4-2020	SP5	Starting fire in switchgear1)
3-9-2019	DRUPS	Blow of transformer
12-11-2018	SP4	Burnt-out inverter
5-9-2017	SP4	Smeared inverter PCB
1-5-2017	UOB	Dry-cooked food
27-2-2017	SP5	Electrical heater causes smoke

1) detection via malfunction notification before fire alarm

UNL is regularly audited by the fire insurance company ‘Atoompool’. These audits are carried out by experts familiar with the nuclear industry. Recommendations and improvements are incorporated into the UNL management system.

In addition, reviews are carried out every 10 years by independent experts with nuclear backgrounds as part of the Periodical Safety Review, the 10 EVA. Recommendations and improvements are incorporated into the UNL management system which ensures follow-up of the actions. The same holds for internal inspections.

UNL stays informed of events taking place in the nuclear industry as well as other relevant incidents including fire incidents. If relevant, UNL considers whether measures are needed to prevent such an incident within UNL. If so, these are incorporated into the UNL management system.

The emergency response team of UNL has been deployed four times in 2022; the same holds for UNL’s first aid team. The deployments were conducted according to written procedures and in time. The first aid cases were not fire-related. The performance of the emergency response and first aid team, in real situations and during exercises, complies with the requirements; there are no recommendations to further improve or adapt the emergency response planning.

In 2022 no higher-impact incidents did occur for which UNL’s Site Emergency Director (SED) was called. In

2020 and in 2021 the SED was called twice for incidents that are not fire-related. All SEDs were trained in a Crisis Management Team (CMT) setting. These trainings showed that UNL's CMT is well equipped for the job.

Other examples are:

- The amount of stored flammable hazardous substances is reduced as a result of the review of UNL's explosion document.
- The fire load in UNL's building is further lowered with focus on wood.
- The control room of SI is provided with fire extinguishers.
- UNL's battery charging stations are adapted to NPR 3299 and charging instructions are provided.

3.4.4.3 Overview of actions and implementation status

An overview of actions in presented in the **Fout! Verwijzingsbron niet gevonden.** below.

Table 3.4 Summary of actions on fire prevention

Date	Building	Action
Q4-2023	SIB	New Chemical Storage according to PGS15
Q4-2023	SP4	New fire resistant storage for contaminated oil
Q1-2024	CSB	Expansion low voltage room in separate fire compartment

The chemical storage at the Stable Isotopes Building SIB did not fulfil the requirements according to PGS15. Therefore a new storage is built in 2023.

Radioactive waste (contaminated oil and filters) is temporarily stored in the Recycling Centre building (RCC) and the Central Service Building (CSB). UNL compiled a program of actions in order to create a storage facility fulfilling the relevant requirements. In a Separation Plant, a fire resistant storage will be built; the storage will be available at the end of 2023.

A failure of electrical power supply in June 2022, resulted in the project for expansion of the low voltage room in CSB. The Program of Requirements is currently in progress; this includes fire safety issues.

In the current situation, there are no other open actions or improvement measures to improve fire safety. Only the pool of SEDs shall be complemented since some rotation of the current SEDs is expected.

3.4.5 FCF Urenco Regulator's assessment of the fire protection concept and conclusions

3.4.5.1 Overview of strength and weaknesses in the fire protection concept

As URENCO is operating an enrichment facility, it manages only low level radioactive material. The major risks of UF_6 are mainly related to toxicity due to its chemical effects (chemotoxicity) and are not due to the effects of radiation.

A strong point is that URENCO has similar installations in different countries, all of which are individually inspected. From these inspections, experience and design improvements can be gathered and shared.

One of the strengths of the fireprotection concept and its implementations is the fact that the installation is subjected to several inspections by national organisations. On the national level this is done by e.g. the ANVS and the regional Safety Region's (VR) fire brigade.

All the relevant action plans, procedures and organizational arrangements are reported in specific documentation, and comply to the applicable decrees, guidelines and standards.

As requested by the licence, fire alarms and fire detection system are certified according to NEN 2535:2017.

Some shortcomings in the availability of protective equipment and communications technology to be used within the URENCO internal emergency response teams have been identified.

3.4.5.2 Lessons learned from inspection and assessment on the implementation of the fire protection concept as part of its regulatory oversight

In 2013, a post-Fukushima stress test analysis was carried out ('Complementary Safety Margin Assessment URENCO Netherlands BV'). Relevant for this TPR, it was observed that:

- UNL has an emergency plan which can be scaled up for management by the crisis management team. The site can be reached by alternative routes. UNL has an emergency response organization with sufficient means to fight different calamities. The emergency fighters are periodically trained for various emergency situations.
- In relation to confinement and subcriticality control of UF6, the design of equipment and plant installation and the operation of the plant show to be adequate. The emergency response organization is prepared and equipped in case of accident conditions.

Every 10 years, a comprehensive revision of the status of the installation from a safety perspective is performed (PSR/10EVA). The last 10EVA was carried out in 2017. From this evaluation, based on SSG-5: clauses 4.38-4.40, and 4.43, the following was pointed out:

- Improvements in the screening of the rooms: which rooms are relevant with regard to nuclear safety), the fire load per room and the consequences of fire on the nuclear safety functions. This is needed to substantiate that the scenarios described in the fire analyses are comprehensive. In addition, it is needed to substantiate whether the ignition sources and fire loads can or cannot be further minimized.
- It should be substantiated that fire dampers and spark arresters are not necessary for the ventilation system.
- What URENCO does well is that they take into account the existing mitigating measures in the analyses they perform. This becomes clear in the fire brigade scenarios drawn up, according to PGS6. In these, a distinction is made between mitigated and unmitigated risks.

3.4.6 FCF Urenco Regulator's conclusions on the adequacy of the fire protection concept and its implementation

The information requested by WENRA for the development of this chapter is reflected in the requirements detailed in the individual licence of Urenco. The licence holder is obliged to draw up, maintain and implement a fire prevention, fire detection and fire-fighting programme substantiated by a risk assessment, aligned with all the topics developed in this chapter, as reflected in the example in Appendix C.

This programme must be updated at least once every five years and submitted to the ANVS for assessment, or if changes are introduced.

The licence holder is currently compliant to the assessment framework.

3.5 SFC COVRA – HABOG

The HABOG was designed in the late 1990s and has been in use since 2003. The development of the approach regarding fire safety and the documentation of requirements were elaborated during that period.

The American standard ANSI/ANS 57.9-1992: 'Design Criteria for an Independent Spent Fuel Storage Installation (Dry Type)' is adhered to. This standard contains the functional requirements, design criteria and guidelines for dry storage of irradiated UO2 fuel assemblies, from commercial light water reactors.

ANSI/ANS 57.9-1992 indicates how the requirements, included in Title 10 'Energy', Code of Federal Regulations, Part 72, 'Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-level Radioactive Waste', can be met. These American licensing requirements concern the storage of nuclear fuel elements and high-level radioactive waste outside nuclear power plants and reprocessing facilities, i.e. independent of the systems of these installations.

Various forms of dry storage are included in ANSI/ANS 57.9-1992, namely storage in containers (cask/silo), underground bunkers (drywell/caisson) or air-cooled bunkers (vault/canyon). The requirements for bunkers cooled with natural ventilation air are met by COVRA used for the storage of heat-producing high-level radioactive waste.

