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Swedish Radiation Safety Authority

Report

TPR 2023 Fire Protection

Swedish National Assessment Report

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Executive Summary

The European Union's Nuclear Safety Directive 2014/87/EURATOM (NSD) requires the member states to undertake topical peer reviews (TPR) every 6 years. The first topical peer review concerned Ageing management and started in 2017.

The member states, acting through the European Nuclear Safety Regulators Group (ENSREG), decided that the topic for the second topical peer review is fire protection. The objective of the second Topical Peer Review is to examine how well Fire safety Programmes in participating countries meet international requirements on fire safety (in particular WENRA Safety Reference Levels – (SRLs) and the IAEA Safety Standards). Moreover, the objectives of the Topical Peer Review are to:

- Enable participating countries to review their provisions for fire safety, 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 Swedish Radiation Safety Authority (SSM) by the provision of the act of nuclear activities (1984:3) can decide by injunction that licensees take the necessary measures required in individual cases for compliance with the act. Based on this legislation SSM in August 2022 decided that licensees operating nuclear reactors, nuclear fuel fabrication, and nuclear fuel deposit should report relevant information according to the technical specification (RHWG Report to WENRA – TPR Technical Specification, 21 June 2022) covering an assessment for fires safety analysis and fire protection, passive as well as active.

This report, issued by SSM, is based on the licensee's assessments and the results from SSM's review.

Reports from all licensees were provided to SSM in January and February 2023. SSM checked the licensee reports for inconsistencies and asked for clarifications. Final licensee reports were provided to SSM in August to September 2023. All information was processed and compiled in this report by SSM during March to October 2023. Finally, the Swedish national report was completed and distributed to ENSREG in the end of October 2023.

The conclusion by SSM is that all facilities included in this national report have an adequate fire protection.

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0 Preamble

The European Union's Nuclear Safety Directive 2014/87/EURATOM (NSD) requires the member states to undertake topical peer reviews (TPR) every 6 years. The first topical peer review concerned Ageing management and started in 2017.

The EU member states, acting through the European Nuclear Safety Regulators Group (ENSREG), decided that the topic for the second topical peer review is fire safety. The objective of the second Topical Peer Review is to examine how well Fire Safety Programmes in nuclear installations operating in participating countries meet international requirements on fire safety, in particular WENRA Safety Reference Levels – (SRLs) and the IAEA Safety Standards. Moreover, the objectives of the Topical Peer Review are to:

- Enable participating countries to review their provisions for fire safety, 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.
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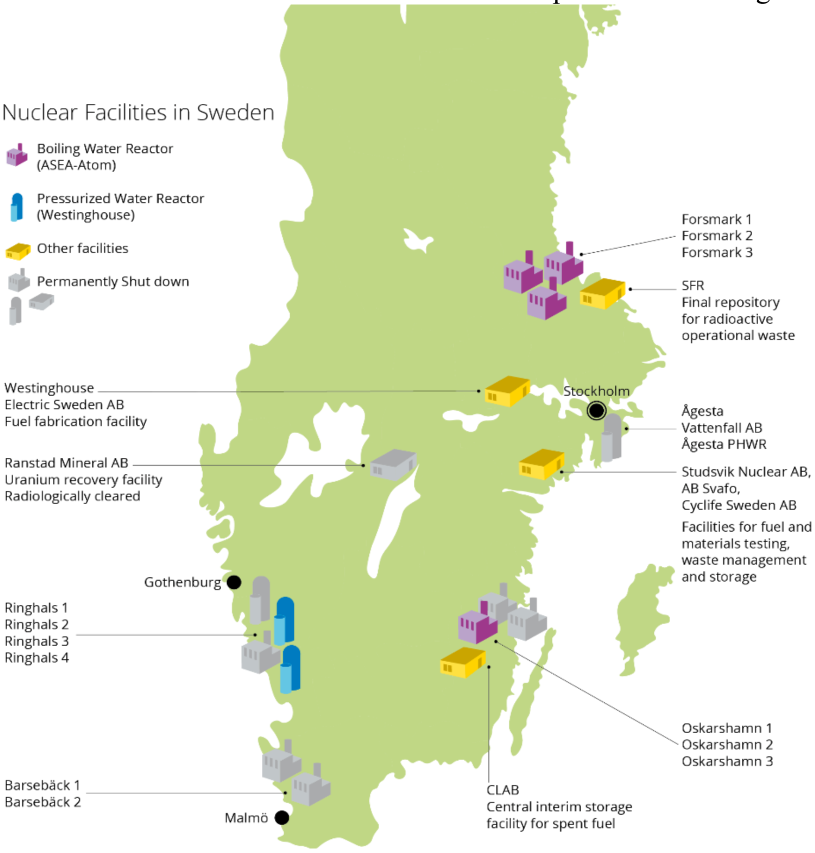
1 General Information

1.1 Nuclear installations identification

An overview of nuclear facilities in Sweden is provided in the figure below:



Nuclear Power Plants
In Sweden, there are three NPP licensees, Forsmarks Kraftgrupp AB (FKA), OKG Aktiebolag (OKG) and Ringhals AB (RAB), currently operating a total of six nuclear reactors at three sites. FKA with units Forsmark 1, Forsmark 2 and Forsmark 3, OKG with unit Oskarshamn 3, all of which are of BWR-type. RAB operates two PWR-units, Ringhals 3 and Ringhals 4.

Research Reactors
Decommissioning and dismantling of two research reactors in Studsvik is ongoing and close to completion.

Fuel cycle facilities
Since 1966 there is in Västerås, about 100 km west of Stockholm, a fuel manufacturing facility operated by Westinghouse.

Dedicated spent fuel storage facilities
Sweden has a central interim storage for spent fuel (Clab) located at the Oskarshamn site which is since 1985 operated by SKB. Clab is currently undergoing upgrades, within a

step-wise licensing process with SSM, to accommodate larger volumes of spent fuel. This is done to bridge the time needed for constructing and taking into operation the final spent fuel repository in Forsmark. Spent fuel is transported from the sites to Clab with a dedicated ship, M/S Sigrid. Construction work is ongoing at Oskarshamn for an encapsulation plant (placing the spent fuel in copper canisters), and at Forsmark for a final spent fuel repository. On January 27, 2022, the government decided to grant SKB permission under the Act on Nuclear Activities to build, own and operate a facility for the final disposal of spent nuclear fuel. The government has also decided on admissibility according to the Environmental Code.

Waste storage facilities
Sweden has through SKB (Swedish Nuclear Fuel and Waste Management Company) a final repository for radioactive waste (SFR) at Forsmark designed for permanent disposal of low- and intermediate-level short-lived waste in vaults excavated from a granite formation, approximately 50 m underground. SFR will be extended to accommodate low- and intermediate-level waste from the ongoing dismantling of reactors at the Barsebäck, Oskarshamn, and Ringhals sites.

Facilities under decommissioning
The following seven reactors have been permanently shut down:

- Oskarshamn 1 in 2017 and Oskarshamn 2 in 2015.
- Ringhals 1 in 2020 and Ringhals 2 in 2019.
- Barsebäck 1 in 1999 and Barsebäck 2 in 2005.
- Ågesta in 1974.

All fuel has been removed from these reactors and they are currently undergoing different phases of decommissioning.

1.1.1 Qualifying nuclear installations

The nuclear facilities included in the Swedish national report are:

- Forsmark 2
- Oskarshamn 3
- Ringhals 3
- Westinghouse Fuel factory
- Clab, the Central Interim Storage Facility for Spent Nuclear Fuel

1.1.2 National selection of installations for TPR II and justification

The justification for the nuclear installations selected is given below:

- Forsmark 2 (BWR), Oskarshamn 3 (BWR) and Ringhals 3 (PWR) represents the three generations and two types of NPPs in Sweden.
- The intermediate spent fuel storage Clab and the Westinghouse fuel factory are the only facilities of their type in Sweden.
- There are presently no research reactors operating in Sweden.
- No plants under decommissioning are included in the scope of this NAR. All fuel has been removed from these reactors, and they therefore represent a much lower radiological risk to the public and the environment compared to the facilities that are included.

- Also the SKB final repository of low- and intermediate level waste (SFR) represent a much lower risk to the public and the environment compared to the facilities that are included.

1.1.3 Key parameters per installation

Technical information on the NPPs in operation is provided in Table 1. Note that a licence to operate nuclear power plants in Sweden is granted without a time limit. Plants can continue operation as long as the Swedish Radiation Safety Authority (SSM) considers them to meet the requirements of applicable laws and regulations. This is secured by the regular oversight activities (see section 1.3) and the mandatory periodic safety reviews (PSR) every ten year. The scheduled shutdown dates in Table 1 are considered as planning conditions that the licensees have set, and are not to be considered as fixed end-dates.

TABLE 1 - OPERATING NUCLEAR POWER PLANTS IN SWEDEN AS OF OCTOBER 2023

Licensee	Reactor	Type of reactor	Licensed thermal power level [MWth]	Electric power output [MWe]	Commercial operation	Scheduled shut-down[1]
Forsmark	Forsmark 1	BWR	2928	1027	1980	2040
	Forsmark 2	BWR	3253	1160	1981	2041
	Forsmark 3	BWR	3300	1208	1985	2045
Oskarshamn	Oskarshamn 3	BWR	3900	1450	1985	2045
Ringhals	Ringhals 3	PWR	3144	1117	1981	2041
	Ringhals 4	PWR	2783	1181	1983	2043

The sections below gives some details on the specific facilities selected for the Swedish national report, including information on their locations.

Forsmark NPP

The site is located at the Baltic Sea coast in the municipality of Östhammar, approximately 120 km north of Stockholm. On-site there are three BWR-units designed by ASEA-Atom. Units 1 and 2 are BWR 69 reactors brought into service in December 1980 and July 1981, respectively, with a 40-year design life. Both Forsmark 1 and Forsmark 2 were originally rated 2711 MWth, 900 MWe, but uprate programmes have increased the reactor power limit for Forsmark 1 to 2928 MWth with generated output to 1027 MWe gross, for Forsmark 2 gradually from original to present 3253 MWth with generated output to 1160 MWe. A total power increase of just over 100 MWe is planned for Forsmark 1 in 2023. Forsmark 3 is a BWR 75 reactor, originally rated for 3020 MWth, 1167 MWe. Following a power uprate the current licensed power is 3300 MWe with generated output of 1208 MWe gross.

[1] The scheduled shutdown date in Table 1 is considered as a planning condition that the licensees have set, and it is not to be considered as a fixed end-date.

The Forsmark site also houses the SKB final repository for low- and intermediate level waste (SFR) and construction is ongoing for the SKB final spent fuel repository.

Oskarshamn NPP
The site is located at the Baltic Sea on the Simpevarp peninsula, about 300 km south of Stockholm in the Oskarshamn municipality. On-site there are three BWR-units of different generations designed by ASEA-Atom. Oskarshamn 1 and Oskarshamn 2 are in decommissioning phase while Oskarshamn 3 commissioned in 1985 is in operation. The license holder is OKG AB. Oskarshamn 3 is an ASEA-Atom BWR75 originally licensed for 3020 MWth. Following two power uprates the current licensed power is 3900 MWth, 1450 MWe.

On-site is also located the Central Interim Storage Facility for Spent Nuclear Fuel (Clab). Clab is owned and operated by SKB, and is an underground storage facility with fuel pools in rock vaults about 30 meters below ground.

Ringhals NPP
The site is located at Kattegatt on the Swedish west coast, close to Värö in the Varberg municipality, approximately 65 km south of Gothenburg.

Ringhals 3 is a PWR furnished by Westinghouse Electric Corporation. The site also houses Ringhals 4, almost identical to Ringhals 3, and two reactors currently under decommissioning, Ringhals 1 and 2.

Ringhals 3 is originally designed for a warranted power output of 2775 MWth. After a steam generator replacement together with the enhancements in fuel performance and other plant modifications the power has been uprated to 3135MWth, which is the current rating.

Central Interim Storage Factory (Clab)
Clab is located at Simpevarp about 25 kilometres north of Oskarshamn municipality in direct connection to the Oskarshamn NPP. Clab is owned and operated by the Swedish nuclear fuel and waste management company, SKB. The operation of the facility started in 1985. This is where all the spent nuclear fuel from Swedish nuclear power plants is stored while waiting for the final spent fuel repository to begin operation. In the storage part, spent nuclear fuel corresponding to 8 000 tonnes of uranium may be stored today. Work is currently underway to expand the permit to 11 000 tonnes.

Westinghouse Fuel Factory
The Westinghouse Fuel Factory is located in Västerås approximately 100 km west of Stockholm and is the only nuclear fuel factory in the world that produces fuel for three different types of reactors (BWR, PWR and WWER). The factory supplies nuclear fuel to more than 30 reactors in Europe, with the largest customers based in France and Ukraine. The facility was mainly built during the 1960s and 70s, in accordance with the building standards applied at that time. Over the years, the plant has been expanded and renovated according to the building standards applicable at that time.

1.1.4 Approach to development of the NAR for the national selection

By the provision of the act of nuclear activities (1984:3), SSM can decide by injunction that licensees take the necessary measures required in individual cases for compliance with the act. Based on this legislation, SSM in August 2022 decided that licensees operating nuclear reactors Forsmark 2, Oskarshamn 3, and Ringhals 3, the Westinghouse fuel factory, and the spent fuel storage facility Clab should report relevant information according to the technical specification (RHWG Report to WENRA – TPR Technical Specification, 21 June 2022).

Reports from all licensees were provided to SSM in January and February 2023. SSM checked the licensee reports for possible inconsistencies and asked for clarifications where needed. The final licensee reports were provided to SSM in August to September 2023. All information was processed and compiled in this report by SSM during March to October 2023. Finally, the Swedish national report was completed and distributed to ENSREG in the end of October 2023.

The information about facilities and sites in section 1.1 is mainly derived from the licensee reports.

The text in chapter 1.2 is a summary of the regulatory framework related to fire analysis and protection, both nuclear and non-nuclear related.

Section 1.3 is added to provide a short description of the basic principles for SSM oversight and SSM oversight structure.

The text in the licensee sections in chapter 2 Fire safety analysis and chapter 3 Fire protection has been taken directly from the final licensee reports.

The assessment and conclusions by SSM in the regulator sections in chapter 2, 3 and 4 are based on a review of the licensee's reports and information, where available, from inspections, notification reviews, event reports and the assessment of such reports, as well as from various meetings with the licensees.

1.2 National regulatory framework

1.2.1 National regulatory requirements and standards

1.2.1.1 Overview

The Swedish legal framework consist of the legally binding acts, ordinances and regulations. With reference to its legal mandate SSM issues legally binding regulations for nuclear facilities in its Code of Statutes, SSMFS. Regulations may include non-binding general advice, which give strong recommendations on how to implement specific requirements. The regulations are also supported by non-binding guidance documents provided for comprehension of the implications of the regulations, with explanations and examples of application.

With regard to fire safety, the nuclear facilities in Sweden have to comply with specific nuclear regulations as well as conventional (non-nuclear) fire protection regulations.

1.2.1.2 *Basic Legislation in relation to nuclear safety in Sweden*

The following five Acts constitute the basic nuclear legislation of Sweden:

- The Environmental Code (entered into force 1 January 1999),
- The Radiation Protection Act (2018:396),
- The Act (1984:3) on Nuclear Activities,
- The Act (2006:647) on Financing of the Management of Residual Products from Nuclear Activities,
- The Act on Liability and Compensation for Radiological Accidents (2010:950).

All acts and the code are all supplemented by a number of ordinances and other secondary legislation which contain more detailed provisions for particular aspects of the regime.

The Swedish Environmental Code for example includes requirements regarding handling of substances that can influence the environment negatively and can be needed to consider when designing confinement of leakage and/or firefighting water.

In cases of accidents which can threaten life and the environment, general obligations are included in the Act (2003:778) on Protection against Accidents and The Ordinance (2003:789) on Protection against Accidents.

1.2.1.2.1 SSM Codes of Statutes (SSMFS)

When the Swedish NPPs were designed there were no nuclear specific national fire protection requirements established. Instead the *General Design Criteria 3 of Appendix A to 10 CFR 50* were used as guidance along with general national building requirements. Specific guidance on fire safety at nuclear power plants developed in 1972 was also used. This guidance was developed by all relevant stakeholders at that time including the Swedish authority "The Delegation for Atomic Energy Affairs" (DFA).

Until 2018, the following SSM regulations cover requirements regarding safety in all nuclear facilities. The regulations have also included general advices issued in direct connection to the regulations in the respective SSMFS publication. The licensees should follow these general advices or take other measures which are justified to be equal from the safety point of view. From 2018 some requirements in the older regulations were superseded by the new basic provisions for licensed activities with ionizing radiation and from 2022 also, these older regulations and general advices shall no longer be applied to NPPs in operation. Interim provisions are applicable to some of the new requirements, i.e. some old requirements are still valid. The older regulations and general advices, except for SSMFS 2008:17 (see below), are however still applicable to other nuclear facilities.

1.2.1.2.2 Old regulations

- SSMFS 2008:1: The Swedish Radiation Safety Authority's Regulations and general advice concerning Safety in Nuclear Facilities: Basic requirements on design, operation, safety management, physical protection, emergency preparedness, assessment and reporting of safety and security, management of nuclear materials and waste, and decommissioning.
- SSMFS 2008:13: The Swedish Radiation Safety Authority's Regulations and general advice concerning Mechanical Components in certain Nuclear Facilities:

Requirements on measures, control- and inspection activities on mechanical components to be taken during plant modifications, maintenance and in-service inspections.

- SSMFS 2008:17: The Swedish Radiation Safety Authority's Regulations and General advice concerning Design and Construction of Nuclear Power Reactors Requirements on design principles, withstanding of failures, conditions and events, and requirements on the design and operation of the reactor core (SKIFS 2004:2 was superseded by SSMFS 2008:17 following the formation of the Swedish Radiation Safety Authority and have identical requirements).
- SSMFS 2008:32: The Swedish Radiation Safety Authority's Regulations and general advice concerning the competence of Operations Personnel at Reactor Facilities. Requirements on competence analysis, training and authorisation as well as requirements on simulators for operational training.

Since the new regulations have not yet been fully applied to the assessments for all facilities, the specific requirements in the old regulations are described below:

Section 3 SSMFS 2008:17
The nuclear power reactor shall be designed so that the safety functions of reactivity control, protection of the primary system integrity, emergency core cooling, residual heat removal and the containment function can be fulfilled to the extent needed depending on the operational state during all events up to and including the event class improbable events.

The design shall take into account events in the event class highly improbable events in accordance with Sections 4 to 9 as well as Sections 18 to 20.

Section 4 SSMFS 2008:17
The following design principles shall be applied in the design of the reactor's defence-in-depth to the extent that is reasonably practicable:
(a) Simplicity and durability in the design of the safety systems
(b) Redundancy, including diversification as well as physical and functional separation in the design of the safety functions
(c) Automatic control or passive function in necessary activation and operational change of the safety functions
(d) Failure in safety classified equipment leading to an acceptable level for safety.

General advice on the application of Section 14 SSMFS 2008:17
Examples of other events that should be taken into account include:

- fire,
- explosion,
- flooding,
- airplane crash, and
- disturbances to or loss of the offsite grid.

In connection with a fire hazards analysis of the facility, a fire that causes all equipment in a fire compartment to fail should be assumed to occur. If a fire hazards analysis can show that the probability of failure of an entire fire cell is low, through protective measures having been taken to prevent fire from spreading, the burn-out of the entire cell need not be assumed. Such a fire hazards analysis should encompass all measures necessary until the fire is extinguished. In the first instance, passive protective measures should be applied, such as room dividers, encapsulation or shielding of equipment, minimized fire loads and distance separation between equipment.

If distance separation alone is counted as a protective measure between redundant pieces of equipment, this should apply to sufficiently large areas and provided that the fire hazards analysis confirms that the separation is sufficient to prevent fire from spreading.

1.2.1.2.3 New regulations

New SSM regulations were put into force in 2018 and 2022. Note that SSMFS 2021:4, :5 and :6 are specifically for nuclear power plants in operation. SSMFS 2018:1 is applicable for all licensed activities with ionizing radiation.

- SSMFS 2018:1 The Swedish Radiation Safety Authority's regulations on basic provisions for licensed activities with ionizing radiation
- SSMFS 2021:4 The Swedish Radiation Safety Authority's regulations and general advice on design of nuclear power plants
- SSMFS 2021:5 The Radiation Safety Authority's regulations and general advice on assessment of safety and nuclear security for nuclear power plants
- SSMFS 2021:6 The Radiation Safety Authority's regulations and general advice on the operation of nuclear power plants

These new regulations cover the former ones, except for SSMFS 2008:13 which is still valid also for NPP:s, but have not yet been fully applied to the existing nuclear power plants. The following parts covers fire:

Chapter 2 Section 1 SSMFS 2018:1

Before an activity begins, during the time it is conducted and when it is decommissioning, events and conditions important to safety and nuclear security shall be identified and evaluated.

Based on the assessment according to the first paragraph, measures shall be implemented so that the operation is conducted in manner that ensures safety and nuclear security. The assessment shall be documented and kept up to date.

Chapter 4 Section 1 up to bullet 1 SSMFS 2021:4

A nuclear power plant shall be designed and constructed so that the events and conditions important to safety and nuclear security and that are directly or indirectly may negatively affect the exposure of workers, the public or the environment to ionizing radiation, or may lead to theft and other unlawful handling of radiation sources, nuclear material and other radioactive substances (assumed events and conditions that are important to safety and nuclear security) can be prevented and managed. The assumed events and conditions referred to in the first paragraph shall be

1. identified with regard to the events and conditions significant to safety and nuclear security as shown in Appendix 1,

Appendix 1, second bullet, SSMFS 2021:4

2. Events and conditions important to safety and nuclear security in a nuclear power plant and that include

a) breakage or damage to mechanical structures, systems and components,

b) incorrect functional rearrangement of structures, systems and components,

c) failure or fault in power supply systems or in instrumentation and control systems,
d) fire or explosion,
e) human error,
f) dropped load,
g) design-specific conditions, and
h) other failure or fault in structures, systems and components.

Chapter 4 Section 2 SSMFS 2021:4
A nuclear power plant shall be designed and constructed with areas, spaces, structures, systems and components, prerequisites for human tasks and organizational prerequisites that, in the event of events and conditions in event class H1–H5, fulfil the main functions
1. control of chain reactions of nuclear fissions in nuclear matter (control of reactivity),
2. removal of heat from radioactive substances (cooling of radioactive material),
3. containment of radioactive substances, shielding of radiation from radioactive substances and control and limitation of releases of radioactive substances (containment, shielding and control), and
4. protection against theft and other unlawful handling of radiation sources, nuclear material and other radioactive substances.
Further provisions on the extent to which the main functions shall be fulfilled can be found in section 5.

Basic information about dependability
Chapter 4 Sections 12 SSMFS 2021:4
Section 12 A nuclear power plant shall be designed so that the functions specified in Sections 2 to 4 can be fulfilled with the highest level of dependability that is reasonably practicable in connection with events and conditions in event classes H1 to H5 and radiological emergency scenarios

Reliability of structures, systems and components
Chapter 4 Section 13 SSMFS 2021:4
Section 13 Structures, systems and components important to radiation safety shall be designed with a level of reliability that is proportionate to their significance in fulfilling the functions specified in Sections 2 to 4 in connection with events and conditions in event classes H1 to H5 and radiological emergency scenarios.
Reliability in accordance with paragraph 1 shall be achieved by application, to the extent necessary, of the design principles
1, proven design,
2. simplicity of design
3. redundancy
4. diversification,
5. physical separation, and
6. functional separation.
In cases where it is not reasonably practicable to apply proven design in accordance with paragraph 2, clause 1, structures, systems and components important to radiation safety shall be systematically verified and validated in accordance with Chapter 3, Section 4 in a manner that demonstrates that they have the functional safety required by their significance to the fulfilment of the functions specified in Sections 2 to 4.

Resistance to environmental conditions, loads and other effects
Chapter 4 Section 14 SSMFS 2021:4
Structures, systems and components important to safety or nuclear security shall be designed so that their design limits are not exceeded by the environmental conditions, loads and other effects to which they may be exposed when their functions contribute to fulfilling the main functions in events and conditions in the event class H1–H5.

Fail-safe design
Chapter 4 Section 15 SSMFS 2021:4
Section 15 Structures, systems and components important to radiation safety shall be designed so that they assume and maintain a position that is anticipated and advantageous for the fulfilment of the functions specified in Sections 2 to 4 in connection with events and conditions in event classes H1 to H5 and radiological emergency scenarios in the event of failure, as far as is reasonably practicable.

Protection against the propagation of failures
Chapter 4 Section 16 SSMFS 2021:4
Section 16 A nuclear power plant shall be designed so that failures in structures, systems and components important to radiation safety do not prevent the fulfilment of those functions of structures, systems and components which, as classified in accordance with Section 10, are of major significance for the fulfilment of the main functions in connection with events and conditions in event classes H1 to H5, as far as is reasonably practicable.

Maintainability
Chapter 4 Section 17 SSMFS 2021:4
Section 17 Structures, systems and components important to radiation safety shall be designed with properties that make it possible
1. to check or test every function that assists with fulfilment of the functions specified in Sections 2 to 4 in connection with events and conditions in event classes H1 to H5 and radiological emergency scenarios, and
2. to maintain or replace them.
It shall be possible to undertake the measures in accordance with paragraph 1 to the extent necessary to ensure the functions of the structures, systems and components with adequate margins against degradation throughout their entire expected service life.

Design for optimal operator performance
Chapter 4 Section 18 SSMFS 2021:4
Section 18 A nuclear power plant shall be designed for optimal operator performance so that the likelihood and the effects of human errors in events and conditions in event classes H1 to H5 and radiological emergency scenarios are limited, by taking performance shaping factors into account by giving due consideration of
1. human tasks,
2. structures, systems and components, uninstalled equipment and the areas and spaces where human tasks are performed,
3. environmental considerations, and
4. organisational conditions.

Considerations for human tasks
Chapter 4 Section 19 SSMFS 2021:4
Section 19 A nuclear power plant shall be designed so that the human tasks assisting with the fulfilment of the functions specified in Sections 2 to 4 in connection with events and

conditions in event classes H1 to H5 and radiological emergency scenarios can be carried out by ensuring that
1. there is enough time to carry out the tasks,
2. there are procedures and training in place for the tasks,
3. information necessary to make decisions to act is presented in a way that makes it possible to follow the sequence of events and to assess the effects of actuations, other operational changeovers and passive functions, and
4. areas, spaces, structures, systems and components that are necessary in order to carry out the tasks are available, accessible and capable of being accessed, taking into account the environmental conditions, loads and other effects that may occur in connection with events and conditions in event classes H1 to H5.