COVRA stores several categories of HRA, such as fuel elements from research reactors with a metallic fuel matrix; vitrified HRA from the recycling of irradiated fuel elements from Dutch nuclear power plants, and other high-level radioactive waste. COVRA does not directly store irradiated fuel assemblies from the NPP, but only part of the waste that is generated during the reprocessing process of the irradiated nuclear fuel elements of the nuclear power plants Borssele.

An important difference between irradiated nuclear fuel elements from nuclear power plants and the HRA processed by COVRA is that the surface contamination of the material supplied to COVRA is substantially smaller, and only small amounts of gaseous radioactive products can escape in the event of accidental damage. This means that not all requirements, design criteria and guidelines contained in ANSI/ANS 57.9-1992 apply to HABOG.

3.5.1 SFS COVRA Fire prevention

3.5.1.1 SFS COVRA Design considerations and prevention means

The nature and scope of the activities make the risk of fire during processing or handling of the radioactive waste extremely small, therefore, no specific measures to prevent fires from starting are necessary for the installation's operation and processes.

Handling stainless steel containers in a mainly concrete building gives a very low fire risk setting.

The HABOG contains small quantities of chemicals, cleaning agents, de-contaminants, greases, lubricants and diesel (for emergency power diesel).

As in the facility a mechanical process is implemented, the postulated source of fire arises from electrical fires, where concentration of cables or electrical equipment are observed (motors, switchgears, cabinets).

3.5.1.2 SFS COVRA Overview of the arrangements for management and control of fire load and ignition sources

All risky work, which also includes work with a risk of fire, must be requested in advance through a work permit. This application is assessed by a team of responsible persons, including at least an operational manager, a radiation expert and a safety expert.

Depending on the work, other specialists will also be consulted. Everything is recorded in the maintenance management system.

3.5.2 SFS COVRA Active Fire protection

3.5.2.1 SFS COVRA Fire detection and alarm provisions

3.5.2.1.1 SFS COVRA Design approach

The installation is designed, constructed and maintained in accordance with the program of requirements as part of the IPB, the (Dutch language) 'Integraal Plan Brandveiligheid', which complies with NEN 2535 and equivalent solutions. This IPB has been submitted to and approved by the VeiligheidsRegio Zeeland, ANVS and local authorities.

COVRA follows the 'Principles of Fire safety', corresponding to the CCV[60] publication of the Model Integral Fire Safety Building Works (Model IBB[61]).

The fire detection system entails sound and visual alarms in the control rooms of HABOG and of the AVG: (waste processing and handling building). The logic controller is located in one of the electronic rooms, where the cabinets for electrical distribution are located. A screen mimic view is located in the control room of the HABOG and repeated with a mimic panel before entering the tourniquet in HABOG. Also a general alarm is given to the control room in AVG.

The risk of an internal fire inside the storage areas is very small due to the very low amount of combustible inventory in HABOG. The areas where more combustible material is present are accommodated with fire detection systems. The system gives sound and visual alarms in the control rooms of HABOG when detecting a fire.

In the areas where mechanical processes are implemented (like cranes and transportation vehicles) and where there is a concentration of cables or electrical equipment (motors, switchgears, cabinets), the postulated source of fire is electrical. All areas containing a fire load density higher than 400 MJ/m2 are classified as fire compartments. Fire compartments are separated from surrounding areas by fire stop barriers (integrated in walls, ceiling, floor, doors, air inlet and exhaust dampers, wall crossings). Resistance requirement for fire stop barriers is 90 minutes at least. Fire detection systems are systematically provided in these areas.

The risk of a fire in the storage area is small and the risk of a release of large amounts of radioactive material in the case of a fire is extremely small.

A fire detection system is implemented in the corridors where there is no possibility of two escape routes.

3.5.2.1.2 SFS COVRA Types, main characteristics and performance expectations

The HABOG is equipped with a fire alarm system with full surveillance. The fire detection means are of two kinds:

- automatic: fixed fire detector (systematically implemented in fire compartments);
- manual: fixed alarm button.

Different measures are taken to assure that the systems are capable to withstand the relevant ambient / hazard conditions, for example, the fire detection system performs its function in case of loss of normal and

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[60] CCV is a Dutch institute developing among other things, certification and inspection guidance. Full Dutch name 'Centrum voor Criminaliteitspreventie en Veiligheid', i.e. Centre for Crime Prevention and Safety.

[61] Dutch: 'Model Integrale Brandveiligheid', IBB

emergency power supply during approximately 12 hours with batteries.

Additionally, the fire alarm installation has been issued with a valid inspection certificate issued on the basis of the CCV inspection Schedule for Fire Alarm Installations.

3.5.2.1.3 SFS COVRA Alternative / temporary provisions

Activities such as the replacement of the fire alarm and evacuation alarm system are carried out in such a way that the system could still function and remain available at the end of each working day.

The necessary compensatory measures are assessed per specific case and recorded on the work permit. This is a standard working method of work preparation and requesting an agreement for the execution of work.

3.5.2.2 SFS COVRA Fire suppression provisions

3.5.2.2.1 SFS COVRA Design approach

Only a starting fire will be completely extinguished by the COVRA BHV personnel. If a larger fire would occur, the arrival of the fire brigade will be awaited.

COVRA has several emergency response resources, like fire-fighting tools and personal protective equipment that can be used to fight a calamity in and around HABOG. The equipment in the HABOG building consists of standard firefighting extinguishers (foam and CO_2).

3.5.2.2.2 SFS COVRA Types, main characteristics and performance expectations

The equipment in the HABOG building consists of standard firefighting extinguishers (foam and CO_2).

HABOG is equipped with a sprinkler system in the room with the emergency diesel tank. These systems start (and stop) automatically in case of occurring fire but can also be operated manually. The diesel generator fire extinguishing system operating principle is as follows: the system will start automatically upon detection of fire in the room. Fine droplets of demineralized water are sprayed by a pump through nozzle ramps located above the Diesel engine and the fuel daily tank in the vicinity. The water is sucked from the demineralized water tank. The main operating parameters are as follows:

- water flow: 15 m^3/h
- system pressure: 800 kPa
- extinguishing duration: about 80 s
- total water demand: about 0.2 m^3

3.5.2.2.3 SFS COVRA Management of harmful effects and consequential hazards

The fire extinguishing system is included in the inspection and control program.

During the commissioning of the fire extinguishing system, an actual test was carried out to demonstrate correct operation. To prevent the system from starting unintentionally, a second detector of the fire alarm system (flame detector) must also signal fire.

The water mist installation will not cause any significant problems after activation. The amount of water used for extinguishing is very limited. The electrical cabinet in the same room will be a point of interest after the a extinguish action.

3.5.2.2.4 SFS COVRA Alternative / temporary provisions

Portable extinguishing means are foreseen in several corridors for the purpose of firefighting by personnel who may discover a fire.

3.5.2.3 SFS COVRA Administrative and organisational fire protection issues

3.5.2.3.1 SFS COVRA Overview of firefighting strategies, administrative arrangements and assurance

COVRA N.V. is not designated as a high-risk company in accordance with the Major Accident Hazards Decree (BRZO 2015[62]) and is also not required to have an internal fire brigade, but like any company it has its internal emergency response organization (BHV).

Periodically, internal exercises are organized and further training takes place in accordance with the guidelines of the NIBHV institute[63]. Various exercises are regularly held with the entire company in the field of firefighting (small extinguishers) and evacuation. The BHV organization actively monitors this and draws attention to it through awareness publications.

3.5.2.3.2 SFS COVRA Firefighting capabilities, responsibilities, organisation and documentation onsite and offsite

COVRA does not have its own internal fire brigade. In case of a fire that cannot be extinguished with a small extinguishing equipment by the company emergency response team (BHV), the fire brigade will be called in. COVRA has direct contact with the VR control room to call in additional help if necessary. Coordination between COVRA personnel and the fire brigade is described in the emergency plan. Detailed information for the fire brigade is written down in documents available at site, and contact with the emergency services will be frequently maintained.

Tasks and responsibilities of the emergency response team are described in COVRA's emergency plan, part of the Integrated Management System. All procedures and work instructions are part of an Integral Management System. The documents are monitored and audited internally on a periodic basis.

An inspection program is carried out to ensure the operability of the fire protection measures over the lifetime of the installation, in accordance with applicable laws and regulations, and are assigned to a recognized fire detection company.

Several actions are taken to ensure that the firefighting resources are familiar with the hazards of the plant. Through very good cooperation with the Zeeland Safety Region, periodic exercises on location are carried out. These exercises are held for the various units of the fire brigade.

There is also an extensive introductory program that safety regions from all over the Netherlands use to gain theoretical knowledge and practical experience about the deployment and response to accidents involving radioactive substances through a training day. For this purpose, COVRA NV also facilitates introductions and exercises in the evenings for the voluntary fire brigade organizations.

By regularly physically arriving on location, the emergency services know what to expect and they become familiar with the working methods and procedures. This is experienced as very useful by the parties involved.

3.5.2.3.3 SFS COVRA Specific provisions, e.g. loss of access

Access to the complex is possible through several access roads and there are several entrance gates on the site.

The complex is intrinsically safe because of the layout and compartments of the complex. Which means that in the event of a fire, expansion within only one compartment is at risk. There is not any fire load near the

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[62] The Major Accident Hazards Decree 2015 (Brzo) integrates laws and regulations on occupational safety, environmental safety and disaster response into a single legal framework. The aim is to prevent and control major accidents involving hazardous substances. The Brzo 2015 sets requirements for the most high-risk companies in the Netherlands.

[63] NIBHV is a Dutch institute for company emergency response activities ('BHV'), developing teaching and learning materials and knowledge documents.

waste.

Personnel evacuation and fire brigade intervention are possible because escape routes and access routes do not interfere with this heat removal approach. Moreover, the stairwells within the HABOG have extra protected escape route status and are therefore outside the fire compartment.

3.5.3 SFS COVRA Passive fire protection

3.5.3.1 SFS COVRA Prevention of fire spreading (barriers)

3.5.3.1.1 SFS COVRA Design approach

In the design of the HABOG, the Dutch standards (NEN) relevant for structural design were used. For all standards, the version valid at that time (01-01-1995) were used.

Two basic approaches are followed in the design of the HABOG facility for fire protection, fire containment and fire influence, as described in the glossary:

- The fire containment approach: Resistance requirement for fire stopping barriers is 90 minutes at least. The fire containment approach assumes that all combustibles within a fire compartment can be consumed during a fire. After such a fire, the undamaged portions of the plant does not involve unsafe conditions. Fire detection systems are systematically provided in these areas.
- The fire influence approach: Some safety items (shielded windows, shielded doors, crossings) cannot be separated from potential fires by fire barriers or cannot constitute fire barriers. In those particular cases, the effect of a fire is limited by combination of distance, quick fire detection, protection features such as fire retardant materials, limitation of combustive and flammable materials. This combination of measures allows to limit the fire spreading and the protection of items till operator or fire brigade intervention.

The standard fire loading curve for a fire in the HABOG has no serious detrimental effects on the building. The cover on the reinforcement is such that the temperature at the reinforcement remains well below critical levels even for fire durations up to 120 min. The basis for a verification of the fire resisting capacity of a concrete structure can be found in the structural building code NEN 6720: art. 9.3. This article provides tables for different structural elements with the required distance between the face of the concrete and the center of reinforcement.

3.5.3.1.2 SFS COVRA Description of fire compartments and/or cells design and key features

The following design principles are then followed:

- a fire compartment is constituted when the fire load density is higher than 400 MJ/m^2 even if an ignition source has not been identified (fire containment approach);
- in other areas, the fire load density shall be lower than 400 MJ/m^2 and the fire influence approach is followed;
- one protected escape route is provided from each working room to an exit of the building. These routes are protected against fire and are therefore classified as protected compartments;
- a fire detection system is implemented in the corridors where there is no possibility of two escape routes. Portable extinguishing means are foreseen in several corridors for the purpose of firefighting by personnel who may discover a fire.

For electrical systems, COVRA uses certified seals at the electrical rooms to ensure safety, efficiency and operational reliability, to a wide range of cables. The ability to open up the seals to add cables or make quick changes simplifies maintenance and retrofit. All other seals are made by a specialized company. It provides Fire Stopping and Sealing Products, such as Fire Retardant board and coatings.

3.5.3.1.3 SFS COVRA Performance assurance through lifetime

A series of measures has been taken to provide a fire safety culture. The team of employees consists of a close-knit group of committed people who carry out their work in accordance with agreements and procedures. Workers are only present in the HABOG during the day, and doors are kept closed during the day to maintain adequate pressure differences ensuring meeting ventilation demands. All doors are closed at the end of the working day. This prevents the unwanted smoke spread should a fire occur.

To ensure the functionality and availability of the access routes and fire safety equipment, periodic maintenance shall be carried out during the usage phase in accordance with the applicable maintenance standards and/or supplier’s instructions. Periodic maintenance is registered in a maintenance management system which automatically provides the annual maintenance schemes.

All maintenance work to be carried out shall be recorded in the appropriate logbooks. Inspections are held through a control program, routes are physically checked.

With concrete walls almost two meters thick and choosing wall penetration systems that are easy to open / close, the need to keep penetrations open is very limited. Where necessary, additional or compensatory measures are taken that have been determined from the work preparation and are registered by means of a work permit. All the penetrations are registered and are periodically checked for presence and possible damage.

3.5.3.2 SFS COVRA Ventilation systems

3.5.3.2.1 SFS COVRA Ventilation system design: segregation and isolation provisions

Rooms classified as fire compartments are provided with fire dampers on the air supply and air exhaust.

Each fire damper is provided with a thermal fuse. Each fire damper is controlled by the automatic fire controller. They can be manually and locally operated and are fitted with manual failure and resetting controls. When a fire happens in a fire compartment, it must not be propagated to the other rooms. As a result, if a duet goes through a fire compartment, it has the same fire rating as the concerned compartment.

Escape routes (and access routes for firefighting) are provided with fire dampers in the ventilation systems. The triggering of the fire dampers protecting the rooms considered as protected areas is controlled by the automatic fire controller. They can be manually and locally operated and are fitted with manual failure and resetting controls. These escape (and access) routes are maintained in slight excess relative pressure with respect to neighbouring areas.

3.5.3.2.2 SFS COVRA Performance and management requirements under fire conditions

In case of a gas cloud detection in the vicinity of the complex, the air inlet and outlet of the building ventilation will be automatically closed by the gas external detection; the air inlet and outlet of the diesel room and the air outlet for the compressor room will be also automatically closed by the gas external detections.