Passive function or automation
Chapter 4 Section 20 SSMFS 2021:4
Section 20 A nuclear power plant shall be designed so that the functions that assist with fulfilment of the main functions in connection with events and conditions in event classes H2 to H5, if they are fulfilled by structures, systems or components that assist with fulfilment of the main functions in connection with events and conditions in event classes H3 to H4B, are, as far as is reasonably practicable
1. are passive, or
2. automatically perform the necessary actuations and other operational changeovers.

Chapter 8 Section 10 SSMFS 2021:4
A nuclear power plant shall be designed with such measures for protection against fire that the main functions can be fulfilled in events and conditions in event class H1–H5, so that fires can be:
1. prevented,
2. detected, and
3. limited and extinguished.

Chapter 8 Section 11 SSMFS 2021:4 on prevention
A nuclear power plant shall be designed so that it is possible to prevent fires from occurring and developing by ensuring that
1. structures, systems and components and uninstalled equipment consists of non-flammable materials as far as reasonably practicable,
2. structures, systems and components as well as uninstalled equipment consisting of flammable materials are separated from possible sources of ignition as far as reasonably practicable.
3. the presence of flammable materials in structures, systems and components and uninstalled equipment, and the extent to which these constitute possible ignition sources, are mapped and documented.

Chapter 8 Section 12 SSMFS 2021:4 on detection
A nuclear power plant shall be designed with detection systems so that fires that start can be detected.
The detection systems shall be designed so that
1. they are adapted to the spaces and the fire loads occurring in them,
2. fires and spread of fire can be pinpointed, and
3. workers can be alerted to an ongoing fires.

Chapter 8 Section 13 SSMFS 2021:4 on limiting and extinguishing
A nuclear power plant shall be designed so that fires can be contained by providing fire cell division of all spaces, where
1. structures, systems and components that are redundant to one another are located in different fire cells as far as reasonably practicable, or
2. if compliance with 1 is not possible, the spread of fire between structures, systems and components that are redundant to one another and located within a fire cell, can be contained as far as reasonably practicable.

Protection against fires shall also be designed so that they can be extinguished with functions that automatically perform the necessary activations or by performing manual tasks.

Chapter 3 Section 9 SSMFS 2021:5
The assessments of the impact on the condition of radiation sources in accordance with Section 1(2), clause 2 shall be conducted in connection with events and conditions in event classes H2 to H5.

The assessments shall either demonstrate that the condition of the radiation sources is not affected or establish the conditions that apply to the assessment of the further event sequence in accordance with Section 10.

Chapter 3 Section 12 bullet 2 SSMFS 2021:5
In the case of assessments in accordance with Section 10(2), clause 2 of events and conditions in event classes H2 to H4A, as far as is reasonably practicable a single fault shall be assumed to occur that is independent of the event and condition and gives rise to the most aggravating circumstances.

In the case of assessments in accordance with Section 10(2), clause 2 of events and conditions in event class H4B in accordance with Chapter 2, Section 8(1), clause 1, as far as is reasonably practicable common cause failures shall be assumed to occur that are independent of the event and condition and give rise to the most aggravating circumstances.

Chapter 4 Section 1 SSMFS 2021:5
Assessments using probabilistic safety analyses shall be conducted as a supplement to the assessments in accordance with Chapter 3, so that they provide a comprehensive view of the protection of the general public and the environment from exposure to ionising radiation and can serve as a basis for the assessment of issues of relevance to this protection. Assumptions made in the assessment shall be justified.

Chapter 2 Section 11 SSMFS 2021:6
A nuclear power reactor shall have procedures implemented for fire protection
The procedures shall include measures for
1. preventing fires,
2. ensuring the capability to detect fires and to alert others to this, and
3. ensuring the capability to extinguish and limit the spread of fire.
The procedures shall also describe how to coordinate with municipal resources.

Chapter 2 Section 22 SSMFS 2021:6
The ability to maintain the radiation safety of the nuclear power reactor shall be ensured, developed and evaluated by means of regular exercises in respect of
1. operation in radiological emergency situations,

2. emergency management in the event of radiological emergency situations,
3. management of malicious acts and conditions, and
4. fire protection.
Exercise activities shall include exercises conducted in cooperation with concerned external organizations, exercises conducted under realistic conditions and exercises conducted with varied scenarios.

Exercises conducted shall be evaluated both in terms of the exercise itself and in terms of the ability of the nuclear power reactor to withstand the scenarios exercised.
There shall be a plan for exercise activities for the next three years that takes into account the results of the evaluations of exercises completed previously.

Chapter 3 Section 2 SSMFS 2021:6
For tasks of importance to radiation safety, there shall be documented assessments that for the nuclear power plant identify
1. the criteria for competence and fitness for duty which are to be met in order to perform the tasks,
2. how to confirm that the people working with the tasks meet these criteria, and
3. how long such confirmation is to be considered valid in order to ensure competence.
For tasks that contribute to fulfil the basic functions, the criteria in clause 1 section 1 shall include familiarity with performing the tasks.

Chapter 3 Section 3 SSMFS 2021:6
It shall be ensured that every person with tasks of relevance to radiation safety is competent for the tasks by assessing whether that person meets the criteria in accordance with Section 2 and is otherwise suitable for the position or role. The assessment shall
1. be conducted periodically at a frequency appropriate to the importance of the task to radiation safety,
2. be documented in an appropriate manner, and
3. form the basis for future assessments.
This assessment shall take place at least once a year for every person who has operational tasks to perform or the authority to make operational decisions in terms of technical aspects

Chapter 6 Section 1 SSMFS 2021:6
Adequate dependability shall be maintained, as far as is reasonably practicable, for each structure, system, component and other equipment of relevance to radiation safety by performing appropriate manual tasks and other measures to the extent necessary to ensure that their required functions can be fulfilled.

Chapter 6 Section 2 SSMFS 2021:6
The programmes for maintenance, surveillance and in-service inspection as referred to in Chapter 2, Section 5(1), clauses 5 to 7 shall ensure that every structure, system, component and uninstalled item of equipment important to radiation safety is maintained, inspected, tested and evaluated to such an extent and in such a manner that their adequate availability is maintained and can be confirmed.

Chapter 6 Section 3 SSMFS 2021:6
Preventive maintenance and functional testing of every structure, system, component and uninstalled item of equipment important to radiation safety shall have an extent and frequency determined systematically, taking into account

1. its importance for radiation safety,
2. its inherent reliability,
3. its assessed ageing characteristics and potential for operation-induced degradation,
4. experiences from operation and development in science and technology,
5. recommendations from vendors, and
6. possible of workers to ionizing radiation.

Chapter 6 Section 6 SSMFS 2021:6
Equipment not installed used when carrying out activities of importance to radiation safety shall be appropriate and ready for operation.

Chapter 6 Section 11 SSMFS 2021:6
The structures, systems, components, areas, spaces and uninstalled equipment of a nuclear power reactor shall be maintained in good order and good condition.
Measures shall be taken to ensure that structures, systems and components and uninstalled equipment important to radiation safety are not damaged or contaminated by foreign objects or exposed to chemical substances to which they are not resistant

1.2.1.3 Conventional fire protection regulations

The following conventional fire protection regulations have to be considered when designing the fire protection. This include requirements regarding fire compartments that are regulated by Boverket (the National Board of Housing, Building and Planning, BBR). These requirements are important regarding segregation of items important to safety from fire loads:

- Civil Protection Act (2003:778), see section 1.2.1.3.1.
- Civil Protection Ordinance (2003:789)
- Flammable and explosive goods act (2010:1011)
- Work Environment Act (1977:1160)
- Work Environment Ordinance (1977:1166)
- Planning and Building Act (2010:900)
- Planning and Building Ordinance (2011:338), see section 1.2.1.3.2.
- Boverket´s (The Swedish National Board of Housing, Building and Planning) building regulations – mandatory provisions and general recommendations, BBR BFS 2011:6 with amendments up to BFS 2018:4.
- Rules on fire load can be found in the Housing Authority's general advice (2013:11) on fire load, BBRBE. (BFS 2011:26). 5:1, , see section 1.2.1.3.3.

The Civil Protection Act (2003:778) includes general requirement regarding preparedness for accidents. The Civil Protection Act (2003:778) chapter 2 §2 states that an appropriate level of fire safety is maintained throughout the lifetime of the building/facility.

The Flammable and explosive goods act (2010:1011) includes requirements regarding handling and storage of flammable liquids.

The Work Environment Act (1977:1160) and Ordinance (1977:1166) includes general requirements needed to be considered for worker protection in case of various hazards including fire.

The requirement resulting from the Planning and Building Act (2010:900) – chapter 2 prevention and spreading of fire between buildings, and chapter 8 in general terms on building fire safety and the Planning and Building Ordinance (2011:338) chapter 3 regarding more specific fire safety requirements. This regulation has altered since the Swedish reactors were built. The building regulation of today is therefore not mandatory for Swedish reactors in general. However it is mandatory when making changes to the building structure, design or when changing the use of the building. The main purpose for the building regulations are evacuation safety.

According to BFS2011:6, the building requirements the fire protection shall be designed, developed and verified through simplified or analytical design. Simplified design means that the given general advices to the requirements shall be followed. Analytical design shall be used when the solutions according to the general advice are not suitable or if the building is too complex for simplified design to be used. General advice for analytical design are given in (BFS 11:26).

1.2.1.3.1 MSB, (Swedish Civil contingencies Agency). The law regarding protection against accidents (LSO 2003:778).

There is much information in the law regarding protection against accidents that is worth mentioning:

Chapter 2 Duties by individuals

Obligations in the case of dangerous activities

§ 4 In the event of a facility where the activities entail a risk of an accident causing serious damage to people or the environment, the owner of the facility, or the person who carries out the activities at the facility, is obliged to reasonably maintain or pay for preparedness with personnel and property and otherwise take the necessary measures to prevent or limit such damages. Whoever carries out the activity is obliged to analyse the risks of such accidents as specified in the first paragraph. The first and second paragraphs also apply to airports that have been granted an operating permit in accordance with ch. 6. Section 8 first paragraph of the Aviation Act (2010:500) and activities covered by the Act (1999:381) on measures to prevent and limit the consequences of serious chemical accidents. Law (2015:234).

§ 5 When toxic or harmful substances are released from a facility referred to in § 4, the operator must notify the county administrative board, the police authority and the municipality if the release requires special measures to protect the public. Notification must also be provided if there is imminent danger of such a release. Law (2014:688).

Chapter 4, Duties by the government on Management

§ 9 The rescue manager is appointed by the authority responsible for the rescue service.

§ 10 The government may prescribe or in special cases decide that a county board or another state authority may take over responsibility for the rescue service in one or more municipalities affected by a rescue operation, if the operation is particularly extensive or there are other special reasons. If an authority has taken over responsibility, the rescue manager is appointed by the authority.

In the matter of clean-up after the release of radioactive substances from a nuclear facility, the government may prescribe or in special cases decide that a county administrative board shall take over the responsibility for the clean-up within several counties or that another government authority shall take over the responsibility within one or more counties. Law (2020:882).

Chapter 5 Supervision
§ 1 The municipality must supervise that individuals comply with this law and regulations that have been issued in connection with the law. The government or the authority designated by the government may issue regulations on how the supervision is to be planned and carried out. Law (2020:882).

§ 1 a The authority for public protection and preparedness must supervise that the municipalities comply with this law and regulations that have been issued in connection with the law. The county administrative boards must provide information on local and regional conditions upon request. Law (2020:882).

§ 1 b The authority that the government determines must have supervision over the state rescue service. In other cases, the authority for public safety and preparedness must supervise that government authorities comply with this law and regulations that have been issued in connection with the law. Law (2020:882).

§ 2 The municipality has the right to gain access to buildings, premises and other facilities for supervision. The municipality also has the right to receive the information and documents needed for supervision. The municipality may issue the orders that are needed in individual cases for this law or regulations that have been issued in connection with the law to be followed. A decision on an injunction may be combined with a fine. If someone does not take a measure that he is obliged to take according to the municipality's order, the municipality may take the measure at his expense. Law (2020:882).

§ 2a State supervisory authorities have the right to obtain from the person to whom the supervision is intended the information and documents necessary for the supervision. If a municipality does not fulfil its obligations according to this law or regulations that have been issued in connection with the law, the Authority for Community Protection and Emergency Preparedness may order the municipality to remedy the deficiencies. Law (2020:882).

§ 3 The police authority must provide the assistance needed for supervision.

§ 4 The municipality may stipulate that a fee must be paid for supervision caused by the provisions in ch. 2. § 2. Law (2020:882).

Chapter 6 Special duties for individuals, municipalities and government authorities
Interference with the rights of others, § 2
If danger to life, health or property or to damage to the environment cannot be adequately prevented in any other way, the rescue leader may, during a rescue operation, prepare himself and participating personnel access to another's property, cordon off or evacuate areas, use, remove or destroy property and make other interventions in the rights of others, to the extent that the intervention is justified with regard to the nature of the danger, the damage caused by the intervention and the circumstances in general. Such interventions may also be made by a committee referred to in ch. 3. § 11 or, in the case of state emergency services, by the authority responsible for the emergency services. If the county board or other government authority in accordance with what is said in ch. 4. § 10, first paragraph, has taken over the responsibility for the municipal rescue service, interventions may be made by that authority instead of by the municipal committee. In case of clean-up after the release of radioactive substances, under the conditions specified in the

first paragraph or if it is necessary to make it possible to reuse the contaminated property, the authority responsible for the clean-up may make such interventions in the rights of others as specified in the first paragraph.

1.2.1.3.2 BFS 2014:3 BBR 21 1 Boverket´s (The Swedish National Board of Housing, Building and Planning) regulations on changes to the agency's building regulations (2011:6) - regulations and general advice; Emerged from print on June 17, 2014

Boverkets regulation is also important and its requirements must be met.

Fire protection

This section contains regulations and general advice for ch. 8. § 9, PBL and ch. 3 Section 8, PBF. The section also contains general advice for ch. 10. § 6 PBL. Section 5:8 also contains regulations and general advice for ch. 8. § 7 PBL. (BFS 2011:26).

General advice

Rules on analytical dimensioning can be found in the Housing Agency's general advice (2011:27) on analytical dimensioning of fire protection of buildings, BBRAD. Rules on the bearing capacity of buildings in the event of fire can be found in section C, ch. 1.1.2 in the Housing Authority's regulations and general advice (2011:10) on the application of European construction standards (Eurocodes), EKS.

1.2.1.3.3 Rules on fire load can be found in the Housing Authority's general advice (2013:11) on fire load, BBRBE. (BFS 2011:26). 5:1.

General conditions:

Buildings must be designed with such fire protection that fire safety is satisfactory. The design of the fire protection must assume that fire can occur. The fire protection must be designed with reassuring robustness so that all or large parts of the protection are not made unavailable due to individual events or stresses. (BFS 2011:26).

General advice

Examples of events and stresses referred to in the second paragraph of the regulation are malfunctions that can affect several protection systems or faults in individual protection systems that are of great importance for fire protection. (BFS 2011:26).

5:11 Dimensioning

Buildings' fire protection must be planned, designed and verified through simplified or analytical dimensioning. (BFS 2011:26).

General advice

General advice on verification can be found in section 2:32. (BFS 2011:26)

5:111 Simplified dimensioning

Simplified dimensioning means that the client meets the regulations through the solutions and methods specified in the general advice in sections 5:2–5:7. (BFS 2011:26).

General advice

The control plan should include a check that only methods and solutions according to simplified dimensioning are applied. (BFS 2011:26). Simplified dimensioning may not be applied if an automatic extinguishing system is used to meet the requirements
a) in more than two regulations, or

b) in more than one regulation,

where there are requirements for an automatic extinguishing system.

The regulations referred to are sections 5:331, 5:336, 5:527, 5:531, 5:5332, 5:534, 5:536, 5:542, 5:548, 5:551, 5:561 and 5:732 and in section C, ch. 1.1.2, § 6 of the Housing Agency's regulations and general advice (2011:10) on the application of European construction standards (Eurocodes), EKS. (BFS 2014:3). 5:112 Analytical dimensioning Analytical dimensioning means that the client fulfils one or more of the regulations in this section in a different way than through simplified dimensioning. The verification of the building's fire protection must be carried out through – qualitative assessment, – scenario analysis, – quantitative risk analysis, or equivalent methods. The methods may also be combined. The verification method must be chosen for the specific object, taking into account how complex the fire protection is. Qualitative assessment may be used as a verification method if the deviations from simplified dimensioning are limited. The same applies if the effect of the design on fire safety is well known and if the design fulfils the regulations by a good margin. Fire protection in buildings in building class Br0 must be verified with analytical dimensioning. (BFS 2011:26).

General advice
Verification should be carried out in the manner stated in Boverkets general advice (2011:27) on analytical dimensioning of buildings' fire protection, BBRAD. (BFS 2011:26). 5:12 Documentation A fire protection documentation must be drawn up. This must show what the prerequisites for the building technical fire protection are and how the constructed building's fire protection is designed, as well as verification that the fire protection meets the requirements in this section and in section C of Boverkets regulations and general advice (2011:10) on the application of European construction standards (euro codes), EKS. The requirement for fire protection documentation does not apply to additional buildings that are no more than 15 m2. (BFS 2011:26).

General advice
The documentation should report the design of the building and its components with regard to fire protection according to section 5, load-bearing capacity in case of fire according to section C of Boverkets regulations and general advice (2011:10) on the application of European construction standards (Eurocodes), EKS, as well as a plan for operating and maintenance according to section 2:5. If the fire protection has been adapted with regard to the ability of the emergency services according to 5:13, this should be reported. The documentation should also describe conditions that may limit how the building is used. Such prerequisites are, for example, what number of people the premises are designed for and what fire load the fire protection is designed for. What is referred to in this section regarding fire load is clarified Boverkets general advice (2013:11) on fire load, BBRBE. Rules on systematic fire protection work are issued by the MSB (Swedish Civil contingencies Agency). (BFS 2013:14).

5:13 Importance of the rescue service's efforts
If the emergency services have a sufficiently quick response time and sufficient ability, evacuation through windows with the help of emergency services according to 5:323 may be applied. (BFS 2011:26).

General advice
Response time refers to the time from when an alarm was received by the emergency services and until the rescue work has begun. The assessment of the rescue service's response time and response ability can be based on the municipal action programs drawn up in accordance with ch. 3. Section 8 of the Act (2003:778) on protection against accidents, LSO. (BFS 2011:26). 5:14 has been superseded by (BFS 2011:26) 5:2.

Fire technical classes and other prerequisites 5:21 Business classes
Spaces in buildings must, based on the intended activity, be divided into activity classes (Vk). (BFS 2011:26).

General advice
The division depends on
- the extent to which the persons are aware of the building and its evacuation possibilities,
- if the people can evacuate for the most part on their own,
- if the people can be expected to be awake, as well
- if there is an increased risk of fire or where a fire can spread very quickly and extensively.
The same building can be divided into several activity classes.

5:211 Business class 1 – Industry, offices, etc.
The business class includes spaces where there are people who can be expected to have good local knowledge, who have the conditions to get themselves to safety and who can be expected to be awake. (BFS 2011:26).

General advice
Examples of premises covered by the regulation are industrial buildings, warehouses and offices. (BFS 2011:26).

1.2.2 Implementation/Application of international standards and guidance

The development of the new regulations in effect from 1 March 2022 included an international comparison in order to make sure that international requirements, guidance and in general state of the art should be considered in the new regulations. This included WENRA Reference Levels 2020 for operating reactors and IAEA Regulations and guidance.

Cross reference checks have verified that all WENRA reference levels are covered by the Swedish national regulatory system for operating reactors. WENRA work is further underway in WENRA RHWG to verify that all reference levels are implemented by the licensees. Below, some examples are given on how the new regulatory statutes on design, assessment and operation of nuclear power reactors consider international standards and guidance:

Examples of consideration of international standards in SSMFS 2021:4, :5 and :6	
Fire protection	WENRA Issues SV5.1, SV5.2 and S30 regarding internal hazards protection (including fires) IAEA SSR-2/1 requirement 74 regarding protection against fires.
Fire prevention:	Requirement 74 in IAEA:s SSR-2/1 concerning that SSCs shall be non-flammable WENRA SRL Issue SV6.11 concerning control and minimizing ignition sources and flammable material in order to prevent fires.
Fire detection	Requirement 74 in IAEA:s SSR-2/1 concerning detection and alarm in case of fire and WENRA SRL Issue SV6.8 concerning in WENRA:s SRL detection and alarm in case of fire.
Fire limitation and extinguishing	The Swedish term fire cell is in agreement with the definition in Boverkets byggregler BBR BFS 2011:6. It also corresponds to the international term fire compartment, e.g. as in IAEA:s SSG-64. There are some language differences between SSMFS and applicable WENRA SRLs. Requirement 74 in IAEA:s SSR-2/1 regarding managing and limiting fires, Issue SV6.4 to SV6.7 in WENRA:s SRL regarding limiting of fire spreading Issue SV6.9 and SV6.10 in WENRA:s SRL regarding the possibility for active and manual fire extinguishing. Issue SV6.12 and SV6.13 regarding appropriate training provided, to cover each area in which a fire might affect SSCs important to safety, emergency training, drills and exercises and coordination between the plant personnel and the offsite response group.

SSMFS2021:5 on assessment of the safety of nuclear power reactors has several paragraphs related to fire:

- Identification of events, grouping and frequency estimation
- Assumptions

Further, in SSMFS2021:6 in operation of nuclear power plants:

- Fire protection during operation, including prevention, detection, and limitation and extinguishing
- Planning of fire exercises including evaluation of experiences from exercises
- Competence and training

WENRA Working Group on Waste and Decommissioning (WGWD), has developed specific Radioactive Waste Treatment and Conditioning Safety Reference Levels (2018). A check indicates that these for fire safety do not differ compared to the 2020 SRLs for reactors.

1.3 SSM oversight principles and oversight structure

The basic principles for SSM oversight are:

- Maintaining an up-to-date picture of the safety status at each licensee and reactor
- Early awareness of degrading safety culture
- Focus on high level issues
  - But spot checks made on detailed level
- Priority / focus based on safety importance
- Focus on internal processes and internal control of the licensee - Examples
  - Regular meetings with licensees
  - Regular checking of Licensee safety review work (notifications, LER reporting)

SSM oversight is based on planning, monitoring of licensee and activity performance, screening w.r.t. radiation safety significance and specific oversight activities (authorisations, inspections and reviews). Based on oversight results, SSM may decide on sanctions on several levels:

- Information to the licensee, stating the issue
- Injunction to licensee to implement corrections (w/wo penalty)
- Prohibition to operate before having implemented corrections
- Special supervision of licensee (comes with special conditions)
- Indictment in case of severe breach of laws or regulations

For very severe deviations, the operating permit may be revoked. For nuclear activities this is decided by the government.

SSM oversight uses (since 2018) basic supervision programs based on a graded approach together with performance based activities. Different oversight programs are used for reactors (represented here by Forsmark 2, Oskarshamn 3 and Ringhals 3), and other nuclear facilities (represented here by Clab and the Westinghouse fuel factory).

The basic oversight program for reactors has 37 oversight groups intended to cover all safety important areas and where the oversight group return frequency and oversight methods are derived from an evaluation of the safety importance of each individual oversight group, i.e. a graded approach is applied. Work is currently underway to revise these basic programs and among other things consider experiences of the first versions.

The performance-based oversight activities are related to:

- Follow-up of information originating from oversight activities in the basic oversight program (findings of cases where regulations are not fully complied with and also good practices etc.)
- Handling of notifications on plant changes where SSM may decide to review or not depending on an assessment of the significance of the change (s).
- Handling and follow-up of event reporting.
- Information in various reporting from licensees to SSM (day, weekly, monthly and yearly).
- Information collected during various meetings, maybe the most important being the meetings with licensee safety departments.

Note that one important aim with the regular contacts (meeting and reporting) is to push the licensees. The meetings are also used to inform the licensees about SSM activities and positions in various issues.

It is also important to understand that the safety review (and the licensee safety departments) plays a very important role in the Swedish approach to nuclear safety). Since the SSM1998:1 Code of statutes, it has been a very clear requirements on safety review, both so called primary review and not the least the independent safety review to be carried out by the (independent) safety department. These reviews are mandatory for plant changes and LER reporting. Much of SSM emphasis is therefore given to checking the work by the licensee safety departments (safety department can in some way be seen as SSMs extended arms).

All information from meetings, reporting, inspections and reviews feeds into the yearly integrated radiation safety assessment of the safety status of the license/facilities and is also used as input to the planning process for coming years, where the basic supervision programs is the basis.

The fire hazards analysis and the Fire-PSA are currently part of the safety analysis oversight group with a return frequency of three years. Fire protection regarding prevention, detection, limitation and extinguishing are covered by several oversight groups, but no group cover all aspects. However, the fact that a subject matter area is included in an oversight group does not automatically result in oversight in that area. The planning including scope is decided from time to time based on an assessment of the significance for safety.

In addition to what is mentioned above, periodic safety reviews (according IAEA SSG-25) are reported to SSM every ten year. SSM reviews these.

2 Fire safety analyses

Note that the text in chapter 2 (except for chapter X.1.1.7) is the licensee's description and conclusions, which has not been edited by the authority.

2.1 Nuclear Power Plants

2.1.1 Forsmark 2

The safety analyses described are based on Forsmark 2, a BWR reactor of ASEA-Atom design (BWR-69).

2.1.1.1 F: Types and scope of the fire safety analyses

Overview

The Safety Analysis Report (SAR) includes a deterministic fire hazard analysis (FHA) and a probabilistic fire risk assessment (Fire PRA).

Internal and external hazards such as fire was included as a Postulated Initiating Event (PIE) in the basic design of Forsmark 2. The power plant is designed with four redundancies numbered A to D, each with a capacity of at least 50%. The redundancies are however grouped into two main redundancies: A/C and B/D. These main redundancies are physically separated from one another by placement in separate fire compartments or fire zones. Within a given main redundancy, separation between the two redundancies (A/C and B/D) has also been realized through placement in separate areas, distance separation and/or shielding.