The ventilation system (supply and exhaust), the diesel generator, the air compressor will be automatically stopped by the gas external detection.

During the commissioning of the HABOG, fire tests were carried out in all rooms with ventilation systems or special structural conditions (height or recesses). The results of these tests have been incorporated into the projection of the fire detectors or adjustments to the ventilation flows.

3.5.4 SFS COVRA Licensee's experience of the implementation of the fire protection

3.5.4.1 Overview of strengths and weaknesses

One of the most important strengths in terms of fire safety at COVRA, is that the buildings and their contents represent a very low potential fire load, decreasing the risk of fire.

COVRA has a well-trained BHV staff, which works closely with the regional fire brigade VR Zeeland, sometimes including members of other regional fire brigades as well, in order to maintain knowledge and awareness of the characteristics of the site. Emergency preparedness exercises are carried out on a yearly basis.

Moreover, COVRA performs regular safety walks (werkplekinspecties) at the COVRA site. Every year the HABOG is subject to these safety walks in which the fire protection systems are also inspected.

3.5.4.2 Lessons learnt from events, reviews, fire safety-related missions, etc.

COVRA is regularly audited by the insurance company ('Nederlandse Atoompool'), usually every 5 years. The fire expert of the insurance company provides feedback to COVRA, and these recommendations can be used to improve fire safety; requirements of the insurance company are to be met. The last inspection was carried out in September 2023, at the time of writing this NAR.

After the survey in 2023, the audit report presented the following observations:

- The emergency power generator in the HABOG building is provided with a fire suppression system.
- The site Fire Intervention Team (BHV) is responsible for firefighting with their focus on early intervention for small fires. They are also trained to guide the professional fire brigade for larger fires and and/or other emergencies.
- Observations regarding housekeeping standards in the HABOG facility electrical generator room and the Emergency Diesel Generator (EDG) room were done. For example, oil and aerosols were being stored outside flammable resistant cabinets.

The suggestions will be considered in a plan of approach for improvement.

3.5.4.3 Overview of actions and implementation status

The HABOG has been recently expanded with a new-build section. To guarantee the fire safety of the HABOG, integral measures have been taken to prevent fire and, on the other hand, to be able to quickly detect and control a fire and to minimize the consequences

'Integral' means that measures in the field of building design, engineering, installation technology, inventory and the deployment of the fire service are coordinated and mutually reinforcing. In order to meet current requirements, the fire alarm and evacuation alarm system of the HABOG has been replaced in 2021.

In order to arrive at a balanced and objective project scope, COVRA went through a definition and selection process. A specification has been drawn up by a certified company. The supplier had to base his offer on the basis of this specification and the final choice was made to replace the fire alarm and evacuation alarm system.

3.5.5 SFS COVRA Regulator's assessment of the fire protection concept and conclusions

3.5.5.1 Overview of strengths and weaknesses

COVRA's HABOG facility is a Spent Fuel Storage, where only limited activities are carried out. The vitrification process is done abroad, and the vitrified waste is then safely stored in HABOG. COVRA is classified as a low risk nuclear installation.

All the relevant action plans, procedures and organizational arrangements are reported in specific documentation, and comply with applicable decrees, guidelines and standards.

One of the strengths of the Fire protection concept and its implementations is the fact that the installation is subjected to several inspections by national organisations. On the national level this is done by e.g. the ANVS and the regional Safety Region (VR) fire brigade. In a separate contractual framework, the company insuring the licensee's facility audits the installation and provides advice on the improvement of the fire protection systems.

After an inspection carried out in 2022, it was found that the updated versions of the corporate emergency plan, incident and accident regulation, and the exercise program of its corporate emergency organization were not shared with the ANVS, and therefore not reviewed. As a result, the administrative obligations from the licence were not sufficiently in view. Due to supervision by the ANVS, COVRA now has improvement plans in place. The activities stemming from these plans are ongoing at the time of writing of this NAR.

3.5.5.2 Lessons learnt from inspection and assessment as part of the regulatory oversight

In the year 2013, following the Fukushima accident, COVRA carried out a Stress Test assessment. In relation to fire safety, it was observed that:

- Extreme high and low air temperatures: Due to the design of the passive ventilation cooling, conservative values in the design and the very high heat capacity of the HPW extremely high air temperatures are not considered as a threat for the safety functions of HABOG. In case of extremely low outside air temperature effects such as decrease in the quality of the diesel fuel inventory, freezing of coolant for the diesel generators and freezing of the fire extinguishing water inventory are taken into account by design (for example via heating of all HABOG rooms and underground waterlines).
- Internal fires: Regarding internal fire protection the following measures are in place at HABOG: The areas where more combustible material is present are equipped with fire detection systems which give sound and visual alarms in the control rooms of HABOG when detecting a fire. All areas containing a fire load density higher than 400 MJ/m^2 are classified fire compartments. Fire compartments are separated from surrounding areas by fire stop barriers. The resistance requirement is 90 minutes at least. Fire detection systems are systematically provided in these areas. Portable extinguishers are located at the entrance of the areas. The diesel room is equipped with an automatic extinguishing system (water spray system).
- Potential explosion scenarios are explosion of diesel inventory and hydrogen explosion. To mitigate an explosion of diesel inventory, the diesel room is a classified fire compartment equipped with an automatic battery backed extinguishing system. In addition manual foam/CO2 fire extinguishers are available. Due to said measures and the small amount of diesel (capacity: 1 day) it is concluded that the fire will be limited and will not be a threat to the fundamental safety functions. The risk of hydrogen explosion is considered to be low, since a flammable concentration of hydrogen is not expected to be reached before 425 days (without ventilation).
- External fire: The risk of an external fire results from the main gas pipeline; neighbouring companies; transport via the rail road; transport via the road Europaweg-Zuid; and the Coal Storage. Since the main wind direction is south-west, the highest chance of fire is assumed to be from the coal storage which is located south of HABOG. Spreading of fire to HABOG by external fire at the neighbouring site and from

the Coal Storage is considered being ‘possible’ indirectly via sparks. Since HABOG is mainly made of steel and concrete, the probability of catching fire is assumed to be low. Due to the short distance to the COVRA site, there will be an influence of smoke and heat production on the ventilation system of the COVRA facilities and on the safety of personnel from COVRA but not on its fundamental safety functions. Evacuation of personnel at the COVRA site due to fire in the neighbouring companies will not cause any safety concerns. The risk of external fire from all the other potential sources is assumed to be negligible because of the large distance and the grass coverage of the area in between HABOG and the potential external fire sources.

- Regarding internal fire protection, an administrative instruction should be introduced to avoid entry of additional fire loads to the HABOG compartments.

The most recent 10EVA was carried out in the period 2009-2018, with the following findings:

- COVRA has taken extensive measures to reduce the risk of both fire as the uncontrolled spread of fire as small as possible to make.
- There is an adequate response to fire (alarms), which means that the consequences of a possible fire are limited as much as possible.
- Some management system documents are required to be supplemented and/or updated soon like documents on fire reporting and suppression.

During the last 10-EVA, it was also identified that the updated versions of the company emergency plan, incident and accident regulation and the company emergency organization exercise program as ongoing projects were still to be shared with the ANVS for review.