In 2004, new regulations were released by the Swedish Radiation Safety Authority. The regulations included new requirements which meant that the single failure criteria should also be considered in the deterministic fire analysis. Thus, there was a need to investigate distance separation and/or shielding more closely compared to previous analyses. This was done by dividing fire compartments into fire cells. Such splits were primarily intended to describe the separation present in the main redundancy in each respective fire compartment. The definition of what constitutes a fire cell is described below:

A fire cell is a subset of a fire compartment. SSCs in the fire cell is protected from fire impact due to fires that may occur in the fire compartment but outside the fire cell. Such protection is realized by a combination of passive arrangements: closed-off using walls, joists, distance separation, shielding and limiting the fire load. In the context of division of the site into fire cells, the following criteria must be met:

- All equipment which can affect the accessibility of safety functions shall be contained within fire cells.
- Within one specific fire cell there may only be equipment belonging to one main redundancy (A/C or B/D).
- The passive protection of a fire cell must be sufficient to qualitatively determine that the frequency of a spread to other fire cells be lower the frequency of a design basis accident.
- The term “fire cell” should be tied solely to fire safety and makes up a prerequisite for performing of deterministic analyses.

– From this definition follows that fires in different fire cells are independent from one another and thus all potential fires can be analysed from the set of all fires that may occur in each fire cell, one by one, in separation. Also following from the definition, fires that occur outside of the fire cells must break an intact boundary belonging to a fire cell in order to affect the safety functions.

No combined sequences of events, for example fire resulting from an earthquake, have been included in the analysis. This is, however, required according to new regulations and is a future development planned for the safety analysis.

Deterministic analysis
The safety analysis report (SAR) includes a deterministic safe shut down analysis which evaluates the residual heat removal needed to shut down the reactor and reach a safe state. The scope of the fire analysis is to verify that in case of an internal fire, the power plant can achieve a safe shut down and be brought to a safe state without exceeding the acceptance criteria for each of the barriers. The fire analysis covers fire events in category H3 (Plant Condition 4[2]), H4 (Plant Condition 5[3]) and DEC (design extension condition).

The analysis covers safe shut down for all plant states except outage. Analysis during outage is not included in the deterministic analysis because each outage is unique, since operations, available redundancies and tests differ between outages. Hence, performing deterministic analyses is fraught with difficulties. Instead, an adapted form of probabilistic safety analysis is performed ahead of each outage.

Probabilistic safety analysis
Fire-PRA is performed for power operation, transition from power operation to cold shutdown reactor, transition from cold shutdown reactor to power operation and refuelling outage. The fire analysis covers both level 1 and level 2. The scope of the fire analysis is to quantify the risk of core damage and the risk of emissions to the external environment in the case of core damage.

2.1.1.2 F: Key assumptions and methodologies

Deterministic analysis – Methodologies
In order to show that the power plant can be brought to a safe state after a fire, all possible types of fires must be analysed, categorized and consequences compared to each acceptance criteria. An analysis is performed in five steps. Areas that, during a given fire which leads to little or no consequences are identified and analysed using simplified methods. Areas that affects a larger number of redundancies are analysed in detail in later steps.

The five steps of the Deterministic analysis are:

Development of prerequisites for shutdown to safe state entails a screening of equipment which can be accredited as available during said shutdown.

Compartmentalization into fire cells entails dividing fire compartments into fire cells based on prerequisites in the facilities and placement of components. Each fire in such an area shall be analysed as a separate event. Thus, compartmentalization of the site into fire cells must ascertain that the spreading of fire between fire cells is very low. A

[2] ANSI/ANS 51.1-1983 for PWR
[3] ANSI/ANS 52.1-1983 for BWR

fire in a fire compartment can be said normally not to affect the barriers of the reactor and solely affects access to separate safety equipment. See definition of fire cell in F2.1.1 and F3.3.1.

Fire with a wholly disabled fire cell entails assuming that all equipment in these fire cells, one at a time, is assumed to be compromised by fire irrespectively of how the fire develops. For these fire cells where it can be shown that shutdown to a safe state combined with single failure meets fulfilled requirements, no further analysis is performed. Other fire cells must be analysed further.

Taking the spread of fire into account entails analysing whether the separation in a fire cell containing more than one redundancy is sufficient for preventing impairment of more than one redundancy in the case of a fire. The analysis is conducted through qualitative analyses of spread of fire and is evaluated against set acceptance criteria for components. For fire cells where it can be shown that shutdown to a safe state combined with single failure meets fulfilled requirements, no further analysis is performed. Other fire cells must be further analysed.

Event frequency range, assessing the frequency of an initiating fire event. For those fire cells where a fire can compromise more than one redundancy, a more detailed calculation of the frequency for an initiating event is performed. From this determined frequency, assessed plant conditions categories can be determined, and thus what acceptance criteria are applicable.

For internal fires with an estimated frequency of occurrence that corresponds to DEC, no single event failure needs to be assumed. For the fire cells containing two redundancies with safety equipment, and where the fire frequency for the initiating event is categorized as DEC, no further analysis is performed. This leads to the conclusion that for events where the frequency of occurrence can be shown to be less than $F < 10^{-7}$ (beyond design basis accidents) are not analysed further.

Deterministic analysis – Assumptions

Internal fire as an initiating event is assumed in every area of the site. By dividing the site into different fire zones, fire compartments and fire cells, fires in every enclosed area can be taken to be independent of one another and as such analysed separately.

For every fire event, the analysis must show that shutdown to safe state, in combination with an assumed single failure, is possible and that no acceptance criteria for each of the barriers are exceeded.

Only structures, systems and components (SSC) corresponding to safety class 1-3[4] can be credited in the deterministic safety analysis.

Effects on components and systems is assessed by comparing with damage criteria pertaining to temperature and heat radiation, as appropriate. Assumption about effects of fires are made in line with NUREG-6850, which is applied to active and passive components are:

[4] — Safety class 1: Any SSC whose failure would lead to consequences of 'high' severity. — Safety class 2: Any SSC whose failure would lead to consequences of 'medium' severity. — Safety class 3: Any SSC whose failure would lead to consequences of 'low' severity

- The same damage criteria can be applied for active components, such as pumps, motors, and valves as for the electrical supply.
- Passive mechanical components made out of metal such as piping, water tanks and valves can be assumed to be affected in the event of fire.

By default, the facilities are assumed to be ready for operations according to the technical specifications, which means that:

- The facilities are cleared out in such a way that fire cells do not contain transient, flammable materials.
- That the integrity of fire zones, fire compartments and fire cells are intact during the initiating fire event (i.e., the doors are shut) and
- That there is a nitrous atmosphere in the containment which prevents immediate fire.

Fire events corresponding to category H2 ($F < 10^{-3}$) are not analysed. Manual activation of the reactor protection system is prerequisite for the sequence.

The automatic fire protection system and manual fire protection action is only considered in the detailed analysis when assessing the frequency of an initiating fire event.

Probabilistic analysis – Methodologies

The methodology for the probabilistic fire analysis can briefly be summarized as the following steps:

- Mapping out the critical components, corresponds to the equipment which is being credited in the deterministic fire analysis
- Mapping of cable routing for critical components
- Mapping of area dependencies for critical components and cabling
- Mapping of fire as initiating event. For a fire event to be classified as initiating, automatic or manual scram needs to be initiated
- Calculation of the frequency of fire for initiating events. The application of such a frequency hinges upon facts about rooms and areas. Here, statistics are collected from the databases of Nordic nuclear reactors.
- Simplified analysis of fire events are performed in the PRA-model. If a significant contribution to core damage is seen, then those events that dominate such contribution are subjected to a deeper analysis where cases are analysed further under more realistic conditions.
- Deeper analysis of dominating events. Conditions for the event studied in greater detail might, among other things, include spacing, fire protection of equipment, and systems for putting out fires.
- Quantification of internal fire events in the PRA model.

Probabilistic analysis – Assumptions

When performing probabilistic safety analysis of fires, a number of simplifications and assumptions are implemented in order to limit the workload.

The following conditions and assumptions are applied in the study for power operation:

- Fire is assumed to lead to automatic or manual scram being initiated for analysis of power operation and transition from cold shutdown reactor to power operation.
- It is assumed that doors have not been left open such that fires can spread through them.
- Spreading between closed areas is not considered.
- In the event of fire, it can be assumed that all objects in the room are compromised immediately. However, passive components are assumed to be unaffected (e.g. safety valves).
- In the case of fire in cables, it should be assumed that short circuiting or interruption ensues, which in turn causes loss of voltage. Cable hot shorts are not considered.
- Signals fail is received in the case of fire if logical voltage gates are connected via operating power and spurious signals is received if logical voltage gates are connected via quiescent current.
- In an analysis of fires, potential effects on the possibilities of manual action should be considered.
- The method does not cover spreading of smoke and fire through ventilation systems.

The following conditions and assumptions are applied in the study for cold shut down:

- The initiating event, the fire, should be divided into phases of the outage and should also consider realistic timespans for the period of outage.
- During all the outage, containment is assumed to be open and filled with air, from which follows that fires may start in containment.
- Ongoing work during an outage lead to an increased frequency of fires in the rooms in which work takes place.

2.1.1.3 F: Fire phenomena analyses: overview of models, data and consequences

Detailed quantification of temperature, pressure, spreading of smoke and soot are not used in the analysis. The focus on the analysis is to quantify what SSC’s are affected in the event of a fire that compromises the whole fire cell. If a fire cell is needed to be analysed further validated models, methods and data should be used when analysing the spread of fire, and uncertainties that might occur must be considered. International experiences from NUREG-6850 and OECD Fire Data base must be utilized in the analyses.

2.1.1.4 F: Main results / dominant events (licensee´s experience)

Deterministic analysis – Main results

The conclusion is that a safe state can be reached for each identified fire hazard. Even with conservative assumption where all objects in a given fire cell are disabled the number of available redundancies are adequate to fulfil the acceptance criteria for all plant states.

Probabilistic analysis – Main results

The fire analysis accounts for a limited subset of the total core damage frequency for power operation, as well as ramping up and down, Level 1.
However, pertaining to cold shutdown, the fire analysis contributes substantially to the total core damage frequency, Level 1.

2.1.1.5 F: Periodic review and management of changes

A review of the fire analyses are performed if it deemed that there is a need for this, for example after modifications of the power plant, which could affect the results of the analysis. No periodic review is performed.

2.1.1.6 F: Licensee's experience of fire safety analyses

- The deterministic fire safety analysis shows that the site lives up to the requirements in the methodology and can be brought to safe state after an arbitrary fire event within the requirements for each plant condition category.
- The probabilistic fire safety analysis accounts for a limited subset of the total core damage frequency for power operation, as well as ramping up and down, Level 1. However, pertaining to cold shutdown, the fire analysis contributes substantially to the total core damage frequency, Level 1.

2.1.1.6.1 F: Overview of strengths and weaknesses identified

Fire analysis for Forsmark 2 fulfils the overall requirements from guides such as IAEA NS-G-1.7. One of the main weaknesses in regards to the safety analysis comes from the initial construction, specifically that some fire compartments contain SSC's for two redundancies. This weakness have been drastically reduced by dividing compartments with vital equipment into separated fire cells. Other improvements, such as reduced oxygen levels in important areas such as electrical relay rooms, have also been implemented to reduce the risk of multiple redundancies being affected.

For fire cells which contain more than one train of redundancies the safety analysis show that a fire cannot spread to the second redundancy, alternatively that the risk of such an event where the fire spreads to the second redundancy is so low that loss of two out of four redundancies are acceptable.

2.1.1.6.2 F: Lessons learned from events, reviews, fire safety related missions, etc.

The experience and events are mainly a part of the continuous improvement in regards to the overall fire safety at the plant. This includes continuous inspection and evaluation to minimize the risk of fire.

One of the most important safety related missions is to ensure that fire compartments and fire cells remain intact during operation of the plant, but also during service of various systems and components, especially during outage. Events and experiences where the integrity of a fire compartment has been compromised are being tracked and analysed within the internal system for events and experiences at Forsmark.

2.1.1.7 F: Regulator's assessment and conclusions on fire safety analyses

2.1.1.7.1 F: Overview of a strengths and weaknesses identified by the regulator

The FHA demonstrates a robust design and a possibility to bring the plant to safe shutdown following a fire. Due to additional regulatory requirements, the analyses have been developed and refined over the years. Use of the detailed mapping of plant cable routing, originally performed for the PSA, ensures that safety-important dependencies are accounted for in the safe shutdown analysis.

The separation between redundant safety-related equipment in the original design were not sufficient to comply with the regulatory requirements of today. Weaknesses in the

construction revealed by analyses have been addressed through plant modifications and additional administrative procedures; see section 3.2.3.3 for more details.
An independent core cooling system (ICCS) is implemented 2020 due to requirement from SSM (all plants have an ICCS). The ICCS is not credited in the FHA, but in case of a fire that affects all trains of the regular safety systems (i.e. beyond the assumptions of the FHA), the ICCS will provide an additional possibility to cool the core and the spent fuel.

2.1.1.7.2 F: Lessons learned from inspection and assessment as part of the regulatory over-sight

In reviewing the updated FHA for Forsmark 2 (SSM2014-6031-8) SSM concluded that the methodology used by FKA did meet the requirements, but that parts of the analysis were not sufficiently documented for SSM to be able to assess how the methodology had been applied. Outstanding issues were mainly related to the description of how fire compartments had been divided into fire cells and the basis for assessing fire frequencies.

SSM decided to review this part in more detail (SSM2018-916-3) and did, as part of this review, a plant walk down limited to a selection of fire cells together with FKA fire experts. It appeared that the documented design requirements for fire cells did not fully correspond to the actual design of the defined fire cells, which also raised additional questions about fire spreading possibilities. Regarding the fire frequency assessment the questions remained as no further documentation was available and it was noted that uncertainties had not been taken into account to the extent that might be expected for such low frequency events. Another finding in the more detailed review were the absence of analyses for other operating modes than at-power.

Conclusions from the review (SSM2018-916-3) were that FKA did not comply with all requirements regarding safety analysis and safety reporting for the FHA. Specific criteria defined for analysis purposes, such as for the division of fire compartments into fire cells, have to be carefully documented. There should be no doubts how they should be applied in the analysis and someone not involved in the analysis must be able to review the result. Engineering judgements and assumptions made must also be motivated to enable an independent review. Handling of uncertainties is considered a general area of improvement for different types of analysis, including fire analyses.

The majority of these issues were handled by FKA in an updated analysis where also the reporting format was restructured. Following the latest review performed (SSM2021-475-8) the issue remaining is related to fire during outages.

The fire PSA has not been reviewed in detail in recent years but PSA reviews on a general level have concluded that FKA have a full scope PSA (SSM2021-2041-12) and also a framework in place to continuously develop and keep their PSA studies up to date (SSM2022-4627-10).

2.1.1.7.3 F: Conclusions drawn on the adequacy of the licensee's fire safety analyses

Fire was included as a PIE in the basic design of Forsmark 2 but regulatory requirements on analyses have changed ever since. Consequently, FKA needed to revise their analyses. Following the fire analysis reviews presented above the remaining outstanding issue is related to analysis of fire during outage. The fire PSA has not been reviewed in detail in recent years, but a general conclusion is that the Forsmark 2 PSA study is full scope and is being kept up to date.

SSM will need to conduct oversight to ensure that FKA comply with the new requirements regarding fire safety as stipulated in the Swedish regulations for nuclear power plants that entered into force on 1 March 2022.

2.1.2 Oskarshamn 3

The safety analyses described are based on Oskarshamn 3, a BWR75 reactor of ASEA-Atom design.

2.1.2.1 O: Types and scope of the fire safety analyses

Overview

The Safety Analysis Report (SAR) includes both FHA and Fire-PSA.

Fire was an assumed Postulated Initiating Event (PIE) in the BWR75 design. The original fire analysis was performed in a conservative and rational manner facilitated by the high redundancy (4 trains), and the rigorously implemented functional and physical separation of redundant trains/electrical sub-divisions, and the arrangement of fire zones[5] and fire compartments. The PIE fire was assumed during power operation and postulated to cause one sub-division inoperable. In addition a single failure was assumed in another train/sub-division. With this assumptions two trains/sub-divisions were still available to perform the safety tasks required to cope with the PIE.

With the arrangement of fire zones and fire compartments in the BWR75 design the PIE fire is limited to the sub-division in which the fire is postulated without the need to credit any of the installed automatic active fire protection means to suppress the fire. However, it is assumed that manual firefighting is performed in due time to prevent any fire to jeopardize more than one sub-division. The fire resistance provided by the fire elements that builds-up fire zones and fire compartments assures ample time to conduct manual firefighting if needed.

It is worth noting that the arrangement of fire compartments was not solely based on a reactor safety perspective. Also conventional fire requirements had to be taken into consideration such as facilitate appropriate escape routes for personnel, access paths for manual firefighting and asset protection.

The main principle for the arrangement is that two trains/sub-division (A/C) are located in one fire compartment and two trains/sub-divisions (B/D) are located in another fire compartment. Equipment within trains/sub-division A and C (or B and D) are installed in separate fire compartments, or (where this was not suitable to be realized in the plant design) separated by distance and shielding.

The original fire analysis also assumed that a fire in the Main Control Room (MCR) could cause the MCR to be abandoned. The BWR75 design is provided with alternate local facility with appropriate monitoring and manoeuvring means to maintain the reactor in a safe shutdown condition in case the MCR has to be abandoned.

After the millennium new regulations resulted in several back fitting measures, re-analysis, and extended scope of the SAR. This also affected the scope of fire analyses, and assumptions and methodologies to perform FHA. Significant impacts on FHA were the extended scope to also include refuelling outage condition and the assumption to assume the

[5] Fire zone is described in section 3.2.4.1.1

unavailability of safety systems in case the Technical Specification (TS) allows on-line maintenance. On-line maintenance is allowed in unit 3 TS. In a total of 60 days per year one train/sub-division can be taken out for on-line maintenance. Normally this is conducted in such a way that each train/sub-division having on-line maintenance about 14 days per year. FHA performed after the new regulations are discussed under the heading "New FHA" below. Key assumptions and methodologies are summarized in section 2.1.2.2.

Fire-PSA is performed for power operation, and transition from power operation to cold shutdown reactor, and transition from cold shutdown reactor to power operation, and refuelling outage. A general description of Fire-PSA is provided under the heading "Fire-PSA".

Fire-PSA

In the Fire-PSA some assumptions are needed to achieve a manageable scope of work. Important assumptions made are as follows:

- Only compartments housing system and components in the PSA-model are assessed.
- Civil structures are assumed to maintain stability and integrity.
- Fully developed fires are assumed, i.e. no fire suppression is credited by the use of active fire protection means or manual firefighting.
- Spreading of fire between fire compartments is unlikely and not taken into consideration.
- The selectivity in the station grid is not affected, i.e. fuses and protective relays are assumed function as designed in case of fire induced shortcut currents.
- All compartments within a fire compartment envelope are assumed to be affected by the fire.
- Active components in affected compartments are considered not operable. This also includes that a fire in a compartment housing cable raceways will cause active components in other compartments or fire compartments inoperable in case components are power supplied from cables routed on the cable raceways.
- Hot shorts are considered. Assumptions are based on guidance to assess hot shorts in Nordic BWRs. The Guidance was developed by the Nordic Owners Group (NOG). NOG includes the OEM and the utilities operating ASEA-Atom BWRs.
- The estimated plant overall fire frequency is uniformly distributed over the total number of compartments included in the PSA-model. The plant overall fire frequency is estimated for power operation (including transition between cold shutdown reactor and power operation) and for refuelling outage, respectively.

The fire PSA is prepared both as PSA Level 1 and PSA Level 2.

New FHA

The safety objective to be demonstrated with FHA can be summarized as follows:

A fire must not jeopardize safety functions and barriers needed to bring and maintain the reactor in a safe shutdown condition. Safe shutdown condition is defined as cold shutdown reactor and should be established within 72 hours following the onset of the PIE fire.

To facilitate the safety objective the following needs to be fulfilled:

- Subcritical condition must be established and maintained.
- Integrity of the reactor coolant pressure boundary must be maintained.
- The core cooling must be ensured and residual heat must be removed to the ultimate heat sink.
- The cooling of irradiated fuel in the spent fuel pools must be maintained.

FHA is performed both for power operation and refuelling outage. The analysis for power operation also bounds hot shutdown reactor and transition from cold reactor to power operation.

FHA performed for power operation can be categorized as follows:

- Fire as a PIE; Fire is postulated in a fire compartment.
- Fire as passive single failure; For non-fire Design Basis Accident (DBA) up to Plant Condition 4 according to ANSI/ANS 52.1-1983 (pipe breaks excluded), fire should be postulated as a passive single failure even if the PIE does not cause a fire. Passive single failure is not assumed within 12 hours following the PIE.
- Fire as a potential consequential hazard of non-fire PIE needs to be considered.
- Fire as a PIE combined with CCF in systems providing safety functions. This sequence is categorized as Design Extension Condition (DEC) and not subject to such rigorous and conservative assumptions as normally applied in deterministic safety analysis for DBA.
- Fire in the containment; Despite the very limited time the plant is operated with non-inerted containment a FHA is performed. Operation with non-inerted containment is only relevant prior and after the need to enter the containment, normally before and after refuelling outage: The TS limits the allowable time for non-inerted operation.
- Fire in the MCR.

FHA for refuelling outage is performed for two scenarios:

- Fire as a PIE in the containment.
- Fire as a PIE outside the containment.

Refuelling outage FHA differs to some extent from power operation FHA. This is reasonable considering the conditions that prevail during refuelling outage. Generally, assumptions applied are less rigorous for refuelling outage FHA. As an example, non-safety grade systems can be credited and the capability to cope with a postulated single failure in safety grade systems must not be fulfilled in case sufficient ample time exist to restore the function or to deploy non-safety grade means.

FHA is performed for the Radwaste Building (Rw/B). The safety objective to be demonstrated with Rw/B FHA is that radioactive releases do not cause effective dose to the public that exceed the dose limit for DBA. The analysis is performed as a conservative bounding case analysis where the PIE is a seismic event assumed to cause the breach of storage tanks containing radioactive waste water and used ion exchange filter masses, and subsequently a fire is postulated to cause the release of volatile suspended solids and compounds.

The PIE fire is defined as a postulated fire in a fire compartment that jeopardizes all safety related components in the fire compartment. However, if justified by analysis based on the fire load and load distribution, the total fire compartment envelope need not be assumed affected. The bounding case normally applied is to postulate a fire that affects one Emergency Diesel Generator (EDG), causing one train/sub-division unavailable in case of Loss of Offsite Power (LOOP).

Seismic induced fire is a potential risk that should be addressed. Earthquake was a PIE considered for the BWR75 design and seismic adequacy is demonstrated for SSCs credited to cope with a seismic event (seismic classified SSC). In the design was also addressed that non-seismic classified SSCs must not jeopardize seismic classified SSCs. This was also formalized by guidance (e.g. enhanced anchorage and ensuring sufficient spatial distance.) for the design and installation of non-seismic SSCs and verified with plant walk-downs. Furthermore, in the BWR75 design there is a rigorously implemented functional separation between safety and non-safety electrical equipment (i.e. functional separation between 1E and non-1E equipment) ensuring that failure of non-1E equipment do not jeopardize the safety related power supply.

The seismically design together with the functional separation and the selectivity in the station grid minimizes the potential for seismic induced fire. Furthermore, in later conducted SMA the Screening Evaluation Work Sheet (SEWS) has been extended to also address the potential that seismic induced fire could jeopardize the equipment evaluated.

2.1.2.2 O: Key assumptions and methodologies

This section describes key assumptions and methodologies for FHA and is addressed separately for FHA for Power operation, Refuelling outage, and Radwaste Building (Rw/B) fire.

Power Operation

- The PIE fire is defined as a postulated fire in a fire compartment that jeopardizes all safety related components within the fire compartment envelope. However, if justified by analysis based on fire load and fire load distribution, the total fire compartment envelope need not be assumed affected.
- The PIE fire is assumed to cause scram. LOOP is assumed as a consequential failure of scram due to turbine trip.
- Following scram (initiated by the RPS) only safety grade systems and components are credited to mitigate the event.
- The single failure criteria is postulated (normally the bounding case is the failure of one EDG causing one train/sub-division unavailable).
- Unavailability due to on-line maintenance is assumed (normally the bounding case is to assume that the electrical power supply in one train/sub-division is unavailable).
- A grace time of 30 minutes is assumed, i.e. no operator actions are credited to mitigate the event within 30 minutes following the PIE.
- No credit is taken from the installed automatic active fire protection means to suppress the fire.

For unit 3 this implies that only safety grade systems and components in 1 out of 4 trains/sub-divisions can be credited to mitigate the PIE fire.

The analysis of a postulated fire in the containment is performed as a qualitative bounding analysis comparing the potential effect of fire with other DBAs in the containment.

The analysis of fire as a PIE combined with CCF in systems providing safety functions is performed as a qualitative bounding analysis comparing with other DEC analyses.

The postulated fire in the MCR sets requirements for the design of the alternate local facility. The alternate local facility shall be provided with monitoring and manoeuvring means as needed to maintain the reactor in a safe shutdown condition in case the MCR has to be abandoned. Furthermore, the design of safety-related I&C and electrical power supply facilitate that a postulated fire in the MCR does not jeopardizes any safety functions, since no equipment within the safety functions is located in the MCR and associated compartments. Spurious actions actuated from the MCR (in case of fire induced hot shorts) is prevented by melt fuses that can either be activated manually in a simple way or relying on melting due to the fire.

Refuelling Outage

- FHAs are based on the procedures for a "standardized" refuelling outage, such as scheduled maintenance outage of safety grade systems.
- The PIE fire is assumed to affect components in one train/sub-division.
- Since turbine trip is not relevant during refuelling outage LOOP is not assumed as a consequential failure. − Non-safety grade systems and components can be credited.
- Coping with a postulated single failure in safety grade systems must not be fulfilled in case sufficient ample time exist to restore the function or to deploy non-safety grade means.
- A grace time of 30 minutes is assumed, i.e. no operator actions are credited to mitigate the event within 30 minutes following the PIE.

Radwaste Building Fire

- A seismic event is assumed to breach storage tanks in the Rw/B causing the total inventory of radioactive waste water and used ion exchange filter masses to be discharge into the Rw/B. It should be noted that slab curbs are arranged for storage tanks containing high activity preventing the spread of fluid in case of tank leakage.
- A subsequent fire is postulated causing the release of volatile suspended solids and compounds.
- The plant is assumed to have been operated with design basis fuel damages prior the event to maximize the activity inventory in the storage tanks.
- Source term is based on guidance provided in US NRC Regulatory Guide 1.183 Rev. 0.
- Fire release rates and fractions are based on IAEA-TECDOC-1162 "Generic procedures for assessment and response during a radiological emergency"
- No ventilation filtering mitigation is credited.
- The release height is assumed to be 20 meters.

2.1.2.3 O: Fire phenomena analyses: overview of models, data and consequences

The rigorously functional and physical separation of redundant trains/ subdivisions, and the arrangement of fire zones and fire compartment in the BWR75 design (as described in section 2.1.2.1), generally facilitates the need for FHA supporting analyses to be limited to analyses demonstrating that design basis fire resistance of fire elements are maintained for actual fire loads and that no unacceptable fire spreading occurs via ventilation systems.

The actual fire loads in the plants fire compartments has been re-evaluated. The actual fire loads are based on calculations supplemented with plant walk-downs to underpin assumptions made in the calculations. A fire compartment envelope can include several compartments. A categorization of compartment-types was conducted to optimize the scope of work. In practice the compartment with the highest fire load within the fire compartment envelope defined the fire load of the fire compartment.

Fire compartments with a fire load up to 200 MJ/m^2 are within the original design basis for fire resistance of 60 minutes (Fire Resistance Class A60) in accordance with guidance provided in the Swedish Fire Protection Association, SBF 72 "*Anvisningar angående brandförsvaret vid kärnkraftverk, Svenska Brandförsvarsföreningen*".

Fire compartments with fire loads exceeding 200 MJ/m^2 were specifically addressed taking into consideration mitigating effects from fire suppression means based on generic guidance in SBF 72, e.g. fire sprinkler systems, or prepared means for manual firefighting. High fire loads are mainly relevant for fire compartments housing oil storage (e.g. lubrication oil) such as in the turbine building.

A re-assessment of civil structure design, and ventilation systems design, and smoke extraction systems design, has been conducted to verify that the original design principles are maintained in the plant. The re-assessment was performed based on review of plant documentation supplemented with plant walk-downs.

2.1.2.4 O: Main results / dominant events (licensee´s experience)
FHA results

Power Operation
The FHAs demonstrate that the safety objective is achieved. The new requirement to assume the unavailability of safety systems in case the TS allow on-line maintenance had an impact on safety margins. With only 1 out of 4 trains/sub-divisions credited the analysis exhibited narrow margin against the maximum allowable temperature in the suppression pool. Supplementing sensitivity analysis was performed to study the narrow margin in more detail. The main outcome of the sensitivity analysis was that stable condensation in the suppression pool can be accomplished via the submerged quenchers and available NPSH is sufficient for safety related pumps using the suppression pool as water supply.

The qualitative analysis of a postulated fire in the containment performed in the SAR demonstrates that the safety functions can be accomplished and the consequences are bounded by safety analyses of other DBAs.

In the SAR it is demonstrated that the reactor can be brought to and maintained in a safe shutdown condition in case the MCR has to be abandoned due to a fire.

In the SAR it is demonstrated that consequences of a postulated fire combined with CCF in systems providing safety functions are bounded by other DEC analyses.

Refuelling Outage
The FHAs demonstrate that the residual heat removal from RPV and SFPs is accomplished. The water temperature is with margin maintained below saturation.

Radwaste Building Fire
The public effective doses estimated for the conservative bounding case Rw/B FHA are with significant margin below the dose limit for DBA.

PSA results
In PSA Level 1 analysis core damage during power operation (including transition between cold shutdown reactor and power operation) is assumed caused by either the Loss of reactivity control, or the Loss of core cooling, or the Loss of residual heat removal. The conservative estimated Core Damage Frequency (CDF) for power operation (including transition between cold shutdown reactor and power operation) does not exceed 10^{-7} per year, which can be neglected in comparison with the result of the overall PSA study. The CDF is with significant margin below the target value in the SAR.

In PSA Level 2 analysis the estimated frequency of nonacceptable releases is about one order of magnitude lower. In PSA Level 1 analysis core damage during refuelling outage is assumed caused by either core damage in the reactor pressure vessel or fuel uncover in the spent fuel pools. The conservative estimated CDF for refuelling outage does not exceed 10^{-7} per year, which can be neglected in comparison with the result of the overall PSA study. The CDF is with significant margin below the target value in the SAR. In PSA Level 2 analysis the estimated frequency of non-acceptable releases is in same order of magnitude.

2.1.2.5 O: Periodic review and management of changes
Maintaining the validity of FHAs is governed by OKG's Management System. The package of procedures provides guidance to initiate update of the SAR and its supporting analyses which also includes FHA and Fire PSA, and the quality assurance process to conduct the update. The need for update varies and the package of procedures provides guidance to address the various update needs, e.g. design changes, changes in operational procedures, or an identified deficiency in existing analysis.

It should be noted that procedures in the Management System sets out that an integrated part of a design change is the update of the SAR and its supporting analyses.

A comprehensive review of the SAR and its supporting analyses (which also includes FHAs and Fire-PSA) is also performed in the Periodic Safety Review (PSR) imposed by the regulator. PSR is conducted about every 10 year.

2.1.2.6 O: Licensee's experience of fire safety analyses
- FHAs performed for unit 3 demonstrates that the design is very robust. In the FHAs no credit is taken from the installed automatic active fire protection means to suppress the fire.
- Secondary hazards from actuation (demanded or spurious) of fire extinguishing systems, or postulated pipe rupture in fire water systems are assessed as part of the plant internal flooding analyses and the analyses demonstrates that the plant can accommodate flooding caused by failures in fire water systems

2.1.2.6.1 O: Overview of strengths and weaknesses identified

The FHAs and Fire-PSA demonstrates the high resilience against fire in unit 3. The high resilience is a result of the BWR75 design with high redundant safety systems and the rigorously implemented functional and physical separation of redundant trains/electrical sub-divisions and the arrangement of fire compartments and fire compartments.

The new requirement to assume the unavailability of safety systems in case the TS allow on-line maintenance had an impact on safety margins. With only 1 out of 4 trains/sub-divisions credited analysis exhibited narrow margin against the maximum allowable temperature in the suppression pool. However, the assumption to only credit 1 out of 4 trains/sub-divisions was not within the original design basis and implicitly demonstrates the robustness of unit 3.

2.1.2.6.2 O: Lessons learned from events, reviews, fire safety related missions, etc.

The re-evaluation and extended scope of FHAs undertaken has further highlighted the importance to maintain knowledge of the OEM design principles for the plant and thereby ensure the in depth resilience against fires is maintained in the future.

2.1.2.7 O: Regulator's assessment and conclusions on fire safety analyses

2.1.2.7.1 O: Overview of a strengths and weaknesses identified by the regulator

The FHA demonstrates a robust design and a possibility to bring the plant to safe shutdown following a fire. Oskarshamn 3 is of the BWR75 design from ASEA-Atom. The functional and physical separation of redundant trains/subdivisions, and the arrangement of fire zones and fire compartments in the BWR75 design, generally limits the need for FHA supporting analyses demonstrating that design basis fire resistance of fire compartments is maintained for actual fire loads and that no unacceptable fire spreading occurs via ventilation systems.

An independent core cooling system (ICCS) is implemented 2020 due to requirement from SSM (all plants have an ICCS). In case of a fire that affects all trains of the regular safety systems (i.e. beyond the assumptions of the FHA), the ICCS will provide a possibility to cool the core and spent fuel. The ICCS therefore provides additional robustness and safety in case of a fire.

2.1.2.7.2 O: Lessons learned from inspection and assessment as part of the regulatory over-sight

SSM reviewed the updated FHA for Oskarshamn 3 in 2017 (SSM2016-1192-4). It was concluded that the FHA was conducted and documented according to requirements, but the specific analyses were not reviewed in detail. In 2018 SSM reviewed the Periodic Safety Review performed by OKG (SSM2017-180-20). The review revealed that the acceptance criterion for the suppression pool temperature was exceeded in two fire analysis cases for Oskarshamn 3. This had been identified as an area of improvement by OKG while SSM considered it a deviation that needed to be addressed. SSM issued an injunction to OKG to present an action plan for addressing the deviations (SSM2017-180-34). SSM considered the plan presented acceptable and in 2021 OKG submitted a change in the Safety Analysis Report regarding the acceptance criterion. SSM found the change too permissive and once again issued an injunction to OKG to present an action plan (SSM2021-3007-9). Follow-up of this is currently ongoing at SSM.

A review of a new area event methodology (SSM2013-541-16) concluded that the method met the requirements at that time with respect to its purpose of providing support for OKG's work with identifying weaknesses and improvements that should aim to keep the area events risk contribution at a low level. However, SSMs assessment remarked that the specified criteria for identifying sensitive fire cells need to be explained and justified in a clearer way and that there was a need to add more clarity regarding the meaning of all simplifications, assumptions, etc. from a risk perspective. Later reviews (O3 PSA in SSM 2015-2052-7) and an operational review (SSM2016-2200-3) concluded that OKG still not had resolved the previous remarks. In recent years the CDF presented has decreased significantly due to plant modifications and less conservative assumptions. This mean that the statement that contribution from fire events can be neglected in comparison with the result of the overall PSA study can be questioned. This is an issue that SSM has to follow up in the future.

2.1.2.7.3 O: Conclusions drawn on the adequacy of the licensee's fire safety analyses
Fire was included as a PIE in the basic design of Oskarshamn 3 but regulatory requirements on analyses have changed ever since. Consequently, OKG reviewed their analyses and concluded that Oskarshamn 3 can withstand a fire. SSM overall conclusion is that the FHA performed for Oskarshamn 3 are adequate and sufficient. The remaining outstanding issue relates to acceptance criteria for the suppression pool.

SSM will need to conduct oversight to ensure that OKG comply with the new requirements regarding fire safety as stipulated in the Swedish regulations for nuclear power plants that entered into force on 1 March 2022.

2.1.3 Ringhals 3

The safety analyses described are based on Ringhals 3, a three-loop Westinghouse PWR.

2.1.3.1 R: Types and scope of the fire safety analyses

Overview
The Safety Analysis Report (SAR) includes both FHA and Fire-PSA.

FHA is performed for all operating and non-operating modes with fuel in the reactor tank. In addition, Fire phenomena analyses have been performed for the non-operating mode and all fuel in the fuel building.

Fire-PSA (or Fire-PRA) is performed for all plant operating modes and include both analysis of core damage (PSA level 1) and analysis of releases to the environment (PSA level 2).

FHA
In this chapter the consequences from fire is presented and so is the analyses that has been conducted to verify that the separation in the plant is adequate.

Fire protection in R3 seeks to prevent that a (any) fire could jeopardize the reactor safety by multiple layers of administrative routines and fire protection measures.

If a larger fire should occur anyway, the separation in the plant should be sufficient in order for the safety functions and shut down equipment to bring the plant to a safe state. To demonstrate adequate separation, verifying analyses of separation have been conducted.

Postulating a fire that affects all equipment within one fire compartment, safety features and safe shutdown equipment shall be proven to be available in sufficient extent after a fire to impede the transient the fire could be initiator of and also bring the plant to, and keep the plant in, a safe state.

For the safety functions an additional single failure is employed.

For the safe shutdown functions used to cool down the plant, a single failure is not employed due to possibilities to keep the plant in a stable condition for an extended period with help by safety functions alone (e.g. cooling by steam generators).

In a conservative manner it is assumed that all fires in all compartments could lead to the consequences / transients Loss of normal feed water (LONF) and Loss off offsite power (LOOP).

Bringing the plant to safe state
After a fire the plant will be tripped either manually or automatically due to effects of the fire, e.g. turbine trip, LOOP or LONF. Thereafter, the plant is brought to a safe state. After a scram (or reactor trip), it is essentially three safety functions that is challenged: Reactivity control (to achieve a subcritical core), Residual heat removal (to avoid overheating) and the Overpressure protection of primary systems (to warrant the integrity of primary systems).

No fires are identified that would cause loss of reactor coolant, whereby safety functions emergency core cooling and containment function are not challenged.

Reactivity control is performed by the control rods. No fire has been identified that would jeopardize this function. Automatic reactor trip (or scram) will be initiated by the RPS (reactor protection system).

This system (RPS) has been designed by the principle of fail-safe, hence a fire is not assumed to prevent the initiation of a reactor trip.

No fire has been identified that would affect the primary side overpressure protection. The transients LONF and LOOP could lead to a low steam generator inventory before reactor scram.

For safe shutdown functions, it is shown that necessary functions within respective safe shutdown function is available to in a controlled manner bring the plant to, and keep the plant in, a safe state.

This means that the physical and functional separation is enough for bringing the plant to, and keep the plant in, a safe state, which is shown more detailed in plant restricted documentation.

Fire in shutdown operating mode with fuel in the core.
For fires that occur in shutdown operating mode during the short period where fuel is in the core with the RCS open, other presumptions are set.

When the reactor is in this mode, the reactor coolant system is opened. Hence, as the residual heat removal cannot be performed through steam generators, it is solely the residual heat removal system that maintain this function.

The residual heat removal system is redundant. This means that the residual heat removal function can be maintained by a train that is not affected by the fire, given that the fire in the first place would affect the cooling system directly or indirectly (cooling of the cooling system) or the electrical power supply to this system.

If for some reason also the unaffected train should fail independently of the fire (single failure) the emergency core cooling function will be credited for cooling in accordance with the analysis of the loss of residual heat removal. The emergency core cooling function, including cooling and power, is shown to be available after the assumed fire.

If none of the trains of the residual heat removal system is possible to take back in operation the plant will be brought to recirculation and cooling will be performed by emergency core cooling function.

This means that the physical and functional separation is adequate, which is shown more detailed in plant restricted documentation.

Fire as initiating event (PIE) and applying additional common cause failure (CCF).
National Swedish regulations requires that certain fire events (related to likelihood of occurrence) are combined with an additional independent common cause failure (CCF) in a safety function.

Hence the separation verification for all the fire compartments show that also a diverse cooling possibility is available.

Below it is showed how fire is combined with additional CCF in the different safety functions needed to handle a fire in accordance with what was presented above.

Fire and applying additional CCF in residual heat removal
Fire could lead to loss of offsite power or loss of main feed water and thereby invoke need of the safety function residual heat removal. In power operating modes (and first stages of shutdown modes) this safety function is or can be maintained by the auxiliary feed water system. The auxiliary feed water system consists of redundant trains and a diverse auxiliary feed water pump.

A fire will only affect one pump according to the analysis performed. A CCF failure would affect either the redundant auxiliary feed water pumps or the diversified auxiliary feed water pump. The diversified auxiliary feed water pump will only be affected by fires that occur in the same fire compartment the pump is located[6].

[6] In fire analysis it is, in a conservative manner analyzed that the cooling function of the steam generator is dependent of the steam lines isolation valves which could fail at specific fires. However, not all isolation valves will fail at once in according to analysis which means that cross connection of the steam generators can be credited.

For fires located outside the fire compartment of the diversified auxiliary feed water pump the safety function residual heat removal will be maintained by the diversified pump.

For fires located in the fire compartment where the diversified pump is located the acceptance criteria is not reached with safety related equipment only. A fire in the diversified auxiliary feed water pump is however not affecting the operation of the plant nor the normal auxiliary feed water system, hence demands on diversity is expected for this fire compartment.

Fire and applying additional CCF in the reactor protection system (RPS)
If the ordinary RPS is malfunctioning due to CCF, the diversified RPS is warrant for tripping the reactor and establishing residual heat removal.

The transients (that can affect the core) induced by fire is covered by the design of the diversified RPS and thereby a fire including CCF on ordinary RPS can be handled by the diversified RPS. The diversified RPS has been separated from the ordinary RPS in such way that a fire in electrical cabinets not simultaneously could affect both ordinary and diversified RPS.

Fire and applying additional CCF in electrical power supply
The consequences is the same as explained in Fire and applying CCF in residual heat removal.

Fire and additional CCF in the cooling chain
Analyses show that fire and additional CCF does not affect the cooling chain.

Consideration of spurious operation scenarios
In the FHA it is generally assumed that a short circuit or an open circuit occurs for components and cables affected by the fire. This results in a loss of voltage and the component will assume its fail-safe mode. The risk for fire-induced spurious operation of objects are reduced by using double break control circuits for components important to safety. The double break design requires two hot shorts to energize a component. Hence the risk for fire induced spurious operation of objects are considered low.

Multiple spurious operation have been studied as a separate part of the FHA by performing circuit analyses based on the methodology in NEI 00-01 Guidance for Post Fire Safe Shutdown Circuit Analysis. In these circuit analyses up to four fire-induced hot shorts in cables exposed to the fire have been considered. Based on the result of these circuit analyses the consequences of multiple spurious operation sequences regarding the ability to fulfil the required safety functions were evaluated. The conclusion of this study was that the consequences of fire-induced spurious operations are acceptable.

Independent Core Cooling System (ICCS)
An independent core cooling system (ICCS) has been installed in 2020. The purpose of the ICCS is to provide alternative core cooling and spent fuel cooling if the regular safety systems are unavailable in the event of design extension conditions (DEC). ICCS is designed to, as far as possible, be independent of the regular plant and is housed in a separate building designed to withstand severe external events. To prevent that the ICCS is affected by a fire in the regular plant cables belonging to the ICCS are physically separated from other cables and constructed with fire-resistant cable. The ICCS is not credited in

the FHA but in case of a fire that affects both trains of the regular safety systems (i.e. beyond the assumptions of the FHA) the ICCS will provide a possibility to cool the core and spent fuel.

Fire-PSA

Fire-PSA (or Fire-PRA) is performed for all plant operating modes and include both analysis of core damage (PSA level 1) and analysis of releases to the environment (PSA level 2).

All buildings containing equipment that in the event of a fire induced failure could initiate a transient involving reactor trip (e.g. loss of main heat sink) or a failure of the safety system have been selected as relevant to the fire-PSA. Analytical fire cells have been defined. In some cases these are similar to the deterministic fire compartments but in other cases the deterministic fire compartments have been subdivided based on e.g. spatial separation.

Fire detection and fire suppression is modelled and if this is successful the sequences are considered successfully handled. In case the fire cannot be extinguished a fire that fails all active equipment in the analysed fire cell is assumed. Cables that are present in the analysed fire cells are also assumed to fail and will cause active components in other compartments or fire cells inoperable in case components are power supplied from cables routed on the cable raceways.

Fire spreading is considered during power operation. However a screening analysis is performed to limit the fire spreading cases that are included in the PSA-model.

2.1.3.2 R: Key assumptions and methodologies

The methodology for the safe shutdown analysis is based on Westinghouse's application of NUREG Guideline 1778 applying our own adaptions to conform with national regulation SSMFS 2008: 17 (and to include pipe break / flooding).

Postulating a fire that affects all equipment within one fire compartment, safety features and safe shutdown equipment shall be proven to be available in sufficient extent after a fire to impede the transient the fire could be initiator of and also bring the plant to, and keep the plant in, a safe state.

For the safety functions an additional single failure is employed. For the safe shutdown functions used to cool down the plant there are possibilities to keep the plant in a stable condition for an extended period with help by safety functions alone.

In a conservative manner it is assumed that all fires in all compartments could lead to the consequences / transients Loss of normal feed water (LONF) and Loss off offsite power (LOOP).

The analysis to achieve safe shutdown and safe state (SSA) after fire as an initial event is integrated in the current PSA-model. Advantages with this is that all dependencies such as electric dependencies and system dependencies which already are modelled in the PSA can be used to analyse functions necessary to achieve safe shutdown and safe state. These dependencies are very complex and difficult to overview if the PSA-model is not used. By integrating the SSA in the PSA-model it is also easier to maintain and recreate the analysis. The PSA-model is reflecting the current plant configuration which leads to that the PSA-model is updated in conjunction with changes of plant configuration, and it is thereby possible to re-analyse the scenarios to verify if the change has an impact on the result. Therefore, the key assumptions presented under PSA below is valid also for the SSA (except fire extinguishment which is not credited).

Multiple spurious operation have been studied as a separate part of the FHA by performing circuit analyses based on the methodology in NEI 00-01 Guidance for Post Fire Safe Shutdown Circuit Analysis.

PSA
Frequencies for initial fires have been assessed in a two-step approach. Building specific frequencies for fire have been calculated using data from the OECD-FIRE database. This frequency has then been distributed to the different locations in the building using the Berry method which is based on features like the amount of combustible material in different locations.

Fire detection and fire suppression is modelled and if this is successful the sequences are considered successfully handled. In case the fire cannot be extinguished a fire that fails all active equipment in the analysed fire cell is assumed. Cables that are present in the analysed fire cells are also assumed to fail and will cause active components in other compartments or fire cells inoperable in case components are power supplied from cables routed on the cable raceways.

Fire spreading is considered during power operation. However a screening analysis is performed to limit the fire spreading cases that are included in the PSA-model.
When performing probabilistic safety analysis of fires, a number of simplifications and assumptions are implemented in order to limit the workload. These include the following:

- Civil structures are assumed to maintain stability and integrity.
- Passive components such as pipes, tanks, heat exchangers, and check valves are assumed not to be susceptible to fire damage.
- It is assumed that pneumatic valves will be put in their fail-safe position after loss of power supply due to fire.
- Hot shorts are not modelled
- The method does not cover spreading of smoke and fire through ventilation systems.
- It is assumed that doors have not been left open such that fires can spread through them.
- If an initial fire cannot be extinguished the same manual actions as for internal events are credited without separate analysis. This is non-conservative and a sensitivity analysis has been performed.

2.1.3.3 R: Fire phenomena analyses: overview of models, data and consequences
When performing fire phenomena analyses it is of key importance to be aware of the limitations and uncertainties of models used. It is however also equally important to use a methodology that is robust and quality assured. For this reason, whenever a fire phenomenon analysis shall be performed the methodology and applied models are based on recommendations in a report produced by Lund University, "Guide on quality assurance in fire safety analysis work for Swedish nuclear power plants ". The guide was produced by request from the Swedish licensees through the national cooperative forum Nationella Brandsäkerhetsgruppen, NBSG, where all Swedish nuclear power plants are represented

along with SKB (Swedish Nuclear Fuel and Waste Management Company) and SSM (Swedish Radiation Safety Authority). This guide provides suggested methodology for fire phenomena analyses and describes what to keep in mind when choosing the proper model for the analysis.

For fire phenomena analyses there are three categories of models:

1. Simplified hand calculations
2. Two-zone models
3. CFD models (Computational fluid dynamics).

There is also the deterministic approach to fire phenomena analyses which is described later in this chapter.

Each model contain inherent uncertainties and limitations and should only be applied in analyses where the conditions for the specific model are met. The models mentioned also have varied levels of accuracy, where hand calculations in general are least accurate and CFD models have the highest level of accuracy. Similarly the calculation time increases significantly for models of higher accuracy. For this reason it might be appropriate to initially use simpler models in order to gain an idea of conditions and setups for the advanced, time consuming models. Hand calculations might also compensate for limitations and uncertainties in advanced models. One example of this is in the FHA in containment building, where a fire occurs below the reactor coolant pumps following a complete oil drainage. In the analysis a CFD model was chosen to simulate the postulated fire. The model chosen is suitable when studying smoke transfer and filling along with the temperature increase in the smoke layer and global temperature in the building. The model is however very limited in the ability to estimate flame height and radiant heat transfer. In order to compensate for this appropriate models for hand calculations were chosen to calculate flame height and the potential impact of radiant heat from the fire to target surfaces.

The uncertainties of the models must be managed during the initial stages of the analysis, preferably during the setup of the model. For CFD-models, more specifically Fire Dynamics Simulator (FDS), a guide for best practice exists, supplying methods to validate the results of the model. This is applied whenever a fire phenomenon analysis is performed. The size and position of the postulated fire is also one uncertainty faced during analysis. This must be chosen such that all relevant cases are contained within the analysed case while not exaggerating the size of the fire. It is also required to perform supplementary simulations as part of a sensitivity analysis, where variables that might affect the result are altered, in order to verify the result of the analysis.

For the quantification of direct fire effects such as temperature, pressure, soot and smoke production these are dependent on user input data. This illustrates the necessity of using reliable input data based on experience from previous fires. Experience from NUREG-6850 and OECD Fire Data base must be utilized when applicable. Soot and smoke production should be chosen based on what materials are burning and as such might differ between analyses. For quality assurance purposes it is importance to be transparent and account for the input data used and the assessment of data.

In addition to using calculation models for fire phenomena analysis a deterministic approach is applied for certain analyses. This approach postulates a predetermined fire situated where most harm might be done. The predetermined fire has been studied based on transient fire load that is allowed without special permit. The deterministic approach does not account for the probability of a fire occurring nor is it applicable for studying global impact of a fire in an enclosure. The approach is rather used for studying local effects and the level of separation between safety equipment situated in the same fire compartment. In order to account for the complexity of fire phenomena, one or more of the models and approach might be used. Whenever a fire phenomenon analysis is performed a conservative approach is applied in order to secure that the results of the fire phenomena does not underestimate the consequences of fire. The conservative approach in combination with the application of several models for each fire phenomena analysis along with applied experiences ensures that the complexity of fire phenomena is accounted for.

2.1.3.4 R: Main results / dominant events (licensee´s experience)

FHA

The overall acceptance criterion for protection against fire in the FHA is that the reactor should always be taken into a safe state, and no barrier preventing the spread of radioactive substance is lost.
Analysis of safe shutdown capabilities after a fire demonstrates that sufficient plant systems and components will remain unaffected by all potential fires inside the plant so a safe state can be achieved. The safe shutdown analysis demonstrates that the fire will be limited in such a way that, for safety functions, one train of systems necessary to achieve and maintain safe shutdown conditions will remain available when a single failure or common cause failure is applied.

PSA

During power operation and start-up/shutdown fire as an initiating event contributes significantly to the core damage frequency and to the nonacceptable release frequency. However the contribution from fire has decreased after the installation of the ICCS which constitutes an important safety feature in PSA and is important for the fire analysis since this system is completely independent and therefore isn't affected by a fire in other parts of the plant. During shutdown operation however, the contribution from fire events is small. During all plant operating modes the results are well below the safety goals that has been defined for PSA results at the site.

2.1.3.5 R: Periodic review and management of changes

Maintaining the validity of the fire safety analysis is vital to the quality assurance of the Safety Analysis Report. The management system at Ringhals ensures satisfying procedures for review of the safety analyses and the management of changes.

FHA

The safe shutdown analyses are updated in conjunction with changes to the plant configuration. At Ringhals there is also the ambition to keep the safe shutdown analyses updated at three year intervals, to ensure that no change has occurred that might affect the ability to bring the plant to a safe state.