The most recent fire related inspections were focused on the general emergency preparedness. It was also observed that a gas extinguishing system was not inspected timely. Several improvements with respect to the plans, the procedures, together with the organizational arrangements are being developed at the time of writing of this NAR.

Additionally, it was observed that a gas extinguishing system in the Waste Treatment Facility was not inspected timely.

As part of the recent expansion of the HABOG, COVRA adapted the fire alarm systems. A number of these installations must comply with the CCV certification for fire alarm systems. In order to comply with this, COVRA had drawn up a Basic Principles Document (UPD, see Glossary) and a Program of Requirements (PvE, see Glossary) for these fire alarm systems, and have them assessed by a certified party. At the time of writing of this NAR, the UPD and PvE are currently being submitted to the city council of Borsele, the Safety Region of Zeeland (VRZ) and the ANVS for approval.

3.5.6 SPS COVRA Regulator’s conclusions on the adequacy of the fire protection concept and its implementation

The fire prevention, fire detection and firefighting program as described in this chapter is requested in the licence, even though in less detail than shown in Appendix C.

The information requested by WENRA for the development of this chapter is reflected in the requirements detailed in the individual licence of the COVRA. The licence holder is obliged to draw up, maintain and implement a fire prevention, fire detection and firefighting programme, aligned with all the topics developed in this chapter.

The licence holder is currently compliant with the assessment framework.

3.6 WSFs at various nuclear facilities

3.6.1 WSFs at Borssele NPP

The low level waste of the plant is temporarily stored in a dedicated building (waste storage building). In that building, in rooms separated from the waste storage, some accident management equipment is stored. This equipment can contain a low amount of diesel or petrol fuel. The equipment and containers with fuel are stored in fire proof cabinets. The nuclear waste is stored in special containers in concrete building parts. The only ignition sources are small electric equipment, cranes and lighting. The fire risk is this building is therefore very low.

3.6.2 WSF near HFR in Petten

The WSF on the EHC in Petten, is just one of the many nuclear facilities on site. The WSF mainly houses legacy and as such has no great relationship with current operation of the HFR.

The cellars are between 2.5 and 5 meters deep. The deep cellars are equipped with pipes . Some of the pipes are closed with a steel or concrete plug (the plug store), the other pipes are covered with steel beams (pipe storage). The less deep cellars are called trenches and are covered with concrete slabs. The plugs, steel beams and concrete slabs form the floor of the WSF.

There are two general ways of storage of radioactive material in the WSF:

- in standardized storage canisters in the plug storage and the pipe storage,
- in racks, safes or placed loose in the trenches.

The shape and dimensions of the waste containers varies. The larger objects are stored in the trenches. Smaller waste with a higher radioactivity is stored in the plug and pipe storage. Irradiated nuclear fuel may and can only be stored in the designated pipes in the plug storage. Non-irradiated fissile materials may be stored in the trenches in specially suitable facilities. In principle, no treatment of the waste takes place within the WSF. Apart from the shielding transport container, the waste is stored in the same packaging in which it was delivered.

The fire detection system of the WSF is used for timely warning of fire and/or smoke in the facility and initiating actions. Within NRG's facilities, all buildings or building sections are equipped with automatic fire and smoke detection systems which are connected to a fire alarm system (BMI, 'Brandmeldinstallatie').

Fire alarms are reported immediately, without delay, to the Company Alarm Center (BAC, 'BedrijfsAlarmCentrale'). Fault reports are also reported and followed up by the Quick Response Team (QRT) for first-line fault response.

In the WSF, fire detectors are installed in four places and connected to the central alarm station. The fire detectors are fed by an emergency power supply. Evacuation alarms are being activated manually.

On the HFR site, full fire surveillance is used in accordance with NEN 2535. With full surveillance, in addition to the necessary manual call points, all rooms are equipped with automatic detectors.

The cabling (alarms) is installed where necessary according to 'function retention', this for 30 minutes according to NEN NPR 2576 (Circuit integrity under fire conditions – Guideline for transmission paths).

In the WSF, portable fire extinguishers are available. Once a year, maintenance is carried out on the portable fire extinguishers following NEN 2559 by QRT employees certified in accordance with the Regulations for Recognition of Maintenance of Extinguishers (REOB). All fire reels are also subject to this inspection. The fire hydrants are kept accessible during the regular site maintenance of the EHC.

QRT audits fire safety of NRG's facilities including the WSF every year in which it produces a list of suggested improvements. Typical subjects of investigation are usability of escape routes, condition and accessibility of fire extinguishers, fire hazard situations, etc.

3.6.3 WSF at HOR

Not applicable to the HOR.

3.6.4 WSF at Urenco, UNL

At UNL installations and buildings are designed in an inherently safe way which includes fire safety, i.e. minimizing the likelihood of fire. Combustible materials are avoided and radioactive materials are only present in fire compartments; specifications are recorded in Programs of Requirements which are checked and validated by an independent team. UNL's fire prevention principles described earlier in sections 2.4 and 3.4 apply to all its installations and buildings, including those used for temporary storage of radioactive wastes.

3.6.5 WSF at COVRA

Not in scope for this report, refer to chapter 1 for substantiation of this decision.

3.6.6 WSFs - Regulator's assessment of the fire protection concept and conclusions

3.6.6.1 WSFs Overview of strengths and weaknesses in the fire protection concept

The risks associated to the WSFs on sites is directly related to the type of waste they would contain. This section is therefore mostly of interest to reactors sites, where high level radioactive materials would be present.

However, at the sites of the NPP and the two research reactors in The Netherlands, the spent fuel assemblies are stored underwater in a pool inside the containment building, connected to the reactor pool. Consequently, the protection of spent fuel assemblies in case of fires is included in the Fire Hazards Analyses of the reactors.

3.6.6.2 WSFs Lessons learned from inspection and assessment on the implementation of the fire protection concept as part of its regulatory oversight

At the NPP KCB, the fire safety in the waste storage building is based on engineering judgement. The fire load is very low (mainly steel and concrete) and no significant ignition sources are present in that building. The building is equipped with a fire detection system and manually operated firefighting equipment.

In the particular case of the HFR, there is a historical waste storage facility on site for legacy waste which dates from decades before a proper classification of waste was in place. A waste characterisation plan has been developed as a requirement before bringing the waste from this facility to the COVRA waste storage facilities. The structures of the storage facility form a concrete bunker and the waste is stored in metal drums, for which the fire load is deemed to be relatively low.

3.6.6.3 WSFs Conclusions on the adequacy of the fire protection concept and its implementation

Waste storage facilities containing nuclear and radioactive materials must be protected against fires, with appropriate fire prevention, fire detection and fire suppression systems. These measures and systems are present in the storages, depending on the associated risks.

Waste storage facilities on site in general are relatively simple facilities where no active processes are needed to maintain safety. They generally are robust, and safety is provided by passive safety functions. For these installations fire safety is primarily related to prevention of radioactive releases from waste in case of fire, rather than to protect SSCs from the effects of fire. The safety analyses for these facilities do not need to be unduly sophisticated.

The legal requirements for the waste storage facilities on site are included in each individual licence, and are based on a graded approach.

4. Overall assessment and general conclusions

The present document was developed by the ANVS in close collaboration with the licensees of selected nuclear facilities: the Nuclear Power Plant Borssele (KCB), the High Flux Reactor Petten (HFR) operated by NRG, the Higher Education Reactor (HOR) of the Delft University of Technology, the uranium enrichment facility of Urenco and the spent fuel storage facilities (HABOG) of COVRA.