PSA

Safety reviews are performed every three years at Ringhals, covering updates of the SAR and the supporting analyses, including the PSA. Improvements to the PSA-model are continually performed and implemented in order to better reflect the plant configuration design. In conjunction with projects altering the plant configuration the PSA-model updates accordingly, to illustrate the changes effect on the PSA-study. The changes to the

PSA-model are documented into a yearly interim report, sent to the regulator between each safety review.

2.1.3.6 R: Licensee's experience of fire safety analyses

- The FHA and safe shutdown analysis demonstrate that the separation and redundancy of safety systems is robust and that a fire does not impair the ability to bring the plant to a safe state after fire.
- Using the PSA-model as a tool to evaluate the effect of design changes to the plant configuration in advance enables projects to ensure that proper fire protection measures are taken, such that the fire protection concept is not deteriorated.

2.1.3.6.1 R: Overview of strengths and weaknesses identified

The results from the FHA and the PSA demonstrates that Ringhals Unit 3 has high resilience against fire events. The resilience against fire is a result of the original plant design along with significant improvements done to the plant configuration, such as the physical separation of safety systems. The FHA demonstrates that at least one train of systems necessary for safe shutdown conditions will be available, after a fire has occurred, even after applying a single failure or common cause failure is applied. In addition to this the independent core cooling system exist as a final backup.

2.1.3.6.2 R: Lessons learned from events, reviews, fire safety related missions, etc.

Following the results of fire safety analyses vulnerabilities of the plant configuration has been identified. After the identification of vulnerabilities their effect on reactor safety have been studied and actions taken when it has been deemed reasonable and possible in order to increase the level of safety at unit 3. A handful of these actions are described in this section.

Fire in circulation oil from Reactor coolant pump (RCP)

Following a complete leakage of the circulation oil from one RCP ignition occurs in the oil below the RCP. The analysis resulted in low likelihood for damage to critical components due to the partial compartmentalization of the RCPs but would however lead to critical conditions for human safety.

The fire is the largest possible within the containment building and in order to manage the risks associated with it, a container for collecting RCP circulation oil has been arranged. Following this measure, the risk associated with this type of fire has been eliminated by encapsuling all oil systems, leading potential oil spill to a metal tank.

Spent fuel pool cooling, separation measures

The fire effects in the compartment housing the pumps used for cooling the spent fuel pool were examined. The analysis showed that without taking fire safety measures of some kind both pumps could be knocked out by a fire in the compartment. Measures were taken to protect the pumps and with a separating wall in place, in combination with arrangements for smoke extraction, no fire can occur that could cause both pumps to break down.

Fire protection improvements in MCR

In order to fulfil the requirements released in 2004 regulations it was necessary to improve the fire protection of the relay rooms so that the plant could withstand fire with regards to reactor safety. The solution applied was to install clean agent extinguishing systems in each of the relay rooms along with improved fire detection capabilities. The effects from this measure is that should a fire occur in one electrical cabinet it cannot spread to the adjacent cabinets.

The fire protection measures mentioned above are only examples of several safety increasing measures taken in the recent years. The construction of the independent core cooling system is a major investment, increasing the safety level at R3, described in 2.1.3.1.

2.1.3.7 R: Regulator's assessment and conclusions on fire safety analyses

2.1.3.7.1 R: Overview of a strengths and weaknesses identified by the regulator

The FHA demonstrates a robust design and a possibility to bring the plant to safe shutdown following a fire. Due to additional regulatory requirements, the analyses have been developed and refined over the years. Use of the detailed mapping of plant cable routing, originally performed for the PSA, ensures that safety-important dependencies are accounted for in the safe shutdown analysis.

The separation between redundant safety-related equipment in the original design were not sufficient to comply with the regulatory requirements of today. Weaknesses in the construction revealed by analyses have been addressed through plant modifications and additional administrative procedures; see section R3.5 for more details.

An independent core cooling system (ICCS) is implemented 2020 due to requirement from SSM (all plants have an ICCS). In case of a fire that affects all trains of the regular safety systems (i.e. beyond the assumptions of the FHA), the ICCS will provide a possibility to cool the core and spent fuel. The ICCS therefore provides additional robustness and safety in case of a fire.

2.1.3.7.2 R: Lessons learned from inspection and assessment as part of the regulatory over-sight

SSM has reviewed Ringhals 3 regarding compliance to additional regulatory requirements (SSM2016-5327-6) on an overall level. SSM concluded that an in depth review of the FHA was required. In the in depth review that followed, SSM assessed that the FHA is adequate with areas for improvement (SSM2020-7843-7). The areas of improvement relates to handling of uncertainties in the assumptions for the FHA and performing an FHA for outages.

The fire PSA has not been reviewed in detail in recent years but a PSA review on a general level has concluded that RAB have internal requirements on PSA as a complement to deterministic safety analyses and that there are procedures for updates and quality assurance in place (SSM2022-6289-12).

2.1.3.7.3 R: Conclusions drawn on the adequacy of the licensee's fire safety analyses

Fire was included as a PIE in the basic design of Ringhals 3 but regulatory requirements on analyses have changed ever since. Consequently, RAB needed to revise their analyses. Following the fire analysis reviews presented above the remaining outstanding issues are related to analysis of fire during outage and regarding uncertainties in the assumptions for the FHA.

SSM will need to conduct oversight to ensure that RAB comply with the new requirements regarding fire safety as stipulated in the Swedish regulations for nuclear power plants that entered into force on 1 March 2022.

2.2 Research reactors

Not applicable. Sweden has no research reactors.

2.3 Fuel cycle facilities – Westinghouse fuel factory

2.3.1 W: Types and scope of the fire safety analyses

The goal of fire safety is to prevent any risk of fire or fire-related accident in the factory. The fuel factory must in all respects comply with fire-protection laws and regulations.

The staff working on site has a good knowledge of the building distribution.

Fire safety and hazardous-material management are carried out (analysed) in agreement with the Swedish laws and Swedish Authority regulations.

- Lag (2003:778) om skydd mot olyckor (Protection against accident Act)
- Lag (2010:1011) om brandfarliga och explosiva varor (Flammable and explosive materials Act)
- Lag (1999:381) om åtgärder för att förebygga och begränsa följderna av allvarliga kemikalieolyckor (Measures to prevent and limit the consequences of serious chemical accidents Act)

Fire analyses and risk assessments (both deterministic and probabilistic) are carried out at intervals that are in accordance with current laws and regulations, regulations, requirements from insurance companies and own ambition. Examples of analyses carried out where fire/explosion scenarios occur are (internal ID in brackets):

- Environmental consequences of assumed disruptions and breakdowns (NTC 94-214)
    - Hydrogen explosion
    - Release of uranium powder in the event of a fire in the filter bank
    - Methanol fire
    - Ammonia fire and formation of nitrogen dioxide
- Analysis of external events (BS 99-286)
    - Fire as a result of lightning
    - Fire as a result of crashing aircraft
    - Fire as a result of a falling helicopter
    - Fire in the factory area – ammonia fire
    - Fire in the factory area – methanol fire
    - Fire in the factory area - other cause
    - Fire outside the factory area
- Handling of flammable goods at the fuel factory (ES 15-377)
- Rough analysis handling of flammable goods (ESS 12-300)

- Assessment and classification of EX areas (WSE0019009)
- Assessment of fire load
- Special risk investigation for handling methanol and hydrogen Within the framework of the company's continuous improvement work, CAP, fire analyses are carried out when a need for these is identified, which continuously leads to improvements in fire safety.

This process is detailed and guided by our own classified instructions.

2.3.2 W: Key assumptions and methodologies

Due to specific factory activities, certain parts of the buildings include spaces with an increased risk of fire start and rapid, widespread fire progression.

Sources of electrical energy, equipment and machinery, sparks from grinders or welders, unsafe behaviours and poor housekeeping are main industrial common causes of ignition sources. Two key factors are at the origin of fire development: 1) combustible materials, and 2) oxidizer (O2).

WSE's operations are covered by laws and regulations on flammable and explosive goods. Requirements for tanks and pipelines for flammable liquids are prescribed in MSBFS 2018:3. Requirements for handling flammable gas are prescribed in MSBFS 2020:1. Requirements for handling flammable liquids are prescribed in SÄIFS 2000:2 with amendments up to and including SÄIFS 2000:5.

Exploding gas wagon
An explosion in an LPG wagon being transported on the railway west of the factory has been studied. The probability that a diesel wagon would explode as a result of a train collision or derailment is assessed as very low as the railway section in question has double tracks. In addition, the distance from the railway to the factory is about 300 m, so the consequence of the explosion for the factory would be moderate. The risk that an exploding LPG trailer could affect the factory in a safety-related manner is considered to be very small.

Methanol
Methanol, which is used for drying the filter cake with AUC, is a fire hazard. However, the greatest risk of fire exists when filling with Methanol.

In report NTC 94-214, the risk of a widespread methanol fire in the filter cake has been assessed as low as the space above the AUC cake is ventilated to the process ventilation to reduce the fire risk. A fire extinguishing system is installed which triggers the sprinkling of carbon dioxide snow over the filter when the temperature of the vapours from the filter exceeds 805 °C.

In EPS 20-061, Sweco's analysis of a dimensioned damage event is reported (case 1 Hit by a tanker during unloading in progress). In the analysis of the dimensioning fire scenario, 15 kW/m^2 for 30 minutes has been used as accepted incident heat radiation. It is the same acceptance criterion prescribed in the Swedish Housing Authority's building regulations, and is the amount of incident radiation over 30 minutes that is expected to ignite a facade made of wood. This is considered a conservative criterion as the surrounding buildings are made with external surface layers in non-combustible materials.

For the dimensioning fire scenario, incident radiation on tanks for methanol class 2a and 2b as well as load changer flats for hydrogen exceeds the acceptance criteria.

Hydrogen gas
In report NTC 94-214, a case has been identified where hydrogen gas could leak from a flange joint inside the oven's insulation. In the event of a leak in the flange connection, hydrogen gas can be led up between the furnace pipe and the insulation with electrical loops, whereby an explosion/fire could occur. However, the flange joint is checked regularly and the probability of a hydrogen gas explosion or hydrogen fire occurring has been assessed as low.

Another event that can occur is an explosive gas explosion in a sintering furnace or in the workshop. The hydrogen gas that flows out of the sintering furnaces at the door opening is ignited in a controlled manner with the help of electric filament coils. The filaments are fed from a diesel-protected network, but should one of the oven's filaments go out, an alarm is given and the door opening is interlocked.

This means that the risk of a hydrogen gas explosion outside the workshop is considered to be very small. A gas explosion inside the oven is more likely to occur, but to prevent major damage to the oven and possible damage to the surroundings, the oven is equipped with spring-loaded explosion hatches to relieve the pressure wave in a controlled manner. In EPS 20-061, Sweco's analysis of a dimensioned damage event is reported (case 4 Fire in a truck on a hydrogen plane. Explosion in a hydrogen bed due to heating and inability to cool properly). In the analysis of the dimensioning fire scenario, 15 kW/m^2 for 30 minutes has been used as accepted incident heat radiation. It is the same acceptance criterion prescribed in the Swedish Housing Authority's building regulations, and is the amount of incident radiation over 30 minutes that is expected to ignite a facade made of wood. This is considered a conservative criterion as the surrounding buildings are made with external surface layers in non-combustible materials.

For the dimensioning fire scenario, incident radiation on surrounding protective objects will be within the limits of what is acceptable. However, to reduce the risk of vessel bursting, the gas bottles can be cooled by applying water.

Our strategy aims at building a corporate safety culture through:

- Increasing awareness of risks (through training actions on dangerous and deviant behaviours).
  - This is achieved i.a. through training of the staff as well as safety briefings where each meeting begins with a review of any risk that has been identified or event that has occurred, both locally in Sweden but also at group level.
- Internal rules and procedures to control sources of heat that could initiate a fire outbreak.
  - This deals with e.g. requirements for which electronic equipment may be brought into the facility as well as rules and routines for how hot work at temporary workplaces must be carried out.
- Setting up physical fire-protection equipment (surveillance, detection, alarm, alert, building design, automatic means of fire extinction).
- Reviewing previous fire incidents to identify common causes through learning.

- This takes place via the company's internal program for continuous improvement, CAP.

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

The hypothesis of fire spread in the ventilation ducts has been identified as a major risk by Westinghouse and SSM. The background to this assessment is the design of the process, which includes flammable liquid, see summary below:

The system consists of five identical rotatable filters (two filters in line 1 and three filters in line 2). After completed precipitation and cooling of a charge in the precipitation vessel, the AUC slurry is pumped over to the rotary filters. The AUC slurry is then filtered. After filtration, the AUC cake is washed with carbonated water. Drying of the AUC cake then takes place using methanol in two rounds. First methanol that was used in the previous precipitation is used, then pure methanol from the methanol tank (731). After methanol and air drying of the AUC cake for about 2 hours is it ready to be transferred to the fluidized bed furnace for reducing the uranium to UO2.

The last revision of the analysis was carried out in 2014.

The release of uranium dust would constitute one of the most dangerous consequences in terms of inhalation and soil contamination by alpha emitting particles.

This scenario was studied and analysed considering several variable parameters such as the speed and spread of fire development in different weather conditions.

To prevent the spread of uranium powder via the chimney, it has quick-closing fire dampers.

2.3.4 W: Main results / dominant events (licensee´s experience)

In case a fire could not be detected due to fire-detector and fire-damper malfunctioning, here is below the list of steps we would follow to avoid ending up in the major crisis situation mentioned above (2.3.1):

- Step 1: Following the release of contaminating particles, the "zone alarm" would be triggered to confine instantly all people in the zone at risk of contamination.
- Step 2: Throughout the duration of the release of contaminating particles, the road and rail traffic would be stopped, with the police prohibiting access to the risk zone (Figure 2).

As the business's type of facility is unique, there are not many relevant statistics to compare with. Temporary fire load, e.g. editions for construction work or audits are always preceded by a risk assessment for the specific case. Furthermore, the business also has rules for how circulation and packaging etc. should be handled.

2.3.5 W: Periodic review and management of changes

Westinghouse Electric Sweden AB carries out Systematic Fire Protection (SFP) work according to LSO (Protection against accidents Act). The factory safety management designs how SFP rules have to be conducted, as well as everyone's responsibility for conducting safety functions in the company. Descriptions are given about routines to follow.

Procedures are also provided in case of any change in the company activity or building rearrangement.

Tasks on fire protection are distributed by company committee members to managers and others with authorities in this area.

Before analyses are published internally and considered valid, they are preceded by a review process where, if the risk is deemed necessary, independent reviewers carry out the review. There are clear instructions for this available via the business's management system.

In the event of a facility modification, the business has routines that state that the fire protection officer must be connected to the project/case. If the fire engineering capability that is relevant for the current modification is not available within the business, external experts are hired.

In the event of a change that is also deemed to have an impact on radiation safety and/or criticality safety, the modification must also be reviewed and approved by the operation's independent safety department before it can be implemented.

The fire engineering installations within the facility follow the operation, control and maintenance plan that appears in the manufacturer's instructions or applicable regulations/standards.

There is no specially established periodicity for fire technical analyses, but these are carried out when the need arises, such as in case of modification of the facility, new laws/regulations, other requirements from insurers or changed own ambition.

1. Training and fire safety education
    - i All visitors to the business must undergo safety training where, among other things, fire safety is dealt with before they are given access to the operational area.
    - ii All employees must attend theoretical fire protection training at least every three years.
    - iii All employees must complete a practical training in handling extinguishing equipment at least every three years.
    - iv Managers of flammable goods must undergo training upon entry, and if the management of the business is changed in such a way, competence needs to be supplemented. Ex. on such change may be new, larger amount flammable, be of a different type that has not been handled before with a different risk profile.
    - v Permits responsible for issuing permits for hot work at temporary workplaces must undergo such training upon entry and then renew their certificate no later than five years.
2. Regular assessment of housekeeping process in terms of fire protection (Internal fire load control, and ignition-source control).
3. Maintenance of existing fire protection equipment and structure.

Examples of measures taken after analyses have been carried out are quick-closing dampers in chimneys to prevent the spread of uranium powder to the surroundings.

2.3.5.1 W: Implementation status of modifications/changes

Structural changes to the site involving modifications of infrastructure, equipment and/or procedures are studied by the safety-and-fire-protection department. They have to follow the recommendations adapted to needs and national regulatory requirements.

2.3.6 W: Licensee's experience of fire safety analyses

- The conducted fire safety analysis shows that the operations complies with regulatory requirements and that necessary measures have been conducted in order to prevent release of airborne UO2 to the environment.

2.3.6.1 W: Overview of strengths and weaknesses identified

Westinghouse commonly shares feedback and information up to the highest (international) decision making level. This policy thus guarantees that all operating units can benefit from solutions, mastered at the global level and adapted to local specificities.

This is described in instructions that are available via the business's management system.

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

Westinghouse aims at building an environment that continuously promotes learning from industry and experience to ensure that safety and quality are held to the highest and most current standards in the performed work. This process is enriched by learning from our operating experience, post-job reviews, self-assessments, benchmarking and much more.

2.3.7 W: Regulator's assessment and conclusions on fire safety analyses

2.3.7.1 W: Overview of a strengths and weaknesses identified by the regulator

The radiological risk to the public associated with a fire in the Westinghouse fuel factory is significantly lower in a fuel factory compared to a nuclear power plant. The FHA has been reported to SSM and its predecessors and handled according to SSM:s review processes.

2.3.7.2 W: Lessons learned from inspection and assessment as part of the regulatory over-sight

SSM assesses that the radiological consequence to the public in case of a fire in the fuel factory is limited. SSM has not performed specific reviews on the FHA in recent years.

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

SSM overall assessment is that the FHA performed by Westinghouse shows the associated limited risk with a fire in the fuel factory and its consequences to the public.
The regulations for nuclear facilities such as the Westinghouse fuel factory is currently being updated. Once finalized, it will require further oversight activities to ensure compliance with current requirements for fire analysis.

2.4 Clab

2.4.1 C: Types and scope of the fire safety analyses

Several different fire safety analyses have been carried out for Clab. Most of these analyses are associated with the facility’s Probabilistic Safety Assessment (PSA). For each analysed fire event, both probability and expected consequence are calculated. Depending on the prevailing ratio between probability and consequence, either the fire event can be considered acceptable, or safety measures need to be taken. There have also been deterministic analyses where different fire scenarios have been investigated regarding the impact on specific critical systems.

Listed below are some examples of potential fire events that have been analysed.

- Cooling of storage pools are lost due to a fire
- Fuel elevator loaded with nuclear fuel stops due to a fire
- Transport containers stays hanging in the overhead crane due to a fire
- Surface cooling of transport container fails due to a fire

2.4.2 C: Key assumptions and methodologies

PSA aims to identify combinations of events that can lead to unwanted consequences and quantitatively evaluate these consequences. All functions credited in the analysis and the way they interact with different disturbances are considered. A PSA model typically consists of a set of event trees that describe the facility's response to an assumed disturbance. The systems available to handle the disturbance are modelled with fault trees. Identified failure events are assigned reliability parameters to quantify the overall probability or frequency of the unwanted consequences.

In all deterministic fire safety analyses the assumption is made that only one fire occurs at a time.

When analysing a fire event using fire progress calculations a worst-case scenario is always selected with conservative choices of input data. It can for example be a large transient fire load, even if there are clear rules and routines to prevent this type of fire load.

2.4.3 C: Fire phenomena analyses: overview of models, data and con-sequences

The most common consequence to analyse is if two redundant components of the cooling chain can be damaged by a single fire event. The fire safety analyses often consist of fire progress calculations for some worst-case fire scenarios, either with the calculation program CFAST[7] or with CFD modelling. If the fire progress calculations shows that two redundant components may be damaged and if there are no other system that can perform the function, measures need to be proposed and taken.

2.4.4 C: Main results / dominant events (licensee´s experience)

There are no statistics on fire incidents for the facility because it has not had a fire.

[7] Consolidated Model of Fire and Smoke Transport

Dominant fire events in the fire safety analysis are fire events that in some way can affect the cooling chain. Depending on the prevailing ratio between probability and consequence, either the fire event can be considered acceptable, or safety measures need to be taken. In many of the fire safety analyses the dominant fire event is a fire in a transient fire load. A transient fire load can for example be a large garbage bag or a cleaning trolley. Examples of results from the fire analyses are provided in section 2.4.5.1.

2.4.5 C: Periodic review and management of changes

The facility has clear routines for how to ensure the quality of the fire safety analyses.

The facility has clear routines for how facility modifications should be handled, for example a fire expert must always be consulted.

Fire technical installations are regularly checked and maintained according to regulations and/or the supplier's instructions.

2.4.5.1 C: Overview of actions

Below are some examples of safety measures that the fire safety analyses have resulted in:

- Repositioning of redundant components in the cooling system. For example, extension of the safety distance between cables or electrical cabinets.
- Installation of heat radiation protection between redundant components in the cooling system.
- Improvement or expansion of the fire cell division.

2.4.5.2 C: Implementation status of modifications/changes

Proposed safety measures according to the established fire safety analyses have been implemented, alternatively there is a clear plan for future implementation of the proposed safety measures.

2.4.6 C: Licensee's experience of fire safety analyses

Clab:s safety analysis does not credit active safety functions, which in most incidents provides both simpler sequences to remedy the incident and more time for decisions and action. However, the facility contains very large amounts of nuclear material, which means that reassuring safety margins are always applied when working with this.

2.4.6.1 C: Overview of strengths and weaknesses identified

The facility's routines and safety culture promotes the quick uncovering and remedy of weaknesses. The level of the facility's fire protection safety is considered to be robust both when it comes to radiation safety, personal safety and property protection. If weaknesses are identified, an action plan for these is immediately established.

The fire load in the facility is generally low and efforts are continuously performed to minimize transient fire load in critical areas.

2.4.6.2 C: Lessons learned from events, reviews, fire safety related missions, etc.

There are no statistics on fire incidents for the facility because it has not had a fire.

Clab is a facility designed according to requirements valid during construction early 1980th. The capacity will be increased which entails upgrades using more comprehensive requirements.

2.4.7 C: Regulator's assessment and conclusions on fire safety analyses

2.4.7.1 C: Overview of a strengths and weaknesses identified by the regulator

The FHA demonstrates a robust design and a possibility to ensure an acceptable consequence to the public following a fire. Due to additional regulatory requirements and reviews, the analyses have been developed and refined over the years.

Clab is a nuclear facility with a different risk compared to nuclear power plants. There is significantly more time available to handle a fire and its consequences compared to a fire at a nuclear power plant. The required actions are still dependent on manual measures (mainly repairs) as a result of not reaching full separation in the construction. This emphasizes the need for education and training of staff that perform these tasks.

2.4.7.2 C: Lessons learned from inspection and assessment as part of the regulatory over-sight

SKB has applied already in 2006 to expand Clab with an encapsulation plant for spent fuel. During the review for the combined encapsulation plant, SSM ordered SKB to identify all event and sequence of events as well as to describe the actuality of the safety analysis report for Clab as built (SSM2013-2538-1). This led to the need for SKB to update the original FHA and develop a Fire-PSA. The updated FHA and Fire-PSA identified a need for several fire safety related improvements, see also chapter 3.5.1.3.3.

SSM has reviewed the FHA and the Fire-PSA in several steps. SSM concluded in the first overall review that Clab had identified all significant events and sequence of events (SSM2016-2449-3).

SSM has reviewed SKB:s application for an expansion of the storage capacity for Clab, where an assessment of the risk of and the consequences of lost cooling has been analysed. Based on the review of the FHA and internal flooding analyses, SSM states that "the ability to maintain and re-establish the cooling function to a certain extent is still dependent on manual measures (mainly repairs) as a result of not reaching full separation in the construction. The assessment by SSM is that high reliability in carrying out the repair measures in spent fuel pool system with support systems is a prerequisite for handling events and conditions affecting the cooling function (SSM2022-8770-41).

SSM has performed two reviews on the PSA. In the first review, SSM concluded that there was room to improve the analysis, as it did not include a fire-PSA (SSM2018-2211-6). SKB updated the PSA to include fire and SSM did find in the second review that the methodology to perform the Fire-PSA has clear prerequisites, a detailed description of the work to be performed and clear expectations on presentation of the results. Furthermore, SSM found that Clab has systematically assessed and presented the risk for radioactive release.

2.4.7.3 C: Conclusions drawn on the adequacy of the licensee's fire safety analyses

Fire was included as a PIE in the basic design of Clab but regulatory requirements and expectation on analyses have changed ever since. The Swedish Nuclear Inspectorate's regulations and general advice (SKIFS 2004:1)[8] concerning the design and construction of nuclear facilities included new requirements intended to develop and maintain safety in the construction. SKB has also applied to expand the facility with an encapsulation plant for spent fuel. Consequently, SKB needed to revise their FHA analyses and develop a Fire-PSA for Clab. SSM concludes that the updated FHA is adequate. The fire PSA has been reviewed and the conclusion is that the Clab PSA study is adequate and is being kept up to date.

The regulations for nuclear facilities such as Clab is currently being updated. Once finalized, it will require further oversight activities to ensure compliance for fire analysis.

2.5 Waste storage facilities

No waste storage facilities are included in the Swedish report.

2.6 Facilities under decommissioning

No facilities under decommissioning are included in the Swedish report.

[8] Superseded by SSMFS 2008:1 following the formation of the Swedish Radiation Safety Authority

3 Fire protection

3.1 Forsmark 2

3.1.1 F: Fire prevention

Fire prevention is the first level in the defence-in-depth for fire protection.

3.1.1.1 F: Design considerations and prevention means

The basic principle of fire protection and fire safety of the facility is to prevent, as far as is reasonable and possible, the occurrence of fire. If a fire should nevertheless occur, the consequences are limited by passive fire protection measures and automatic and or manual extinguishing efforts.

Fire safety aims to ensure that the safety functions of the plant can fulfil their tasks and that the plant's barriers to prevent radioactive emissions to the environment can be maintained even in the event of a fire.

For fire protection, a defence-in-depth principle is applied with three lines of defence:

Level 1 Preventive fire protection - Fires must be prevented from occurring.

Level 2 Detection and response - Fires that nevertheless arise should be quickly detected and extinguished to limit their harmful effect.

Level 3 Consequence mitigation - Fires that are not extinguished should not be able to affect safe shutdown and not result in the installations barriers against radioactive emissions to the surroundings are degraded.

In order to prevent the spread of fire, safety related equipment is located in separate spaces or physically separated by other means. In cases where equipment cannot be placed in separate spaces, the spread of fire is prevented by distance separation, shielding, encapsulation or by lowered oxygen in certain spaces. In addition, material selection takes place in such a way that the fire load and the risk of fire spread are as small as possible.