The legal framework regarding fire safety and fire protection related topics is broad and includes national laws, decrees, and norms, European regulations as well as international standards and guidelines. The compliance to the requirements of the legal framework is overseen by different organisations, including the ANVS and the so-called Safety Regions, among others. The companies insuring the nuclear installations perform their own checks, improving the safety awareness through their respective inspections.

Depending on the risk profile of the installation, these may be requested to have an internal fire brigade to fight fires. As a minimum, an emergency response team is requested by (the working) law in all the installations. This team may have limited firefighting capacities, and a coordination and assistance role in case of calamities. Additionally, all the installations must have an established emergency plan, developed in collaboration with the regional fire brigades. Other than to extinguish fires and providing assistance in the event of an accident, the fire brigades also carry out measurements of the presence of hazardous substances, solicited and unsolicited fire safety inspections, and provide fire prevention information to companies and institutions.

International missions are frequently organised to benefit from the experience from experts from different countries. IPSART and OSART missions are examples of the missions organized by the ANVS. The NPP KCB organised a mission from WANO as well. Licence holders participate in ad hoc international collaboration groups or databases, in order to share and gain experiences from similar installations.

All the topics specified by WENRA in the ‘Technical Specification for the NAR’ report, following the Defence-in-Depth principles, are consistent with the requirements specified in the individual licences of the nuclear installations. In general, the individual licences enumerate several requirements related to Fire Safety and Fire protection aspects, such as:

- Requirements for the development of a Fire Hazards Analysis, and a corresponding risk evaluation. The Fire Hazards Analysis is generally conceived as part of the Safety Analysis of each installation.

- Requirements for the development of a Fire Safety plan/program, including the considerations for preventing fires from starting, detecting starting fires (and smoke), extinguishing fires that have started and preventing fires from spreading, accounting for all the different design aspects.
- Requirements for the organizational arrangements, to ensure all the key roles and responsibilities are identified and implemented, and to ensure the proper agreements with the regional emergency response organizations (VR) are in place and systematically updated.

It should be noted that, for all the installations included in this NAR, the original licences have been granted decades ago, and the ANVS works together with the licensees in updating the applicable requirements, when deemed necessary. Furthermore, the gained experience will be considered in future licence requests for new installations. A generic example of the requirements introduced in the individual licences is presented in Appendix C.

The Netherlands has a unique approach in the use of risk assessment to support the Safety Analyses, developing a full scope PSA for all reactors (not limited to power reactors) and a risk assessment for all the non-reactor nuclear installations.

All the licensees have elaborated the corresponding documentation, including a Fire Hazards Analysis -and a risk assessment, and a fire prevention, fire detection and fire suppression program, and work together with the regional fire brigades in the development of emergency plans. They inform the ANVS of the status and changes when these happen. Fire hazards are considered as part of the internal and external hazards of the installations.

In general, every 10 years, the licence holders and the ANVS evaluate the Fire Safety Analysis as part of the integral Periodic Safety Review of each installation, considering a graded approach. The methodology for Fire Hazards Analysis is in agreement with the IAEA guidelines and it is completed by a risk assessment. Moreover, if the installations undergo major modifications, an update of the Safety Analyses is requested.

Additionally, the ANVS organizes inspections with the support of the TSO regarding Fire Safety and Fire Protection aspects, including plant walkdowns, the revision of processes and technical documentation, as well as the description of the organisational arrangements.

The information presented in Chapters 1, 2 and 3 substantiate the fulfillment of the Fire Safety Objective, and ultimately the Main Safety Objective, by ensuring that the relevant safety functions, systems, structures and components are adequately protected against fire hazards.

5. References to the NAR

Due to the broad scope of the NAR, and the number of different organisations involved in developing its content, it was decided for the sake of simplicity to add the relevant references as footnotes on the respective pages.

In this section, the most relevant national and international references are listed, in order to provide a general understanding of the legal and technical framework used by the licensee's and the ANVS.

Reference documents from the Netherlands

- Convention on Nuclear Safety, National Report of the Netherlands for the combined 8th and 9th review meeting in 2023, link: https://www.rijksoverheid.nl/documenten/rapporten/2022/12/20/bijlage-report-of-the-kingdom-of-the-netherlands-for-the-combined-8th-and-9th-review-meeting-in-2023
- ANVS Guide on Level 3 PSA, ANVS, Den Haag, 2020, https://english.autoriteitnvs.nl/binaries/anvs-en/documenten/publication/2020/03/10/anvs-guide-on-level-3-psa/2020-02-27+ANVS+Guide+on+Level+3+PSA.pdf
- ANVS Guidelines on the Safe Design and Operation of Nuclear Reactors and DSR, ANVS, Den Haag, 2020, https://english.autoriteitnvs.nl/binaries/anvs-en/documenten/publication/2023/04/05/guidelines-safe-design-and-operation-of-nuclear-reactors-and-dsr/guidelines-for-the-safe-design-and-operation-of-nuclear-reactors-april-2023.pdf
- NEN 2535:2009+C1:2010, Brandveiligheid van gebouwen - Brandmeldinstallaties - Systeem- en kwaliteitseisen en projectierichtlijnen, NEN, 2010
- NEN-EN 50575: Power, control and communication cables – Cables for general applications in construction works subject to reaction to fire requirements standards, NEN, 2014

Reference documents from IAEA

- IAEA Safety Standard Series No. SSG-2, Deterministic Safety Analysis for Nuclear Power Plants, IAEA, Vienna, 2009
- IAEA Safety Standard Series No. SSG-3, Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants, IAEA, Vienna, 2010
- IAEA Safety Standard Series No. SSG-4, Development and Application of Level 2 Probabilistic Safety Assessment for Nuclear Power Plants, IAEA, Vienna, 2010
- IAEA Safety Standards Series No. NS-G-2.1, Fire Safety in the Operation of Nuclear Power Plants, IAEA, Vienna, 2000.
- IAEA Safety Standards Series No. NS-G-1.7, Protection against Internal Fires and Explosions in the Design of Nuclear Power Plants, IAEA, Vienna, 2004
- IAEA Safety Series No. 50-P-9, Evaluation of Fire Hazard Analyses for NPPs: A Safety Practice, IAEA, Vienna, 1995

- IAEA Safety Report Series No.8, Preparation of Fire Hazard Analyses for Nuclear Power Plants, IAEA, Vienna, 1998
- IAEA Safety Standards Series No. NS-G-2.4, The Operating Organization for Nuclear Power Plants, IAEA, Vienna, 2002
- IAEA Safety Standards Series No. SSG-5, Safety of Conversion Facilities and Uranium Enrichment Facilities, IAEA, Vienna, 2010
- IAEA Safety Standards Series No. NS-R-1, Safety of Nuclear Power Plants: Design, IAEA, Vienna, 2000
- IAEA Safety Standards Series No. SSR-2/1, Safety of Nuclear Power Plants: Design, IAEA, Vienna, 2016
- IAEA Safety Standards Series No. SSR-2/2, Safety of Nuclear Power Plants: Commissioning and Operation, IAEA, Vienna, 2016
- IAEA Safety Standards Series No. SSR-3, Safety of Research Reactors, IAEA, Vienna, 2016
- IAEA Safety Standards Series No. SSR-4, Safety of Nuclear Fuel Cycle Facilities, IAEA, Vienna, 2017
- IAEA Safety Standards Series No. GSR-4, Safety Assessment for Facilities and Activities, IAEA, Vienna, 2016
- IAEA Safety Standards Series No. SSG-22, Use of a Graded Approach in the Application of the Safety Requirements for Research Reactors, IAEA, Vienna, 2012
- IAEA Safety Standards Series No. SSG-50, Operating Experience Feedback for Nuclear Installations, IAEA, Vienna, 2018
- IAEA Safety Standards Series No. SSG-64, Protection against Internal Hazards in the Design of Nuclear Power Plants, IAEA, Vienna, 2021
- IAEA-TECDOC-1944, Fire Protection in Nuclear Power Plants, IAEA, Vienna, 2021
- IAEA draft Safety Standard No. DS284, The Safety Case and Safety Assessment for Predisposal Management of Radioactive Waste, IAEA, Vienna, 2011

Reference documents from OECD/NEA and WENRA

- OECD- NEA, Committee on the Safety of Nuclear Installations (CSNI): OECD FIRE Project – Topical Report No. 1, Analysis of High Energy Arcing Fault (HEAF) Fire Events, NEA/CSNI/R(2013)6, Paris, France, June 2013, http://www.oecd-nea.org/documents/2013/sin/csni-r2013-6.pdf
- OECD-NEA, Committee on the Safety of Nuclear Installations (CSNI): A Review of Current Calculation Methods Used to Predict Damage from High Energy Arcing Fault (HEAF) Events, NEA/CSNI/R(2015)10, Par-is, France, 2015, https://www.oecd-nea.org/nsd/docs/2015/csni-r2015-10.pdf
- OECD-NEA, Committee on the Safety of Nuclear Installations (CSNI): Experimental Results from the International High Energy Arcing Fault (HEAF) Research Program Testing Phase 2014 to 2016, NEA/CSNI/R(2017)7, Paris, France, (2017), http://www.oecd-nea.org/documents/2016/sin/csni-r2017-7.pdf
- WENRA Waste and spent fuel storage safety reference levels report, version 2.1, WENRA Working Group on Waste and Decommissioning (WGWD), Stockholm, February 2011

Other reference documents

- KTA 2101.1 (12/2000), Fire Protection in Nuclear Power Plants. Part 1: Basic Requirements, (Brandschutz in Kernkraftwerken, Teil 1: Grundsätze des Brandschutzes).
- KTA 2101.2 (12/2000), Fire Protection in Nuclear Power Plants. Part 2: Fire Protection of Structural Plant Components, (Brandschutz in Kernkraftwerken, Teil 2: Brandschutz an baulichen Anlagen).

- KTA 2101.3 (12/2000), Fire Protection in Nuclear Power Plants. Part 3: Fire Protection of Mechanical and Electrical Plant Components, (Brandschutz in Kernkraftwerken,Teil 3: Brandschutz an maschinen- und elektrotechnischen Anlagen).
- NUREG/CR-6850, EPRI 1011989 ‘EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities, Final Report’ , EPRI & US NRC, 2005, supplement 2010.
- SKI Report 02-27, Guidance for External Events Analysis, M. Knochenhauer and P. Louko, SKI, Sweden, 2003

Appendix A Development of the national selection

The Netherlands has decided in principle to include all nuclear installations under the scope of the Euratom Nuclear Safety Directive except for the following, considering the guidance for the NAR provided by WENRA:

- Kerncentrale Dodewaard (out of scope, according to guidance in 00.3, para 2, first bullet, sub third bullet);
- SHINE (out of scope, according to guidance 00.3, para 2 second bullet);
- PALLAS (out of scope, according to guidance 00.3, para 2 second bullet);
- COVRA VOG-, LOG- and COG-buildings (out of scope, not on same site as nuclear installation);
- DWT (treatment, no storage but only short term buffer before transport).

The Board of the competent regulatory body, the ANVS, agreed on this, but in line with their suggestion it was agreed to voluntary include some information of interest about the PALLAS reactor, for which the construction licence was granted and which came into force in April 2023.

In table below, all considerations have been included.

Selection of installations for TPRII – Fire protection
The Netherlands

Facilities	Selected	Technology	Licensee	Comments
Nuclear power plants				
1 NPP in operation				
Kerncentrale Borssele (KCB)	Yes	2-loop PWR, P = 485 MW_e	EPZ	In scope, in operation since 1973, including waste storage building (AOG)
0 units under construction *0 units in decommissioning*				
1 NPP in safe enclosure				
Kerncentrale Dodewaard	No	BWR, P = 60 MW_e	GKN	Out of scope: all non-fixed radioactivity already removed, safe enclosure (2005)
Research reactors				
2 reactors in operation				
Hoger Onderwijs Reactor (HOR)	Yes	Tank-in-pool, P = 2 MW_{th}	RID	In scope, in operation since 1964
High Flux Reactor (HFR)	Yes	Tank-in-pool, P = 45	NRG	In scope, in operation since 1961

		MW$_{th}$		
Waste Storage Facility (WSF)	Yes	Storage facility		In scope, legacy waste from HFR
Decontamination & Waste Treatment (DWT)	No	Waste treatment		Facility that houses short term buffer storage for resins from HFR
1 reactor in pre-licensing				
PALLAS	No	Tank-in-pool, P = 25 MW$_{th}$	PALLAS	Out of scope: no licence will be granted before 30th June 2022/ Voluntary information provided (Board suggestion)
SHINE	No	Sub-critical assembly	SHINE	Out of scope: exception to RRs & no licence will be granted before 30th June 2022
1 reactors under construction				
0 reactors in decommissioning				
Spent fuel storage facilities				
1 facility in operation				
HABOG	Yes	Spent fuel storage facility	COVRA	In scope, storage facility for the storage of high-level waste from KCB and spent fuel of RRs
VOG, VOG-2, LOG, and COG	No	Storage facilities	COVRA	Out of scope: not on the same site as KCB or other nuclear installations
0 facilities under construction				
0 facilities in decommissioning				
Fuel cycle facilities				
1 facility in operation				
Uranium Enrichment Company	Yes	Enrichment plant	URENCO	In scope, in operation since 1973
0 facilities under construction				
0 facilities in decommissioning				

Appendix B Information PALLAS reactor

B.1 General information PALLAS reactor

The information in this appendix to the NAR is provided on a voluntary basis, as suggested by the TPR Board. According to TS 00.3 sub 2 last bullet, PALLAS would be excluded from the TPR since the construction licence was granted in February 2023.

Key parameters PALLAS

The PALLAS reactor has a thermal power of 25 MW. Its purpose is mainly the production of radioisotopes for medical application. Also research activities are to be carried out.

Applied regulations PALLAS

Like for other nuclear facilities the national nuclear regulations apply. It was the first installation which was reviewed against the Dutch Safety Requirements (DSR) for nuclear installations (VOBK, 2015), using a graded approach. The DSR covers amongst others IAEA standards and WENRA reference levels. Current national conventional standards for fire protection are applied as well. As licence is needed from the safety region. Fire protection needs approval by ANVS and the Safety Region.