According to this principle, a fire that occurs in a space with safety related equipment will not affect spaces containing safety related equipment belonging to other redundant safety trains.

3.1.1.2 F: Overview of arrangements for management and control of fire load and ignition sources

Through systematic fire protection work, the risks of fires occurring are minimized. The systematic fire protection work includes, among other things, inspections in the facility, rules for what at Forsmark is defined as hot work and limiting the amount of combustible material in the plant. Combustible liquids are stored in dedicated areas and packaging materials are handled in an orderly manner. In spaces with safety related equipment, requirements for the maximum permissible fire load are prescribed and strict. The inspections of the operating staff in the facility include observing whether temporary fire loads have been added. The inspections carried out by the internal fire brigade include identification, and if necessary plans for removal, of any material that increases the fire load.

During the initial planning and preparation of work in the facilities, an assessment should be made if the fire load will increase during the work, if so, a Fire Safety Directive should be requested. The internal fire brigade will do checks at workplaces at least once every shift. For the preparation of work in spaces that have been identified as having a greater impact on reactor safety, supplementary rules apply.

3.1.1.3 F: Licensee's experience of the implementation of the fire prevention
A prerequisite for a well-functioning fire prevention is to establish a policy in fire safety and have an organization that works specifically with fire safety. One of the most important tasks for the fire organization is to get everyone who work at the power plant be aware of the importance of their personal role in order to maintaining a strong fire protection.

All personnel must have the prerequisites to be able to identify and act on deviations in the fire prevention and in the event of fire. This is done through recurring training and information efforts in fire safety.

Having a good safety culture and making everyone feel responsible and have a high willingness to report is an important parameter to be able to detect deficiencies in fire prevention equipment and initiate repairs in order to reduce the risk of a fire event.

Another important part of fire prevention is to have a good collaboration between the fire organization and the maintenance department. To ensure this a specific role called fire technician is appointed who, among other things, is responsible for issuing permits and performs a post evaluation for hot works. The fire technicians have a good and close contact with the maintenance staff and the operating staff. After each month, a follow-up is made of the preventive fire protection work carried out and any deviations that have been discovered.

Another part that has been introduced in recent years is systematic fire safety rounds with operating personnel and the internal fire brigade, which strengthens the cooperation between the fire brigade and operating personnel. These safety rounds also increases the understanding and experience of the various safety work which is a part of the fire protection.

3.1.1.3.1 F: Overview of strengths and weaknesses
One of the strengths in fire prevention is the high quality of buildings construction and overall high level of separation between safety systems. Another strength is the fire organization and having a well-trained onsite fire brigade and good cooperation with the municipal rescue services.

A weakness in the construction is that some fire compartments contain SSC's for two redundancies.

3.1.1.3.2 F: Lessons learned from events, reviews fire safety related missions, etc.
One event that led to several improvements in fire prevention was a fire in an electrical cabinet in 2005 that affected safety related equipment in two safety trains. The fire led to several improvements in fire prevention, among others, physical separation of some relay

and electrical cabinet rooms, re-construction of venting system, updated instructions and improved pre-fire plans and development of intervention cards for the most important rooms in a reactor safety point of view.

There are several national and international forums to share information and experiences from events. One forum is Norderf, which provides the Nordic nuclear power plants with external experience from the nuclear industry in the world.

There is also a National Fire Safety Forum (NBSG) where the licensees and regulator are members. The overall focus is to create increased knowledge in the field of fire safety at nuclear facilities and increased knowledge in the field of reactor safety-related fire safety. The group's work will lead to synergies in the field of fire safety by jointly funding research, testing and dissemination of information. The focus of the works carried out on behalf of the NBSG shall be attributable to any of the categories presented below:

- Support/development of practical fire protection by, for example, improving response planning.
- Clarification of requirements by working for a common interpretation and harmonized view of new rules and requirements. This will facilitate ongoing modernization of existing nuclear power plants and SKB's (Swedish Nuclear Fuel and Waste Management Company) existing facilities. It will also provide support in the decommissioning of existing nuclear power plants and in the design of SKB's future facilities.
- Experience feedback by, for example, analysing historical data or by improving systems for such management.
- Monitor and participate in national and international developments in fire research, with a special focus on the energy field.
- Influence interest groups in order to support/carry out research useful for the nuclear industry
- Development of analysis tools and data support.
- Develop methodology for fire protection during the decommissioning of nuclear facilities.

3.1.1.3.3 F: Overview of actions and implementation status

Some of the actions that have been implemented to improve the fire prevention includes:

- Separation of electrical cabinet rooms, some electrical cabinets belonging to different redundancies within a main redundancy that were located in the same fire compartment are now separated and placed in different fire compartments.
- Implementation of a fire prevention system with reduced oxygen in some electrical rooms that has safety related equipment belonging to two redundancies in the same fire compartment.
- Reinforced fire detection in some electrical cabinets with sampling detectors.
- Installation of alarms of the most important fire compartment doors.
- Fire protection measures on outdoor transformers, new transformers, fire protection metal grating (instead of bedrock) installed over transformer pits for main transformers.

3.1.2 F: Regulator's assessment of the fire prevention

Requirements for fire prevention has historically been regulated by other authorities than SSM, see section 1.2.1. These requirements are generic for industrial buildings and not specific for nuclear power plants.

Prior to 2022, SSM did not have any specific requirements on fire prevention as shown in section 1.2.1 for nuclear power plants. As such, there have not been any inspections and no formal lessons learned with regards to the fire prevention programs for the licensees.

3.1.2.1 F: Overview of strengths and weaknesses in the fire prevention

FKA has an active fire prevention program that ensures that the fire loads are as low as reasonably achievable and lowers the probability of fires. This include routines to manage and control fire loads and ignition sources at the plant as well as that personnel have the prerequisites to be able to identify and act on deviations in fire prevention and in the event of fire. As a part of the systematic fire protection work, regular inspections are performed in the facility to ensure proper control of fire loads and ignition sources. In case of hot work, specific training and a work specific permit is required.

Forsmark 2 have also installed a system to reduce the oxygen levels in certain areas to reduce the risk of a fire. The reduced levels prevents fires from occurring and makes it less severe if it does, ensuring that it only affect one safety train. See also section F3.5.

There are several national and international forums where the licensees and regulator share information and experiences from events. One forum is Norderf, which provides the Nordic nuclear power plants with external experience from the nuclear industry in the world. Another is the NEA project OECD-FIRE, that have collected information from over 500 events that have occurred at NPP:s.

FKA, RAB, OKG, SSM and SKB are members in NBSG. The overall focus with NBSG is to create increased knowledge in the field of fire safety at nuclear facilities and increased knowledge in the field of reactor safety-related fire safety. The group's work aim to achieve synergies in the field of fire safety by jointly funding research, testing and dissemination of information.

3.1.2.2 F: Lessons learned from inspection and assessment on the fire prevention as part of its regulatory oversight

As part of general oversight activities related to operations, SSM does inspect housekeeping practices, both during focussed housekeeping inspections, and as observations during other inspections. Conclusions from the latest inspection particularly focused on housekeeping are that FKA complies with regulatory requirements (SSM2013-650-8).

SSM:s main conclusion is that the fire preventing programs relies heavily on the responsibility on every individual that enters a nuclear facility to do their part to reduce the risk of a fire occurring and spreading. This is done by ensuring a limitation of combustible materials and lower the risk for ignition. One lesson learned is that this is of importance during maintenance work to ensure that the risk of a fire is sufficiently low, this is followed up during normal scheduled inspections both by the licensee and SSM.

3.1.3 F: Active fire protection

3.1.3.1 F: Fire detection and alarm provisions

A comprehensive fire alarm system covering all areas is installed at the facility.

3.1.3.1.1 F: Design approach

The fire alarm system consists of several fire alarm centres divided into redundancy A and B. The electricity supply to the system is secured by battery supply in an A and B part placed in different fire compartments. The fire alarm centres communicate with control systems for control and status monitoring of objects.

The parent system consists of two redundant servers as well as two operator stations and an operator terminal. The parent system is divided into redundancy C and D. Operator stations and operator terminal are used for all presentation and management. Fire alarm centres with associated control panels and control systems are located in the main control room.

The system also includes detectors and alarm buttons that via loop lines, scattering and junction boxes and supply lines are connected to the fire alarm centres.

The placement of detectors has been according to SBF 110 “Rules for automatic fire alarm”

Alarm buttons are placed in principle at each fire hydrant outlet and at the place where automatic measures such as fire ventilation can be started locally, as well as at each stairwell and planned access route.

Locally via the fire alarm system, you can thus start e.g. fire water pumps, activate the section's automatic actions and fire ventilate stairwells and cable spaces.

Controls are automatically issued to various objects in the station after an alarm has been received by the control unit. Examples of objects controlled by the fire alarm are:

- Start of fire pumps
- Start of overpressure fans in stairwells
- Starting extinguishing systems
- Closure of fire dampers
- Closure of recirculation dampers

3.1.3.1.2 F: Types, main characteristics and performance expectations

The system predominantly uses multi-criteria detectors with both smoke chambers and thermal sensors, but other detector types also occur, such as heat detectors and highly sensitive smoke detectors and in certain rooms aspirating smoke detectors.

The multi-criteria detectors are "interactive", which in this case means that the detector in collaboration with the fire alarm centre cooperates in the evaluation of measurement values. In each detector there is an evaluation algorithm programmed. This algorithm can be changed from the parent system, to adapt the detector for different environments. In this way, the fire alarm can be kept active in, for example, a room where welding work is underway.

In the event of a failure of the parent computer systems, alarm management can take place at the fire alarm centres’ control panels.

Failure of central equipment (fire alarm centre or control system) for one redundant division must not affect the function of the second redundant division. Failure of parent computer systems must not affect the function of other equipment. Loss of server or operator station shall not affect the function of redundant server or operator station.

In the event of loss of regular power supply, there are accumulators that can keep the system in operation for several hours.

3.1.3.1.3 F: Alternative/temporary provisions

The fire alarm is never turned off during welding work as the interactive multi detectors can detect the type of smoke that is generated. If one part of the system needs to be shut down for maintenance, fire guards are deployed to control the affected areas.

3.1.3.2 F: Fire suppression provisions

To prevent a fire from developing into a dimensioning fire there are different types of fire suppression systems.

Extinguishing agents that are used are water, foam, inert gas, carbon dioxide and powder. Some of these agents occur in fixed systems and some solely for manual firefighting.

Water is the basis for essentially all expected fires at the plant.

The fire water facility has been dimensioned according to “Svenska brandförsvarsföreningens anvisningar” (The Swedish Fire Protection Association's instructions) from 1972, which means that the system must have the capacity to supply the largest dimensioning water sprinkler centre while using the system for manual firefighting. The dimensioning water sprinkler centre requires approximately 8600 litres/min and together with an estimated value of 2000 litres/min for manual firefighting and drainage losses of 240 litres/min the requirement for the system is 10 860 litres/min.

There is no requirement for how long sprinkling should be able to last and thus no requirement for the storage tank capacity or for fuel storage for the diesel fire pumps. The volume of the storage tank allows sprinkling for 90 minutes with a water outlet of 200 kg/s. After 90 minutes, manual actions are required to add water to the tank.

There is a common storage tank that supplies unit 1 and 2 with fire water, the tank is located outdoors at the common service building. The storage tank contains 1500m³ and is normally supplied with water from the industrial water system.

Unit 1 and 2 each have two fire water pumps, one electric and one diesel-powered. The fire hydrant network for unit 1 and 2 are interconnected, which means that all 4 fire water pumps can be used for each unit. The fire pumps for unit 1 and unit 2, respectively, have been placed in different fire compartments.

The fire hydrant network of each unit is designed as a ring line in the various buildings of the station. Each building has been equipped with manual shut-off valves. In the event of a pipe breakage in the line, it is possible to feed water from the other side of the ring line.

3.1.3.2.1 F: Design approach

The design approach for the fire water system is that indoor fire hydrants are positioned so that all spaces including roofs can be covered with water from the fire hydrants normally associated hose. The dimension is a simple narrow hose socket (42 mm) with 2x20 meter hose and nozzle. Wall fire hydrants are located in the foundation wall of the station with a distance of about 75 meters between. The dimension is double normal hose sockets (76mm).

Spaces with a high fire load and where at the same time there are certain fire risks have been equipped with permanently installed water sprinkling systems.

Sprinkler valves open automatically in the event of a fire alarm within the respective sprinkling area. Normal sprinkling time is 5 minutes and is controlled via the fire alarm system. If necessary, renewed sprinkling can be triggered from the MCR.

- Water sprinkling is available for:
- Cable culverts and cable shafts.
- The turbines and its peripherals. One sprinkling section goes to the point and floor sprinkling of the respective turbines. One section goes to the respective turbine oil tanks as well as oil gutters.
- Some spaces in the waste building

Foam sprinkler is available for:

- Emergency diesel generator (manual activation)
- Oil coolers for feed water pumps

Inert gas is available for:

- Electrical relay rooms under the MCR

3.1.3.2.2 F: Types, main characteristics and performance expectations

The system must have the capacity and ability to fight a fire in all areas and buildings of the facility.

The requirement is met by sprinkling with water and foam, as well as suffocation of the fire with inert gas (Inergen). In spaces that are not sprinkled or otherwise do not have automatic firefighting, there is access to extinguishing water via appropriately placed fire hydrants.

The system is single-fault steely. To meet the requirement, there are two pipes from the common water tank, as well as a redundant water supply from the low-water reservoir. Further, the system has four fire water pumps, each of which or together have the required capacity. To ensure function in the event of a loss of electric power supply, two of the fire water pumps are diesel powered.

3.1.3.2.3 F: Management of harmful effects and consequential hazards

Incorrect base position of valve can prevent water flow into the system. For the system essential valves are lock-interlocked in base mode.

Accidental shutdown of the automatic water sprinkler system is prevented by shut-off valves that are monitored by limit position indications that give an error signal in case of unjustified closure.

Unwarranted manual triggering of sprinkling or other extinguishing equipment leads to sprinkling and may lead to double ground faults which in turn can lead to process impact.

3.1.3.2.4 F: Alternative/temporary provisions

In the case of maintenance on the system, compensatory measures must be taken to ensure the required extinguishing capacity is available. If a section of the system is unavailable for maintenance, hoses can be taken from other parts of the system for manual firefighting in the affected space.

3.1.3.3 F: Administrative and organisational fire protection issues

To ensure the operability of fire protection equipment there are administrative routines in place, maintenance plans are available for all fire protection equipment, the plans are entered into the regular maintenance system and are carried out at predetermined intervals.

3.1.3.3.1 F: Overview of firefighting strategies, administrative arrangements and assurance

Actions in the event of a fire, as well as other occurring abnormal events at the station, are guided by pre-issued instructions. These shall describe the measures to be taken to prevent any uncontrollable situations. For fire, the following instructions are developed:

- An overall instruction that describes routines for rescue operations, including how responsibility is distributed in the event of an operation and what the communication routes look like.
- Typical events describing the most common fire scenarios at nuclear power plants and existing risks and extinguishing measures.
- A firefighting plan with prepared measures to be taken by the operations personnel in the control room depending on the area affected.
- Intervention cards for specific spaces with information on the fire load/fire hazards of the space, any automatic measures, access routes, fixed and mobile firefighting equipment and appropriate extinguishing action.
- An emergency routine for the internal fire brigade that describes each person's role in different types of alarms.

The firefighting plan and intervention cards are available in the fire truck at the internal fire brigade and in the MCR.

The frequency of review for the instructions is at most every three years. Quality assurance is managed thru systematic fire protection work and is continuously monitored. The intervention cards are part of the inspections that the internal fire brigade does together with the operations staff, they go to a room and have the intervention cards with them and has a dialog over the plan and risks in the specific room.

3.1.3.3.2 F: Firefighting capabilities, responsibilities, organisation and documentation on-site and offsite

There is an internal fire brigade stationed on the site. The fire brigade is outsourced to a professional contractor with the same demand on the firefighting personnel as an ordinary fire brigade according to Swedish regulations. The fire brigade is manned 24 hours a day, all year around, by four teams working in shifts. During office hour the staff is increased by fire technicians that are also trained as firefighters. They are required to immediately respond to an alarm and to be able to start rescue intervention at the address point inside the plant maximum 10 minutes after the alarm. The fire brigade also performs systematic fire protection work at site that makes them very familiarized with the plant and risk connected to the process.

There is a Service Level Agreement (SLA) with the fire brigade that describes in detail the mission and skill requirements of the fire brigade.

Training and drills for the station fire brigade is always ongoing and in various forms. The training plan is based on the typical events of probable fire scenarios that have been developed.

Some training and drills are also performed in liaison with the operations personnel and some with the offsite fire brigade. An annual fire drill is performed with each operations shift team (7 per unit).

On each operations shift team there are process operators who shall meet the fire brigade at the entry point and provide necessary keys and support the fire brigade regarding process knowledge. The process operators receive special training in firefighting and they have their own firefighting personal protective equipment and are trained to use a self-contained breathing apparatus.

The nearest offsite fire brigade has approximately 20 minutes to get to the site. There is a good cooperation with the offsite fire brigade and multiple fire drills of various types are arranged. The aim is to get the outside organizations familiarized with the site and nuclear in general. For commanding officers most of the drills are table-top and simulation drills.

The onsite fire brigade are always called upon in case of a fire alarm or other emergencies such as medical emergencies, accidents or nitrogen alarms. The criteria to deploy the offsite fire brigade is that two or more fire detectors have detected fire or smoke or if there is a confirmed fire. For other emergencies the fire brigade foreman does an assessment in each case if there is a need to call upon external rescue services.

3.1.3.3.3 F: Specific provisions, e.g. loss of access

There are an alternative road that can be used to access the site. Depending on where the event has occurred there are often several different paths available to access the affected area. The operations personnel and the internal fire brigade are also very familiar with the facility. The fire brigade has necessary tools and equipment to be able to force their way thru doors that for some reason can’t be opened the ordinary way.

3.1.4 F: Passive fire protection

The basis of the fire protection of the facility is the passive fire protection, which is based on that the buildings of the plant are made with fire-resistant material and divided in such a way that the spread of fire is made more difficult. Passive fire protection also includes other design solutions preventing or delaying the spread of fire, e.g. by selecting materials, shielding, distance separation or reduced oxygen content.

In addition to passive and active fire protection, active and systematic fire prevention work is carried out that includes fire safety rounds, limiting the amount of fire load, tests of the active fire protection, exercises and training of personnel and works with an increased fire risk, or that affect the active or passive fire protection, are guided by instructions with regard to compensatory measures.

Despite the fire prevention measures, it must be assumed that a dimensioning fire can occur. Therefore, there is a consequence mitigation fire protection in the form of physical separation. The separation includes both room separation and distance separation.

Room separation means that different systems is separated from each other by being placed in separate spaces, these spaces can be either fire zones, fire compartments or fire cells.

In general, the division into fire zones provides the best separation due to the fact that no common systems are in principle shared between different fire zones. A fire compartment, on the other hand, may have some common systems.

3.1.4.1 F: Prevention of fire spreading (barriers)

The definition of fire zone, fire compartment and fire cell are as follows:

Fire zone
A fire zone consists of one or more fire compartments with a separate ventilation system (own supply and exhaust air system). Exceptions can be made for the exhaust air, which, after the exhaust fans, can be merged into the common main chimney.

Fire compartment
A fire compartment refers to a demarcated part of a building within which a fire can, for a prescribed minimum period of time, develop without spreading to other parts of the building. The fire compartment must be separated from the rest of the building, by enclosing walls and joists so that equipment and people in adjacent fire compartments are protected for the prescribed time.

A fire compartment can be divided into several fire cells.

Division into different fire compartments is made so that requirements regarding reactor safety, personal safety and protection of the plant in general can be met. Fire compartments are made in class A60 and designed according to the Swedish building standard for the time of the construction, equivalent to EI60 according to today's regulations.

Fire cell
A fire cell constitutes a subset of a fire compartment which protects therein enclosed equipment from fires that may occur inside the fire compartment but outside the fire cell. Such protection is realized by a combination of passive arrangements: closed-off using walls, joists, distance separation, shielding and limiting the fire load. In the context of division of the site into fire cells, the following criteria must be met:

- All equipment which can affect the accessibility of safety functions shall be contained within fire cells.
- Within one specific fire cell there may only be equipment belonging to one main redundancy (A/C or B/D).
- The passive protection of a fire cell must be sufficient to qualitatively determine that the frequency of a spread to other fire cells be lower the frequency of a design basis accident.

The concept of fire cells is applied strictly linked to fire safety and constitutes an analytical prerequisite for the deterministic fire analysis.

3.1.4.1.1 F: Design approach

All safety related systems are divided in four redundancies (A/C and B/D) with 4x50% capacity. The redundancies are generally fire separated but there are some exceptions where two redundancies are located in the same fire compartment with only physical distance between the redundancies.

Separation between main redundancies is realized with separate fire zones or fire compartments carried out in at least fire technical class A60 or equivalent. However, exceptions to this requirement are made for the reactor containment and central control room, where distance separation and active protection methods are credited.

Separation within a main redundancy can be realized with separate fire compartments carried out in at least fire technical class A60 or other measures such as encapsulation, shielding, distance separation and electrical fuse.

In spaces where there is equipment important to safety that belongs to several redundancies and where fire protection between the redundancies cannot be achieved by division into fire compartments or fire cells, fire protection is provided by the spaces being completely or partially nitrogen gas-filled.

During power operation, the reactor containment, which constitutes its own fire compartment, is completely filled with nitrogen gas.

In some spaces containing equipment important to safety, an oxygen reducing system is installed to ensure a high level of redundancy. The oxygen level is reduced in all operating modes except in cases where operational requirements do not exist for one of the main redundancies, A/C or B/D.

By lowering the oxygen level, the emergence of fire is made more difficult and the spread of fire is prevented.

3.1.4.1.2 F: Description of fire compartments and/or cells design and key features

Openings in firewalls are protected with fire doors at least class 60 minutes. Cable glands protected with approved fire seals. Inspection of fire barriers are part of the fire brigades regular walk-downs.

All the fire doors are certified and rated. Generally, fire door is rated minimum 60 minutes. All doors are self-closing and latching.

Fire doors important to safety are provided with an alarm that activates if the doors are kept in open position. The alarm is transferred to the control room.

To reduce the risk of spreading fire, all power cables are of one type with self-extinguishing external insulation.

Cable ladders are mounted at such a distance that the spread of fire is made more difficult and in some cases cable ladders are encapsulated with sheet metal. Where distance separation has not been deemed sufficient, there are shielding of non-combustible material. Cable culverts with cables of importance for safety is also covered by the active fire protection.

Penetrations in fire compartment boundaries are sealed so that the penetration meets the same fire technical class applicable to wall or door. "Catholes" for temporary routing of cables or hoses are sealed with sheet metal cassettes when not in use and with special seals that can be adjusted depending on the number of hoses or cables passing through the penetration.

3.1.4.1.3 F: Performance assurance through lifetime

Inspection of fire barriers are part of the fire brigades regular walk-downs. For rooms containing equipment important for safety the inspections are carried out more often than for other rooms.

There are written instructions for how and when an opening through fire barriers for cables or pipes should be sealed. The equipment used is fire resistant with a rating consistent with the fire barriers. All seals are properly marked and have labels.

3.1.4.2 F: Ventilation systems

3.1.4.2.1 F: Ventilation system design: segregation and isolation provisions (as applicable)

The ventilation systems are designed so that smoke cannot be spread between fire compartments containing safety-related redundant equipment or to the control room or reactor containment. Each fire zone has separated ventilation equipment.

The design of the fire ventilation has been done according to two different principles, all according to the existing conditions. In principle, fire ventilation involves releasing fire gases at ceiling height and then taking in the corresponding amount of fresh air into the lower parts of the space.

According to the first principle, fire ventilation is done by opening a fire hatch in the upper parts of the space. This is done manually by a magnetic lock releasing the hatch. Opening of the hatch is done from a control cabinet. The hatches have been fitted with end-position connectors that show the position of the hatch locally and in the MCR.

According to the second principle, fire ventilation is done by a smoke gas fan mechanically sucking out the fire gases from the upper parts of the space. Fan start-up is done automatically in the event of a fire alarm.

In both cases, the supply air comes partly from the existing supply air and partly from temporary openings.

To prevent fire gas spread between certain spaces that have the same ventilation system, dampers are automatically closed in the event of an alarm from the fire alarm system.

To ensure that access routes and stairwells have a smoke-free environment in the event of a fire in adjacent spaces, overpressure ventilation is automatically provided. This means that smoke penetration is prevented by isolating the stairwells with fire dampers from the ventilation system in the event of an alarm from the fire alarm system, while an overpressure fan starts and blows in fresh air directly from the outside. The fans shall give an overpressure of about 100-200 Pa.

Fire dampers should have at least fire technical class EI60.

Fans should be electrically cross-wired from the opposite main redundancy.

3.1.4.2.2 F: Performance and management requirements under fire conditions
In the event of a fire alarm, automatic functions will control the ventilation system:

- Fire dampers in fire cell boundaries are closed.
- Overpressure fans start to create overpressure in stairwells and ensure the possibility of evacuation and access for fire brigade.
- Smoke hatches are opened were possible.

3.1.5 F: Licensee's experience of the implementation of the fire protection concept

The high level of separation between redundant safety-related equipment and the measures taken where separation could not be carried out means that the plant is very robust when it comes to limiting of fire spreading.

Maintaining the integrity of fire compartments is of key importance to ensure the plant's passive fire protection, to ensure this there are measures in place, e.g., alarms on fire compartment doors, continuous rounding of operations and fire brigade personnel, education for all staff on the importance of closing fire compartment doors.

There is a well-trained fire brigade onsite that's part of the fire organization. The fire organization continuously works to improve the fire safety. The fire brigade performs educations in fire safety for all personnel and carries out systematic fire protection work at the facility.

In order to maintain the fire protection of the facility, active work is required to monitor and maintain these systems. For this, clear instructions and procedures are required that describe what should be performed and how it should be carried out.

An important parameter is an understanding of how the fire protection is designed. This needs to be clearly described the plant's safety analysis report.

In the event of changes in the fire protection due to renovations or new regulations, it is important to document what has been done and why a particular solution has been chosen.

Over the years, a number of improvements have been made in the fire protection against the original design. Most due to additional requirements and renewed regulations. Some improvements have been made following recommendations from insurance companies.