B.2 Fire Safety Analyses of PALLAS

Deterministic safety analyses have been carried out at this stage (construction licence). In addition a full PSA will be done as part of the operating licence application.

Deterministic safety analyses

A fire hazard analysis has been carried out, including internal/external fire and explosions. They are all managed through the design and the fire protection concept (prevention, detection, compartments, extinction etc..). Internal explosions are potentially existing in two places:

- The deuterium recombination circuit of the Heavy Water Cooling and Purification System and
- The batteries of the Uninterrupted Power Supply (UPS).

The potential impacts of external fire and/or explosions have been analysed and its pressure waves pose no significant risk to the installation or are excluded because of the distance to PALLAS; external pipelines are at least at distance of 4 km, ships are on canal or at sea, too far away for any relevant impact.

The design of the reactor building and its Aircraft Protection Shell provide sufficient protection against external hazards (including earthquakes) and its effects, including the effects of an airplane crash and consequential kerosine fire. Analyses have shown that damage to the containment can be incurred, but no penetration of the containment will take place. The kerosine fire is of such short duration that the heat load is resisted.

B.3 Fire Protection Concept and Its Implementation

B.3.1 Fire prevention

B3.1.1 Design considerations and prevention means

The Nuclear Island Building has the following design characteristics:

- The construction withstands all operational loads during normal operation, incidents and accidents, internal (including fire and explosions) and external (including earthquake, explosions and airplane crash) and under these loads the fundamental safety functions are fulfilled.
- It encompasses the containment, where all high radioactive parts are housed and takes care of sufficient inclusion and protection of radioactive materials.
- Passive structural fire protection, compartments and sufficient escape routes to comply with the requirements of the Construction Decree. Fire compartment have wall with a fire resistance of generally 60 minutes, 90 minutes for the storage of fuel elements and radiation targets and concrete parts at least 120 minutes.
- A fire detection, alarming and extinction system.
- Safety systems or parts thereof are physically separated.

B3.1.2 Arrangements for management and control of fire load and ignition sources

In the design it is foreseen the storage of material creating a potential fire load will be limited. Also, the use of inflammable materials is limited and used material should possibly be fire retarding. Flammable liquids are not to be stored permanently in the Reactor Building. There will be small amounts of inflammable fluids present for cleaning and maintenance. The inventory, use and access to these are to be strictly controlled.

Coal filters shall be used with fire suppression and cables need to be fire resistant and to provide reduced smoke. There will be earthing protection.

One of the design measures is to limit the amount of diesel fuel in the nuclear island building. Therefore emergency diesels are placed outside this building in two separate buildings, one of which is protected against fire.

Cutting, processing and welding of metal can generate ignitions. These activities are to be carried out under strict procedures.

B.3.2 Active fire protection

B.3.2.1 Fire detection and alarm provisions

The detection and alarm system sends manually or automatically generated signals to the Main Control Room, Supplementary Control Room and Central Alarm Station. The location of the fire can then be identified. At least two automatic or one manual activation is needed in order to prevent unforeseen activation. Through external communications if needed the external fire brigade can be called in. Self-diagnosis of detection and alarm systems, in combination with periodic testing, inspection and maintenance prevents malfunctioning.

B3.2.2. Fire suppression provisions

Manual means are available everywhere in the reactor, in addition automatic means are implemented to prevent damage to safety related SSCs. To minimize damage in important switch cabinets and SSCs, rooms containing main electrical distributors and I&C-cabinets are provided with fire suppression systems using gas. Fires in rooms containing safety relevant SSCs, are suppressed with a water mist system to limit the amount of water and therefor damage to equipment. Rooms with suppressions systems using water where needed are provided with water drainage.

B3.2.3. Administrative and organisational fire protection issues

The licensee of PALLAS will before fuel loading:

- Conclude Emergency Preparedness and Response arrangements with relevant partners, the main being the Safety Region.
- Taking into account different existing arrangements such as:
    - Regional crisis plan Safety Region Noord-Holland Noord;
    - Crisis management Plan HFR reactor;
    - Incident Management Plan of the Energy and Health Campus;
    - National Handbook Crisis Decision making;
    - National Crisis plan Radiation.

In addition before start of its operation, PALLAS will have a fire protection plan in place, agreed with the Safety Region and ANVS. Also it will make sure before the commencing operation that it has in place and trained the organization that is able to execute the emergency response procedures.

B.3.3 Passive fire protection

B3.3.1. Prevention of fire spreading (barriers)

The fire compartments are determined on the basis of the safety classification in every room. Rooms containing systems and components of safety class 1 are separate fire compartments. Per room the fire load is determined and also the fire duration, which determines the fire resistance of separations between rooms.

B3.3.2. Ventilation systems

Safety functions are implemented in ventilation systems to manage spreading of fire and smoke, including barriers.

Appendix C Example of Fire Safety related requirements in the licence

The following is an example of the type of fire-safety related requirements that can be stated in the licences of nuclear facilities in the Netherlands.

1. The licensee must comply with NS-G-2.1, *IAEA Safety Guide Safety Standard Series No. NS-G-2.1, Fire Safety in the operation of NPPs*.
2. The provisions *from NS-G-1.7, IAEA Safety Guide Safety Standard Series No. NS-G-1.7, Protection Against Internal Fires and Explosions in the Design of NPPs* must be met, unless it is justified why this cannot reasonably be expected.
3. The licensee must have a fire risk analysis report in which the fire risks of the nuclear power plant are analyzed and a fire safety strategy document in which the strategy with regard to fire safety is described.
4. The documents referred to in provision 1, or the implementation documents supporting them, must, at least, describe the following:
    - the identification of the hazards: choice of scenario based on a thorough identification of the hazards and associated risk analysis;
    - the control/combat tactics for the normative incident scenarios, including a motivation for the chosen tactics and a chronological overview of the measures for control of the normative scenarios;
    - the way in which damage from incidents is kept to a minimum, incidents are managed and the measures taken for this purpose;
    - the detection of incidents (method, type, availability, reliability, speed of detection, including motivation for the chosen detection method);
    - the alarm methods;
    - a technical description of the facilities present and resources to be used (stationary extinguishing facilities, availability, inspection/maintenance, reliability, capacity, protection against freezing and irradiation, and collection of any contaminated extinguishing water), including a motivation for the resources chosen;
    - a description of the organization for the distinct phases in the management of incidents; - the management of the organization, safeguarding knowledge and skills (practice cycle, process and material knowledge);

- a system description: Plan, Do, Check, Act cycle for the facility (related to emergency management and facilities) and - clear drawings/graphic representations of repressive facilities, road plan.

5. The fire risk analysis report must be updated at least once every two years and the fire safety strategy document must be updated every year. A fundamental evaluation and updating of both documents should take place every ten years.
6. Changes to the documents referred above must be submitted to the ANVS for information.
7. The site must be laid out in such a way, and the accessibility must be monitored in such a way, that the facility can be reached from at least two directions at all times, except in force majeure situations.
8. The fire alarm installation must be provided with a valid inspection certificate issued on the basis of the CCV Inspection Schedule for Fire Alarm Installations.
9. The permanently installed fire extinguishing systems must be provided with a valid inspection certificate issued on the basis of the CCV inspection scheme Permanently installed Fire Management and Fire Extinguishing Systems (VBB). This certification obligation does not apply to existing installations for which the licensee can demonstrate that certification is impossible or disproportionately expensive.

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