3.1.6 F: Regulator's assessment of the fire protection concept and conclusions

FKA has a fire protection concept including fire prevention, fire detection and fire limitation and extinguishing. Forsmark provides a detailed description of the fire lines of defence where the protection is based on management and control of fire ignition and load sources, separation in compartment or by distance of safety related equipment, and eventually in case of fire, detection and limiting/extinguishing. Forsmark describes their internal inspections executed to secure that ignition sources and loads are minimized. Forsmark also has internal requirements on initial planning and preparation of work which includes specific assessment of fire risk. It is mentioned that one of the most important fire defences is to get every employee aware of fire risks. This is achieved by training and information efforts.

The fire protection measures include fire compartments, fire alarms, automatic and manually actuated fire protection systems as well as the professional fire brigades.

By division into fire compartments it is secured that a maximum of one redundant part of a safety system can be affected by a fire. In those cases when redundant parts of a safety system are placed in the same fire compartment, these are protected by room separation, distance separation, barriers and/or sprinkling. The complete separation has not been possible due to original design and or conflicts between requirements for fire protection and other plant requirements.

Following the results of the FHA, see also chapter 2.1.1.6.1, vulnerabilities of the plant configuration has been identified and actions to improve the fire protection, including reducing the risk of multiple redundancies being affected. These includes dividing compartments with vital equipment into separated fire cells and reduced oxygen levels in important areas such as electrical relay rooms.

FKA has a professional fire brigade on site, which lowers the response time compared to an off-site fire brigade and ensures that the firefighters have appropriate knowledge of the facility and guidelines on how to handle different kinds of fires that can arise. The fire brigade and other staff are trained to extinguish the fires that may occur at Forsmark 2.

Certain failures of the fire protection system as well as fires that affect components important to safety are reported to SSM as licensee event reports as they are included in the OLC. All these events are reviewed and assessed by SSM. SSM finds that the fire protections concept is adequate and works in practise, as has been shown when a fire has occurred.

SSM oversight activities regarding fire are limited. An inspection series in 2013 looked at house-keeping (in general) and concluded that requirements were fulfilled. As mentioned above, some other oversight activities have been carried out regarding Fire Hazard Analysis and fire-PSA. SSM also follows fire protection works via participation in the National Fire safety Forum (NBSG) where the licensees share experiences and initiate small R&D efforts focusing on practical fire protection issues. NBSG is also a common point of contact for the OECD/FIRE database project collecting and sharing information on fires as a basis for fire defences development and fire frequency estimations.

Strengths mentioned by FKA are the high quality of building construction and separation of safety system redundancies. Also a well-trained on-site fire brigade and good co-operation with the municipal rescue service is mentioned as a strength. A weakness is that some fire compartments contain SSC for two redundancies.

In addition to the strengths mentioned by FKA, SSM also want to mention the National Fire Safety Forum (NBSG) where the licensees and regulator are members. NBSG overall focus is to create increased knowledge in the field of fire safety at nuclear facilities and increased knowledge in the field of reactor safety-related fire safety.

The adherence to fire requirements are checked by not only SSM, but maybe more by other authorities and insurance companies. This contributes to a solid fire protection concept.

Observations and recommendations originating from internal analysis and checks as well as checks by external organisations have led to many improvements in fire protection, and is an ongoing effort.

3.1.7 F: Conclusions on the adequacy of the fire protection concept and its implementation

SSM concludes that Forsmark 2 has an adequately fire protection concept implemented.

3.2 Oskarshamn 3

3.2.1 O: Fire prevention

Preventing fires to occur is the first level in the Defence-in-Depth (DiD) for fire protection set out for unit 3, which includes:

- The amount of combustible materials in the plant should be minimized. The first approach should be to apply non-combustible materials for SSCs.
- In case non-combustible materials is applied the alternate materials should as far as reasonable be non-flammable or inherently resist fire spread.
- SSCs shall be designed in manner that minimizes the risk of ignition.
- Administrative fire protection procedures shall be in place with the objectives to minimize fire loads and to minimize the risk of ignition, in the plant.

The package of procedures supporting the DiD strategy for fire prevention is part of OKG's Management System.

3.2.1.1 O: Design considerations and prevention means

There are procedures that provide guidance to support the first level of DiD when conducting design changes, e.g. materials to be selected and design attributes for components. Furthermore, the template for the top document (project report) that describes a design change sets out that Fire Protection should be addressed.

3.2.1.2 O: Overview of arrangements for management and control of fire load and ignition sources

There are procedures for the management of fire load and the compliance is supervised by e.g. fire engineers performing fire safety inspections (BRAK) on regularly basis, or by field operators on the rounds, or during safety rounds which is also governed by procedures.

3.2.1.3 O: Licensee's experience of the implementation of the fire prevention

Providing in-house personnel and contractors with appropriate prerequisites is of key importance to achieve effective fire prevention. This includes both the understanding and providing resources in the form of knowledge and time.

Keeping messages simple and available is also of importance to achieve effective fire prevention.

It is of importance that managers ensure that in-house personnel or contractors are provided with appropriate prerequisites. Only procedures are not safeguarding the fire prevention, prerequisites to effectively comply with procedures should also be provided.

3.2.1.3.1 O: Overview of strengths and weaknesses

The close cooperation with the municipal rescue services is a strength. The municipal rescue services provide high skilled firefighters stationed on-site safeguarding sufficient staffing in case of an event.

The municipal rescue services also performs initial training and refresher fire protection training for operating personnel to support the fire brigade.

3.2.1.3.2 O: Lessons learned from events, reviews fire safety related missions, etc.

There are national forums assessing events and providing information and findings to the members. One forum is the Norderf[9] where all Swedish licensees, and the Finnish utility TVO, and the Swedish company Nuclear Training and Safety Centre (KSU) are members. The Norderf uses information sources such as NRC Bulletin Generic Letter and Information Notice, and IAEA Incident Reporting System, and WANO Reports. There is also a national fire safety forum (NBSG[10]) in Sweden were the regulator and licensees are members. The NBSG amongst other things conduct international surveillance and managing R&D in the field of fire protection and provides information and findings to the plant organization. No explicit lessons learned have led to remedy recently.

There are procedures in place for the management of fire loads and the compliance is supervised by e.g. fire engineers performing fire safety inspections. Providing in-house personnel and contractors with appropriate prerequisites is of key importance to achieve effective fire prevention.

3.2.1.3.3 O: Overview of actions and implementation status

There are always on-going works within the fire protection program implemented at OKG.

3.2.2 O: Regulator's assessment of the fire prevention

Requirements for fire prevention has historically been regulated by other authorities than SSM, see chapter 1.2.1. These requirements are generic for industrial buildings and not specific for nuclear power plants.

Prior to 2022, SSM did not have any specific requirements on fire prevention as shown in chapter 1.2.1 for nuclear power plants. As such, there have not been any inspections and no formal lessons learned with regards to the fire prevention programs for the licensees.

3.2.2.1 O: Overview of strengths and weaknesses in the fire prevention

OKG has an active fire prevention program that ensures that the fire loads are as low as reasonably achievable and lowers the probability of a fire. This include routines to manage and control fire load and ignition sources at the plant as well as personnel have the

[9] Organisation that provides the Nordic nuclear power plants with external experience from the nuclear power industry in the world.

[10] Nationella BrandSäkerhetsGruppen

prerequisites to be able to identify and act on deviations in the fire prevention and in the event of fire. As a part of the systematic fire protection work, regular inspections are performed in the facility to ensure proper control of fire load and ignition sources. In case of hot work, specific training and a work specific permit is required.

There are several national and international forums where the licensees and regulator share information and experiences from events. One forum is Norderf, which provides the Nordic nuclear power plants with external experience from the nuclear industry in the world. Another is the NEA project OECD-FIRE, that have collected information from over 500 events that have occurred at NPP:s.

FKA, RAB, OKG, SSM and SKB are members in NBSG. The overall focus with NBSG is to create increased knowledge in the field of fire safety at nuclear facilities and increased knowledge in the field of reactor safety-related fire safety. The group's work will lead to synergies in the field of fire safety by jointly funding research, testing and dissemination of information.

3.2.2.2 O: Lessons learned from inspection and assessment on the fire prevention as part of its regulatory oversight

As part of general oversight activities related to operations, SSM does inspect housekeeping practices, both during focussed housekeeping inspections and as observations during other inspections. Conclusions from the latest inspection particularly focused on housekeeping are that OKG complies with regulatory requirements. It was noted in particular that escape routes were kept clear, but also some areas for improvement were identified (SSM2014-5594-4).

SSM:s main conclusion is that the fire preventing programs relies on everyone that enters a nuclear facility does their part to reduce the risk of a fire occurring and spreading. This is done by ensuring a limitation of combustible materials and lower the risk for ignition. One lesson learned is that this is of importance during maintenance work to ensure that the risk of a fire is sufficiently low, this is done by inspections by the licensee.

3.2.3 O: Active fire protection

Detecting and extinguishing quickly those fires which do start is the second level in the Defence-in-Depth (DiD) for fire protection set out for unit 3, which includes:

- Fire detection and alarm
- Active fire suppression
- Manual firefighting

3.2.3.1 O: Fire detection and alarm provisions

This section addresses the fire alarm system. In section 3.2.3.2.1 it is described how the fire alarm system actuates fire suppression provisions.

3.2.3.1.1 O: Design approach

As per SBF 110:6 “Regler för automatisk brandlarmanläggning” the fire detection and alarm system shall be comprehensive such that all compartments in the plant shall be provided with automatic fire detection.

The fire alarm system is divided into two sub-system, one sub-system serving the fire compartment side A and the other sub-system serving the fire compartment side B. The fire compartment side A associates to components within train/subdivision A and C, and the fire compartment side B associates to components within train/sub-division B and D.

The fire alarm system main surveillance and actuation are located in the MCR. The fire alarm system is power supplied with two battery backed and independent power supplies. All fire detectors are continuously supervised by means that the fire alarm system continuously checks that the fire detectors are responding. In case a fire detector is not responding failure message is triggered

The fire signalling system display panel is located in the MCR. Alternate display panels are located at two other locations. Fire alarm signal is also transmitted to the plant security office and the fire brigade.

3.2.3.1.2 O: Types, main characteristics and performance expectations

The fire alarm system is designed to detect, annunciate and actuate (e.g. fire suppression systems, dampers and fans).

The fire alarm system is designed to enable detectors to be shut off to facilitate e.g. hot works during refuelling outage.

Individual fire detector circuits are designed to allow any detectors to be supplied from two directions in the detector circuit. Therefore, in case a small portion of the detector circuit is damaged e.g. by fire, the rest of the detector circuit is still operable.

A postulated pipe break may cause detectors triggering alarm e.g. due to humidity or water spray.

3.2.3.1.3 O: Alternative/temporary provisions

Temporary provisions applied include fire watch guards (on a specific location or on rounds) or camera monitoring.

Applying alternative/temporary provisions are governed by the plant TS.

3.2.3.2 O: Fire suppression provisions

The fire water facility is designed based on guidance provided in "*International Guidelines for the Fire Protection of Nuclear Power Plants*". The fire water facility provides water supply to active fire protection means and for manual firefighting and is designed based on a manual hose stream demand of about 2000 l/min plus the largest design demand of any fire suppression system for a period of about 2 two hours. The fire water facility includes two outdoor fire water storage tanks, each with a volume of 1500 m^3. There are two diesel driven and two electrical driven fire pumps. The two diesel driven fire pumps are located in different fire compartments. The two electrical driven fire pumps are located in a common fire compartment separated from the two fire compartments housing the diesel driven fire pumps. The fire water storage tanks are interconnected providing the fire main loop can be fed from either or both.

3.2.3.2.1 O: Design approach

The main design approach for water-based sprinkler systems is that compartments with fire load exceeding 200 MJ/m^2 should be provided with water sprinkler system. There are two main water-based sprinkler system installed in unit 3.

- Water sprinkler system for compartments (culverts/shafts) housing cable raceways/cable trays. The system is divided into several sub-systems (sections) and serves compartments in the Reactor Building, Diesel Buildings, Auxiliary Systems Buildings, High Voltage Switchgear Building, Radwaste Building, Service Building and Active Workshop Building. The required sprinkler density is 5 mm/min based on RUS 120:2 "Regler för automatisk vattensprinkleranläggning" (except for portions in the Active Workshop Building with a required sprinkler density of 7,5 mm/min). The fire alarm system initiates water sprinkling by activating the sub-system serving the area affected by the fire. Portions of the sprinkler system in the Active Workshop are of wetpipe design and the sprinkler is activated automatically at a defined temperature.
- Water sprinkler system for compartments in the Turbine Building. The system is divided into several sub-systems (sections). The required sprinkler density is 8 mm/min based on tests performed by Statens Provningsanstalt (National Swedish Authority for Testing, Inspection and Metrology) at the test facility in Borås, Sweden. The fire alarm system initiates water sprinkling by activating the sub-system serving the area affected by the fire.

Some compartments in the reactor building housing electrical and I&C equipment are provided with Inergen Gaseous System. The Inergen Gaseous System is divided into 4 sub-systems each serving one compartment. The fire alarm system initiates the sub-system serving the fire affected compartment.

Buildings housing the EDGs and the diesel driven fire pumps are provided with provisions to deploy foam spray from mobile equipment managed and handled by the on-site fire brigade.

To facilitate manual firefighting all buildings on all floors are provided with hose stations supplied from standpipes. Hose stations are located in the near vicinity of the stairwells. Furthermore, there are additional hose stations and fire extinguishers to the extent considered needed to facilitate manual firefighting. Outdoor hydrants are arranged with appropriate distance on the yard main system.

3.2.3.2.2 O: Types, main characteristics and performance expectations

In the original design only some portions of the fire water system was seismically designed, generally main piping and standpipes in the reactor building. However, as a post-Fukushima measure large portions of the fire water system, including the fire water facility, has been assessed and demonstrated to be seismically adequate. The rationale to conduct the seismic assessment was to credit fire water supply as a means in the coping strategy for DEC events, e.g. to provide core cooling and SFP cooling. Furthermore, as part of DEC coping strategy a design change was conducted to facilitate the refilling of fire water storage tanks directly from the on-site freshwater reservoir.

3.2.3.2.3 O: Management of harmful effects and consequential hazards

Secondary hazards from actuation (demanded or spurious) of fire extinguishing systems, or postulated pipe rupture in fire water systems are assessed and included as supporting analysis in the SAR. In particular for water-based system postulated failures are analysed as part of the plant internal flooding analyses and the analyses demonstrates that the plant can accommodate flooding caused by failures in the fire water system.

The consequences of demanded actuation of water sprinkler system are bounded by spuriously actuation, since the sprinkler valve will automatically close 3 minutes after actuation. In case further suppression is needed the sprinkler valve can be remotely opened for additional 3 minutes duration, and so forth.

For gaseous system it is demonstrated that the compartment pressure increase after activation cannot jeopardize the structural integrity. This is also included as supporting analysis in the SAR.

In the SAR it is demonstrated that the storage for fresh fuel will maintain sub-critical condition applying conservative assumptions, including various densities of homogenous air/water mixture.

3.2.3.2.4 O: Alternative/temporary provisions

Applying alternative/temporary provisions are governed by the plant TS.

3.2.3.3 O: Administrative and organisational fire protection issues

There is an on-going work striving for continuously improvements as part of the fire protection program at OKG. Currently there are no issues needed to be remedied.

3.2.3.3.1 O: Overview of firefighting strategies, administrative arrangements and assurance

There are prepared type scenario charts (Typhändelsekort) describing various type-fire-scenarios, e.g. battery fire, oil fire, and transformer fire. These Typhändelsekort are supplemented with firefighting deployment charts (Insatskort) prepared by the rescue services addressing specific components and compartments in the plant.

The developed charts are used during deployment trainings.

3.2.3.3.2 O: Firefighting capabilities, responsibilities, organisation and documentation on-site and offsite

The on-site fire brigade staffing belongs to the same organization as the off-site fire brigade i.e. the municipal rescue services. Therefore, similar equipment, trainings and firefighting management are ensured.

The municipal rescue services also performs initial training and refresher fire protection training for operating personnel to support the fire brigade.

3.2.3.3.3 O: Specific provisions, e.g. loss of access

The operating personnel support the fire brigade with information needed about appropriate access path to perform firefighting based on the event occurred.

3.2.4 O: Passive fire protection

The third level in the Defence-in-Depth (DiD) for fire protection set out for unit 3 is that fires which have not been extinguished shall be prevented to be spread such that safety functions could be jeopardized.

From the reactor safety perspective the BWR75 is designed to cope with the PIE fire without credit of any installed automatic active fire protection means to suppress the fire. This design principle is provided by the rigorously implemented functional and physical separation of redundant trains/electrical sub-divisions and the arrangement of fire compartments and fire compartments as described in section 2.1.2.1.

3.2.4.1 O: Prevention of fire spreading (barriers)

Unit 3 is divided into fire zones and fire compartments. The main principle for the arrangement of fire zones and fire compartments is reactor safety but also conventional fire requirements has been taken into consideration such as facilitate appropriate escape routes for personnel, access paths for firefighting and asset protection.

3.2.4.1.1 O: Design approach

Unit 3 is divided into 13 fire compartments.

The minimum requirement for fire compartments housing safety related SSCs is the Fire Resistance Class A120 which implies the prevention of fire spreading for 120 minutes and that fire elements (e.g. walls and slabs) maintain its stability and integrity. The fire compartment concept also include that no fire compartment is sharing ventilation equipment or air ducts with another fire compartment (except for the main stack), i.e. separate systems are provided for normal ventilation, stand by gas treatment system and smoke extraction systems. Air ducts are not routed between different fire compartments.

The main principle for the arrangement of safety trains is that two safety trains (A/C) are located in one fire compartment and two safety trains (B/D) are located in another fire compartment.

Unit 3 is divided into a couple of hundred o more than 200 fire compartments. The minimum fire resistance requirement for fire compartments is Fire Resistance Class A60[11] . As described in section 2.1.2.1 the arrangement of fire compartments was not solely based on reactor safety, also conventional fire requirements has been taken into consideration. However, in this section only the design approach from a reactor safety perspective is described.

In BWR75 safety systems can be categorized into four-fold and two-fold safety systems. Two-fold safety systems can be considered as mitigating systems such as the Flammability Control System. Furthermore, back fitting measures in unit 3 has involved the installation of several safety features to cope with DEC events, such as the FCV system, Independent core cooling system for ELAP coping, and an alternate residual heat removal system for the RPV. Below is described the principle for the arrangement of four-fold and two-fold safety systems into fire compartments, and the arrangement of the SFP cooling and the reactivity control system.

In four-fold safety system the sub-divisions A and C (or B and D) and its supporting systems, such as EDG and electrical power distribution systems, are installed in different fire compartments (or fire-compartments). The four-fold safety systems are:

- Low Pressure Core Injection System
- High Pressure Core Injection System
- Residual Heat Removal System (heat removal from the suppression pool to the ultimate heat sink)

[11] Fire Resistance Class A60 practically mean that the design shall prevent fire spreading due to hot gases to such an extent that a cotton ball placed on the non-fire affected side do not ignite and that the surface temperature does not exceed 330ºC, during the first hour of the fire. In accordance with guidance in SBF 72 this implies for fire loads up to 50 MCal/m2 (equals 209 MJ/m2)

Two-fold safety systems are arranged with each sub-division in different fire compartment, e.g. one train in sub-division C and one in sub-division D.

Two-fold safety systems are:

- Standby Liquid Control System (boron injection)
- Flammability Control System
- Standby Gas Treatment System

The SFP cooling system was originally designed as a two train system in sub-division A and C. However, as part of the latest power uprate project the SFP cooling has been back fitted with an additional two train system in sub-division B and D. The separation of cable routing and components for the SFP cooling are to some extent relied upon physical separation by distance and shielding within each redundant SFP cooling system, i.e. sub-division A and C are separated by distance and shielding, and sub-division B and D are separated by distance and shielding.

The BWR75 is provided with 169 control rods. In unit 3 the control rods are divided into 20 SCRAM-groups, each group serving 8 or 9 CRDs. The SCRAM-groups are divided into sub-divisions A, B, C and D, and each sub-division (e.g. SCRAM-Groups in division A) is installed in a separate fire compartment in the reactor building. The scram system is of fail-safe design and will actuate scram in case of loss of power supply. Furthermore, the EDG backed Fine Motion CRD motors are power supplied from another subdivision compared to the designated SCRAM-group division.

3.2.4.1.2 O: Description of fire compartments and/or cells design and key features
General description of fire Zones and fire compartment are provided in section 3.2.4.1.1. This section addresses key features for the separation of sub-divisions in different fire compartments, and the principle applied when physical separation is achieved by distance and shielding within a common fire compartment.

The separation of sub-divisions in separate fire compartments is a straightforward approach and applied e.g. for the four-fold safety systems described in section 3.2.4.1.1.

3.2.4.1.3 O: Performance assurance through lifetime
The plant specific maintenance program includes SSCs in the category Fire barrier element e.g., walls, ceilings, floors, doors, dampers, penetration seals. There is scheduled interval for inspections and maintenance of such SSCs. In case deviations or deficiencies are identified appropriate measures are taken.

The Long Term Operation program currently being developed includes SSCs in the category Fire barrier element.

3.2.4.2 O: Ventilation systems

Ventilation systems providing tasks in the overall fire protection strategy in the BWR75 design can be categorized in the following categories:

- Normal Ventilation
- Standby Gas Treatment System (Emergency Ventilation)
- Smoke Extraction Systems Design features for these 3 categories are described in section 3.2.4.2.1.

3.2.4.2.1 O: Ventilation system design: segregation and isolation provisions (as applicable)

As described in section 3.2.4.1.1 the fire compartment concept includes that no fire compartment allows the sharing of ventilation equipment or air ducts with another fire compartment (except for the main stack), i.e. separate systems are provided for normal ventilation, stand by gas treatment system and smoke extraction systems. A result of this approach is much evident for the reactor building, divided into two fire compartments, for which the Normal Ventilation and Stand Standby Gas Treatment System (Emergency Ventilation) has been duplicated.

The design principle for the normal ventilation in fire compartments are divided into two categories:

- Fire compartments with separate normal ventilation
- Fire compartments with common normal ventilation

It should be kept in mind that the A/C side are provided with separate ventilation with respect to the B/D side as part of the fire compartment concept as described above.
BWR75 was designed with the following premises having fire compartments with separate ventilation:

- Each of the four redundant trains/sub-divisions (separated into different fire compartments) in non-Controlled Area. Buildings with different functions.
- Controlled and non-Controlled areas
- Electrical installation compartments.
- Process compartments.
- Cable paths (shafts, runways, distribution compartments) in non-Controlled areas.
- Computer compartment.
- Main exit paths.

In BWR75 fire compartments in the following premises was allowed to be provided with common ventilation:

- Fire compartments housing the four-fold core cooling and residual heat removal systems (see section 3.2.4.1.1) located on controlled area. This also imply for the associated electrical and I&C equipment located on Controlled area.
- Stairwell, escape routes etc. in accordance with conventional fire requirements.
- Certain compartments with high fire load, or compartments housing components of high asset importance, or compartments provided with fire suppression means, e.g. fire sprinkler system.

The design principle for Smoke Extraction Systems (Fire Ventilation) aligns with the design principle for Normal ventilation, i.e. divided into two categories:

- Fire compartments with separate smoke extraction
- Fire compartments with common smoke extraction

Fire dampers are installed to ensure that separation between fire compartments is maintained.

3.2.4.2.2 O: Performance and management requirements under fire conditions

In the Smoke Extraction Systems fans, dampers and smoke hatches are actuated automatically by the fire alarm system. There are also dampers and hatches activated by temperature relying on fusible link. Dampers in other ventilation systems that need to be manoeuvred in case of fire are actuated by the fire alarm system or by fusible link.

3.2.5 O: Licensee's experience of the implementation of the fire protection concept

Unit 3 fulfils applicable regulations and requirements.

Maintaining the plant's design concept is of key importance to maintain the in depth resilience against fire. This includes both the actual design and the knowledge of how design principles/philosophy has resulted in the actual design.

The fire protection concept should be described in appropriate detail in the SAR providing a common thread between the fire protection concept and reactor safety. Furthermore, an on-going work with different aspects of the fire protection concept is of key importance, e.g. minimizing combustible materials in the plant as part of the first level (Fire prevention) in the DiD for fire protection.

Minimizing the amount of combustible materials and the risk of ignition is an overall goal and should be strived for, e.g. in design changes. Procedures are in place to support this first level in the DiD for fire protection.

In year 2009 IAEA conducted an OSART mission at OKG. It should be noted that in year 2009 unit 1 and unit 2 were not in decommissioning phase. One subject addressed in the OSART report NSNI/OSAR/09/151 was Fire Prevention and Protection Program. No Issues resulting in Recommendation or Suggestion were identified within this subject. However, in the OSART report OKG was encouraged to furthermore decrease the fire load, wherever possible, based on observations made during the review. Efforts to minimize fire loads and arrangements for the management and control of fire loads are an ongoing work as described in sections 3.2.1.3.3.

Functional and physical separation of redundant trains/electrical sub-divisions and the arrangement of fire compartments and fire cells are of key importance to achieve robustness to cope with fire events.

As a post-Fukushima measure large portions of the fire water system, including the fire water facility, has been assessed and demonstrated to be seismically adequate. Furthermore, a design change was conducted to facilitate the refilling of fire water storage tanks directly from the on-site freshwater reservoir using seismically adequate SSCs.

The design guidance in International Guidelines for the Fire Protection of Nuclear Power Plants is considered to provide a robust arrangement for the fire water facility, e.g. fire water storage tanks and fire pumps.

3.2.6 O: Regulator's assessment of the fire protection concept and conclusions

OKG has a fire protection concept including fire prevention, fire detection and fire limitation and extinguishing. OKG provides a detailed description of the fire lines of defence where the protection is based on management and control of fire ignition and load sources, separation in compartment or by distance of safety related equipment, and eventually in case of fire, detection and limiting/extinguishing. A template for design changes sets out that fire protection shall be addressed. Furthermore, there are procedures for the management of fire load and the compliance is supervised by e.g. fire engineers performing fire safety inspections (BRAK) on regularly basis, or by field operators on the rounds, or during safety rounds which is also governed by procedures.

It is mentioned the importance for fire prevention of knowledge and understanding fire, keeping messages simple and follow procedures.

The fire protection measures include fire compartments, fire alarms, automatic and manually actuated fire protection systems as well as the professional fire brigades.

By division into fire compartments it is secured that a maximum of one redundant part of a safety system can be affected by a fire. The main principle for the arrangement of fire zones and fire compartments is reactor safety but also conventional fire requirements has been taken into consideration such as facilitate appropriate escape routes for personnel, access paths for firefighting and asset protection.

Following the results of the FHA, see also chapter 2.1.2.4, no vulnerabilities of the plant configuration was identified by OKG. Some improvements were identified post Fukushima, such as facilitating the refilling of fire water storage tanks directly from the on-site freshwater reservoir using seismically adequate SSCs.

OKG has a professional fire brigade on site, which lower the response time compared to an off-site fire brigade and ensures that the firefighters have appropriate knowledge of the facility and guidelines on how to handle different kinds of fires that can arise. The fire brigade and other staff are trained to extinguish the fires that may occur in Oskarshamn 3. The first responding off-site brigade is also trained in the same way for a fire occurring at Oskarshamn 3, as both the on-site and the off-site fire brigades are a part of the same municipal fire brigade.

Certain failures of the fire protection system as well as fires that affect components important to safety are reported to SSM as licensee event reports as they are included in the OLC[12]. All these events are reviewed and assessed by SSM. SSM finds that the fire protections concept is adequate and works in practise, as has been shown when fires have occurred.

OKG does also share experiences with others with regards to fire protection, see 3.2.1.3.2.

OKG mentions that IAEA conducted an OSART mission in 2009. It should be noted that in year 2009 unit 1 and unit 2 were not in decommissioning phase. One subject addressed in the OSART report NSNI/OSAR/09/151 was Fire Prevention and Protection Program. No Issues resulting in Recommendation or Suggestion were identified within this subject. However, in the OSART report OKG was encouraged to furthermore decrease the fire load, wherever possible, based on observations made during the review. Efforts to minimize fire loads and arrangements for the management and control of fire loads are an ongoing work.

[12] Operational limits and conditions

SSM oversight activities regarding fire are limited. An inspection series in 2014 looked at house-keeping (in general and concluded that requirements were fulfilled. As mentioned above, some other oversight activities have been carried out regarding Fire Hazard Analysis and fire-PSA. SSM also follows fire protection works via participation in the National Fire safety Forum (NBSG) where the licensees share experiences and initiate small R&D efforts focusing on practical fire protection issues. NBSG is also a common point of contact for the OECD/FIRE database project collecting and sharing information on fires as a basis for fire defences development and fire frequency estimations.

Strengths mentioned by OKG are the close cooperation with the municipal rescue service that provide high skilled firefighters stationed on-site securing sufficient staffing in case of an event. The municipal rescue services also performs initial training and refresher fire protection training for operating personnel to support the fire brigade.

In addition to the strengths mentioned by Oskarshamn, SSM also want to mention the National Fire Safety Forum (NBSG) where the licensees and regulator are members. NBSG overall focus is to create increased knowledge in the field of fire safety at nuclear facilities and increased knowledge in the field of reactor safety-related fire safety.

The adherence to fire requirements are checked by not only SSM, but maybe more by other authorities and insurance companies. This contributes to a solid fire protection concept.

Observations and recommendations originating from internal analysis and checks as well as checks by external organisations have led to many improvements in fire protection, and is an ongoing effort.

3.2.7 O: Conclusions on the adequacy of the fire protection concept and its implementation

SSM concludes that Oskarshamn 3 has an adequate fire protection concept implemented.

3.3 Ringhals 3

3.3.1 R: Fire prevention

The preventive fire protection is operable if the unit is cleaned and in order with regard to the fire load. Limitation of combustible substances leads both to reduced risk of fire and to limited consequences if there should be a fire. An operable fire compartment ensures that a fire does not spread to spaces outside this fire compartment. By division into fire compartments it is secured that a maximum of one redundant part of a safety system can be affected by a fire. In those cases when redundant parts of a safety system are placed in the same fire compartments, these are protected by room separation, distance separation barriers and/or sprinkling.

In aspect of technical requirements for operation the preventive fire protection at the site is defined in the LCO (Limiting Conditions of Operations).

3.3.1.1 R: Design considerations and prevention means

Fire prevention is the first level in the Defence-in-Depth (DiD) for fire protection set out for unit 3. This is also the basic principle of fire protection and safety, preventing the risk of a fire occurring. The idea of fire prevention is integrated into the design of unit 3.

As a part of the design the unit has been constructed using non-combustible and heat-resistant materials as far as have been technically possible. Cladding materials are chosen by their ability to resist fire spread within each fire compartment and in addition fire load is kept at a minimum at all times. Flammable and combustible liquids and gases are minimized as far as possible and kept in dedicated storages/lockers. Rooms containing more than189 litres (one barrel) combustible liquid are provided with proper confinement measures to contain leakages.

By design the amount of ignition sources are minimized in order to prevent fires to occur. In short, ignition sources have been identified and separated from combustible materials by several means. For example, flammable liquid piping is drawn away from possible hot surfaces or provided with shielding. Also all work with the potential to generate heat or sparks (Hot works) is controlled and permitted in accordance with instructions.

3.3.1.2 R: Overview of arrangements for management and control of fire load and ignition sources

There are several routines in practice to manage and control fire load and ignition sources at the plant. The fire load should always be at a minimum and kept apart from ignition sources. Combustible liquids and gas are stored in cabinets dedicated for the purpose. Before temporary fire load is transported into the site a special permit is required and special laydown areas are appointed for temporary fire load when applicable. Similarly a work permit is required before any Hot Work is carried out.

As a part of the Systematic Fire Protection Work regular inspections are performed in the facility to ensure proper control of fire load and ignition sources. Rules for management of fire load and Hot Work are continually enforced during these inspections. Daily inspections are performed by the operating staff and control inspections performed by the internal fire brigade with the objective to identify any deviations from the management and control process of fire load and ignition sources. In areas identified as having a greater reactor safety impact supplementary rules apply.

3.3.1.3 R: Licensee's experience of the implementation of the fire prevention

Experience from events when the fire prevention has fallen short has made it clear that it is of key importance to provide personnel and contractors with the proper information of the importance of fire safety. Sometimes there are conflicts of interests between fire prevention and the task some staff need to carry out. It has been noted that an increased understanding of the importance of fire prevention will increase the likelihood of expected performance.

Making sure the information is simple and easily available is also noted as a key factor for proper fire prevention performance.

3.3.1.3.1 R: Overview of strengths and weaknesses

Ringhals 3 has good separation between the independent safety trains, ensuring that a fire on one train will not jeopardize the security of the other train. The electrical sub:s in each safety train however is not fully separated. Instead the separation of the electrical sub:s in some occasions depend on conditions set in analysis which should be noted as a weakness.

In the latest versions of the Safe Shutdown analysis the analysis is performed primarily with the fire compartments as fire barriers. This has shown the strength of the fire compartmentalization since the plant can be safely shut down, in spite of the weakness in the electrical sub:s separation mentioned above.

The close knit cooperation with the internal fire brigade is a highly valued strength. The personnel gains proper knowledge of the plant layout and where for example temporary fire load is located which might complicate any potential rescue operation.

3.3.1.3.2 R: Lessons learned from events, reviews fire safety related missions, etc.
After a larger transformer fire in 2006 on the step-down transformer several fire protection improvements have been performed on all transformers.

This includes improved sealing in penetrations to the adjacent turbine wall, new oil pit separation under transformers to separate any oil spill from stepdown transformers to be able to flow under step-up transformers (and vice versa). Improved Davy's net between oil pit and transformer, possibilities to drain extinguishing water and the installation of a dry-pipe extinguishing system that can be connected to fire-trucks or fire main.

Also, the transformers have been replaced to new on all positions and one reason for this is the potential of fire in ageing transformers.

There are several national and international forums to share information and experiences from events. One forum is Norderf, which provides the Nordic nuclear power plants with external experience from the nuclear industry in the world.

There is also a National Fire Safety Forum (NBSG) where the licensees and regulator are members. The overall focus is to create increased knowledge in the field of fire safety at nuclear facilities and increased knowledge in the field of reactor safety-related fire safety. The group's work will lead to synergies in the field of fire safety by jointly funding research, testing and dissemination of information. The focus of the works carried out on behalf of the NBSG shall be attributable to any of the categories presented below:

- Support/development of practical fire protection by, for example, improving response planning.
- Clarification of requirements by working for a common interpretation and harmonized view of new rules and requirements. This will facilitate ongoing modernization of existing nuclear power plants and SKB's (Swedish Nuclear Fuel and Waste Management Company) existing facilities. It will also provide support in the decommissioning of existing nuclear power plants and in the design of SKB's future facilities.
- Experience feedback by, for example, analysing historical data or by improving systems for such management.
- Monitor and participate in national and international developments in fire research, with a special focus on the energy field.
- Influence interest groups in order to support/carry out research useful for the nuclear industry
- Development of analysis tools and data support.

- Develop methodology for fire protection during the decommissioning of nuclear facilities.

3.3.1.3.3 R: Overview of actions and implementation status

One current action to improve the fire protection is the implementation of Laydown areas for temporary fire load. The action is undertaken following a WANO AFI in Fire protection, criticizing the management and control process of temporary fire load. The updated management and control process has recently been implemented and evaluation will follow in autumn 2023.

A campaign for ensuring that fire doors are properly closed has also been performed during the winter of 2022. The campaign consisted of participation in group meetings by a fire engineer, informing of the importance of making sure fire doors are properly shut. The campaign was finished before the turn of the year and effects will be evaluated continually in the onsite Fire protection council.

The actions mentioned above are only recent examples of actions to improve the fire prevention. There are always ongoing actions to make improvements to the fire protection concept. Other implemented measures are mentioned in 2.1.3.6.2.

3.3.2 R: Regulator’s assessment of the fire prevention

Requirements for fire prevention has historically been regulated by other authorities than SSM, see section 1.2.1. These requirements are generic for industrial buildings and not specific for nuclear power plants.

Prior to 2022, SSM did not have any specific requirements on fire prevention as shown in section 1.2.1 for nuclear power plants. As such, there have not been any inspections and no formal lessons learned with regards to the fire prevention programs for the licensees.

3.3.2.1 R: Overview of strengths and weaknesses in the fire prevention

RAB has an active fire prevention program that ensures that the fire loads are as low as reasonably achievable and lowers the probability of a fire occurring. This include routines to manage and control fire load and ignition sources at the plant as well as personnel have the prerequisites to be able to identify and act on deviations in the fire prevention and in the event of fire. As a part of the systematic fire protection work, regular inspections are performed in the facility to ensure proper control of fire load and ignition sources. In case of hot work, specific training and a work specific permit is required. Permits are also required to be able to transport temporary fire loads into the site.

There are several national and international forums where the licensees and regulator share information and experiences from events. One forum is Norderf, which provides the Nordic nuclear power plants with external experience from the nuclear industry in the world. Another is the NEA project OECD-FIRE, that have collected information from over 500 events that have occurred at NPP:s.

FKA, RAB, OKG, SSM and SKB are members in NBSG. The overall focus with NBSG is to create increased knowledge in the field of fire safety at nuclear facilities and increased knowledge in the field of reactor safety-related fire safety. The group's work will lead to synergies in the field of fire safety by jointly funding research, testing and dissemination of information.

3.3.2.2 R: Lessons learned from inspection and assessment on the fire prevention as part of its regulatory oversight

As part of general oversight activities related to operations, SSM does inspect housekeeping practices, both during focussed housekeeping inspections and as observations during other inspections. Conclusions from the latest inspection particularly focused on housekeeping are that RAB complies with regulatory requirements, but that there are some areas for improvement (SSM2015-576-5).

SSM:s main conclusion is that the fire preventing programs relies on everyone that enters a nuclear facility does their part to reduce the risk of a fire occurring and spreading. This is done by ensuring a limitation of combustible materials and lower the risk for ignition. One lesson learned is that this is of importance during maintenance work to ensure that the risk of a fire is sufficiently low, this is done by inspections by the licensee.

3.3.3 R: Active fire protection

The second level of the DiD consists of the ability to detect and extinguish those fires which do occur. At Ringhals unit 3, this includes:

- Fire detection and alarm,
- Active fire suppression systems and
- Manual firefighting

3.3.3.1 R: Fire detection and alarm provisions

This section addresses the fire alarm system. Unit 3 is completely covered by a comprehensive fire alarm system installed at the facility.

3.3.3.1.1 R: Design approach

The design of the existing system is based on RUS 110 and new installations follow SBF 110. The types and numbers of detectors needed are based on room configuration and fire load in each room. The fire detection system consists of the following:

- The fire alarm central (Brandlarmcentral, BLC)
- Programmable logic controller (PLC)
- Presentation system (PS).

The BLC consists of two units on each side, A and B respectively. The PLC consists of one unit on each side, A and B. In case of smoke or fire detection or detector faults this is indicated in the PS, connected to the BLC. An audible fire alarm acts as an indication to the operators and information in case of an alarm is given as a label, placing, access route and fire compartment of the affected detector. In some cases the activation of the fire alarm is two-detector-dependent.

The design approach of the alarm system coverage can be described with the following three principles:

1. Areas of importance for reactor safety are monitored by detectors connected to the A- and B-side of the fire alarm central respectively. This guarantees continuous fire and smoke detection, even in the event of failure of one BLC.
2. Other areas considered important are monitored by two BLC from the same side, A or B side.
3. Remaining areas are monitored by one BLC from either side.

Types of detectors have been chosen considering the expected fire load and work activities in the corresponding areas. In certain areas a combination of detector types has been used, for example areas with high ceiling heights. Areas where high humidity can be expected are provided with appropriate detectors in order to avoid activation due to high humidity.

In addition to detectors, alarm buttons have been provided for manual actuation of the fire alarm system. In general alarm buttons are placed in the vicinity of indoor fire hydrants, at local control areas where activation of fire protection system can be done and in every stairwell.

When fire is indicated to the BLC the PLC automatically control appropriate functions in the fire protection system. Examples of functions controlled by the PLC are:

- Fire pump activation
- Normal ventilation stop and emergency ventilation activation
- Start of overpressure fan in stairwells
- Activation of fire suppression systems
- Closure of fire dampers and recirculation dampers

3.3.3.1.2 R: Types, main characteristics and performance expectations

The fire detection system is expected to detect and alarm the control room in case of smoke or fire in all areas that contain or represent a fire exposure to equipment important to safety.

The system predominantly uses optical smoke detectors but other types of detectors are used when necessary. Examples of other detector types used are as following:

- Ionizing smoke detectors
- Extra sensitive smoke detectors
- Line smoke detectors
- Heat detectors
- Flame detectors
- Air analysing detector systems.

The detectors are constantly exposed to environmental effects, dust, humidity and changes in temperature. A permit based maintenance schedule states when detectors need replacing in order to avoid failures due to aging detectors.

The fire detection and alarm system on A and B side are wholly independent of each other. The subunits on each side are also independent, but to a lesser degree, meaning failure of one BLC will not affect the remaining BLC in operation. Equipment failure on one side will not affect the equipment on the other side. Power is supplied by two separate systems equipped with battery backup.

3.3.3.1.3 R: Alternative/temporary provisions

Should it be required, specific detectors in an area can be temporarily deactivated. This is done when specific tasks must be performed that produce smoke. During the deactivation of detectors temporary provisions are necessary to ensure that fire detection is not neglected. Temporary provisions applied include fire watch guards, stationed or making rounds.

Temporary provisions are applied in accordance to existing instructions.

3.3.3.2 R: Fire suppression provisions

Areas with high fire load and potential risk of fire shall be equipped with suppression systems designed to suppress or control fires until manual firefighting is possible.

Extinguishing agents vary depending on the rooms they cover. Agents used are water, foam, inert gas and powder. Some of these agents only occur in fixed systems and some are solely for manual firefighting.

The most commonly used extinguishing agent in unit 3 is water. The fire protection water supply and distribution system consists of the following:

- Fire pumps e Reservoir
- Fire main
- Fire hydrants

The fire pumps consists of one diesel operated pump specifically for unit 3 and one backup diesel pump, shared between units 3 and 4. Pumps are located in separate fire compartments with separate ventilation systems. The diesel operated pumps ensures the system is insensitive to disturbances in the electrical power supply and are equipped with day tanks (diesel oil), sized for more than 10 hours of continuous operation.

This means that fire pumps are installed with an overcapacity. One pump is delivering 100% water supply for the biggest sprinkler system and additional 2 000 l/min for manual firefighting. The water supply is in total 11 500 m^3 of which at least 1 500 m^3 is reserved for fire protection.

The fire main is built in the form of two ring headers. Together with the unit 4 system the fire protection system have three 100% fire pumps and will form an inner three ring header arrangement and one outer two ring header arrangement. Each main inlet provides connections for supply to each fire pump, cooling water to emergency diesels and service water systems.

3.3.3.2.1 R: Design approach

The water-based fire suppression system in general is designed according to NFPA standards. Pumps, the main ring header and the fire mains are designed in accordance to NFPA 24, 13 and 14. The sprinkler systems in the turbine buildings are older and designed in accordance with good practice and prior knowledge. Sprinkler systems in the cable rooms are designed according to NFPA. A new diesel generator was built some years ago and this building is equipped with a NFPA water sprinkler system.

In addition to the automatic sprinkler systems indoor fire hydrants are placed to make it possible to reach all surfaces with the fire hydrant equipment.

Clean agent gas extinguishing systems are installed in compartment where water sprinkling are un-appropriate in accordance to SBF 500. The system is designed to lower the oxygen concentration below a set limit.

3.3.3.2.2 R: Types, main characteristics and performance expectations

The fire suppression systems is expected to have the capacity and ability to suppress and/or control the expected fire. The type of fire suppression system has been installed depending on the most effective agent for the corresponding area. It is also expected that the actuation of fire suppression systems do not result in damages to systems and components required for reactor safety.

The requirement is met by the installation of water and foam sprinklers and systems for suffocating the fire with inert gas. In spaces which do not have automatic suppression systems installations exist to facilitate manual firefighting either by operating personnel or by the internal fire brigade. Examples for this are outdoor and indoor fire hydrants and appropriately placed fire extinguishers.

3.3.3.2.3 R: Management of harmful effects and consequential hazards

Secondary hazards from fire suppression systems has been identified and the potential harmful effects are properly assessed.

Flooding following sprinkler actuation is managed by the arrangement of flood paths to secure against internal flooding that may cause harmful effects to systems and components. The sprinkler system is also arranged in such a way that actuation does not risk damaging electrical components, either by spacing or by protection of the components.

Compartments with gaseous fire suppression systems are provided with overpressure hatches so that the pressure increase following actuation does not jeopardize structural integrity.

For human safety reasons, gaseous fire suppression systems are preceded by an alarm signal before actuation. This ensures that people within the compartment are given proper egress time before actuation.

3.3.3.2.4 R: Alternative/temporary provisions

The automatic fire suppression system should always be in operation. In the case of maintenance on the system compensatory measures must be taken to ensure required fire suppression capabilities. Applicable measures might be to use "smart hoses" connected to fire hydrants as acting sprinklers. In addition it is often required to use fire watch guards making continuous rounds in affected areas. Should a fire be detected the fire watch guards will manually open the flow of water to the smart hoses. As these fire watches also are educated fire fighters, they will constitute complement (extra personnel) to the arriving onsite fire brigade.

3.3.3.3 R: Administrative and organisational fire protection issues

3.3.3.3.1 R: Overview of firefighting strategies, administrative arrangements and assurance

Actions in the event of a fire, as well as other occurring abnormal events at the station, are guided by pre-issued instructions. These shall describe, as far as possible, the measures to be taken to prevent any uncontrollable situations. For fire, the following instructions are developed:

- An overall instruction that describes routines for rescue operations, including how responsibility is distributed in the event of an operation and what the communication routines look like.
- Typical events describing the most common fire scenarios at nuclear power plants and existing risks and extinguishing measures.
- A firefighting instruction with prepared measures to be taken by the operations personnel in the control room depending on the area affected. In case of a fire

alarm, part of the shift teams operations personnel are deployed to verify the fire and to determine its scope. They also deploy initial fire-fighting measures and provide support to the internal rescue services. The rest of the shift team is assigned to either keep operating in a safe manner or bring the reactor to safe shutdown depending on where the fire is located and the possible consequences of the fire. In this assignment is included to make proper operating deflections (electrical shifting etc.) in order to make it safe for the fire brigade to enter a certain fire compartment. The procedures are pre-defined in written instructions for every single fire compartment.

Intervention layouts (rooms, detectors and so on) and fire compartment layouts are sometimes supplemented with specially developed intervention plans for complex spaces. These are available together with a mapping of special risks such as gas cylinders or high radiation to be made available as decision support for personnel leading the intervention.

The firefighting plan, intervention cards and instructions are available in the fire truck at the internal fire brigade and in the MCR. A full setup of documentation is also accessible for fire brigade staff function in the office areas (this documentation is also digitally available from work computer stations).

The frequency of review for the instructions is at most every five years. Quality assurance is managed through systematic fire protection work and is continuously monitored.

3.3.3.3.2 R: Firefighting capabilities, responsibilities, organisation and documentation on-site and offsite

The onsite rescue services at Ringhals are responsible for operative rescue services and are required to immediately respond to an alarm and to be able to start rescue intervention at the address point inside the plant maximum 10 minutes after the alarm.

In addition, the internal fire brigade issues permits (hot works etc.), training / education, maintenance of portable equipment and testing in the area of fire protection which makes them very familiarized with the plant and risk connected to the process.

The fire brigade consists of one commander and three full time fire-fighters 24/7/365. The commander is also a health physics engineer and hence can take responsibility for offsite fire brigades radiation protection if needed. The fire brigade is outsourced to a professional contractor with the same demand on the firefighting personnel as an ordinary fire brigade according to Swedish regulations. In daytime or when many jobs are performed at site, the organization is larger since fire protection coordinators / all contracted FP personnel also will respond on alarms, at least three extra resources.

There is a Service Level Agreement (SLA) with the fire brigade that describes in detail the mission and skill requirements of the fire brigade.

Training and drills for the station fire brigade is always ongoing and in various forms. The training plan is based on the typical events of probable fire scenarios that have been developed.

Some training and drills are also performed in liaison with the operations personnel and some with the offsite fire brigade. An annual fire drill is performed with each operations shift team (7 per unit).

The first link between onsite and offsite fire brigade is the internal commander.

In addition to the on-site rescue force there is a 24/7 on call information support officer (RIS) that will be alerted along with the municipal rescue services in order to assist them with risk analysis and other essential information needed, where coordination between plant personnel / expertise / decision makers and offsite resources is an important part. RIS is cross functional and consists of various personnel with different backgrounds within fire protection area.

The criteria to deploy the offsite fire brigade is that a confirmed fire has occurred. For other emergencies the internal fire brigade commander does an assessment in each case if there is a need to call upon external rescue services.

Offsite fire brigade is equal to the municipal rescue service and they have a fixed alarm plan for the site including a large number of vehicles, personnel and equipment. In case these stations already are busy on other event an automatic dynamic resource handling system will call for similar resources from other stations. The nearest offsite fire brigade has approximately 20 minutes to get to the site. There is a good cooperation with the offsite fire brigade and multiple fire drills of various types are arranged. The aim is to get the outside organizations familiarized with the site and nuclear in general. For commanding officers most of the drills are table-top and simulation drills.

Once the off-site (municipal) rescue services arrive, they also have the command of the overall intervention.

In case of more severe fire the intervention could be taken over by state (national) intervention command.

3.3.3.3.3 R: Specific provisions, e.g. loss of access

In case of ordinary access routes are lost, the operating personnel support the fire brigade with information needed about appropriate access path to perform firefighting based on the event occurred. For the offsite fire brigade there exist more than one road to access the site.

3.3.4 R: Passive fire protection

3.3.4.1 R: Prevention of fire spreading (barriers)

The third level of the DiD principle is the mitigation of consequences from fire and the prevention of fire spreading.

3.3.4.1.1 R: Design approach

The operability of the consequence mitigating fire protections means that the division into fire compartments are intact and the fire ventilation, as far as possible, ensure access to the safety systems during an ongoing fire.

An operable fire compartment ensures that a fire does not spread to spaces outside this fire compartment. By division into fire compartments it is secured that a maximum of one redundant part of a safety system can be affected by a fire. In those cases when redundant parts of a safety system are placed in the same fire compartment, these are protected by room separation, distance separation, barriers and/or sprinkling.

In aspect of technical requirements for operation the consequence mitigating fire protection at the site is defined in the LCO.

The consequence mitigating fire protection consists of the subsystems:

1. Fire ventilation.
2. Fire compartments.

3.3.4.1.2 R: Description of fire compartments and/or cells design and key features

Fire compartments

A fire compartment is a building or a part of a building that is completely surrounded by fire resisting barriers; all walls, the floor and the ceiling including penetrations.

Buildings are divided into different fire compartments based on the fire load data and the need for separation between safety systems. Fire compartments are designed to resist a total burnout of a specific fire load of maximum 200 MJ/m2 surrounding area. This led to the fire resisting barriers being classified to at least El 60. According to the fire load database compartments have been identified to have a fire load exceeding 200 MJ/m2 surrounding area. The adequacy of these fire resisting barriers is documented in Deterministic fire hazard analyses.

The fire doors are not generally classified as El 60 (European classification) but A60 instead. A60 is the national classification that were used in the time of designing / building the plant. It could be noted that there is a rather marginal difference between A60 and E160. In order to prevent damage of equipment due to heat radiation from doors a separation distance from door to equipment is required. When replaced, E160 doors are chosen.

Fire protection of equipment inside a fire compartment

In some cases fire compartments have not been possible to create between redundant systems due to original design and or conflicts between requirements for fire protection and other plant requirements. In these areas, fire protection has been provided by a combination of separation by distance, local passive fire protection and fire extinguishing systems. The separation by analytical dimensioning leads to the creation of Fire cells within a fire compartment.

The separation into fire cells is based on the presumption that redundant systems should be provided with enough separation such that at least one system is unaffected by a fire.

3.3.4.1.3 R: Performance assurance through lifetime

Inspections to ensure structural integrity and performance is done on a regular basis. There are plant specific maintenance programs describing what should be controlled/maintained and how often. In addition to the maintenance programs the internal fire brigade and operating staff are performing regular walk downs to identify deficiencies in the fire barriers.

When an opening is required in a fire barrier there are written instructions for how an opening for cables or pipes should be sealed. The equipment and methods used are resistant to fire with the same rating as the corresponding fire barrier. All seals are properly marked and controlled.

Exchange programs are initiated when needed, for example smoke hatches on turbine hall have been exchanged, also fire dampers are exchanged in all buildings. Fire doors are sometimes repaired or exchanged when needed etc.

3.3.4.2 R: Ventilation systems

As described in R3.3.1.1, the operability of the consequence mitigating fire protections means that the division into fire compartments are intact and the fire ventilation, as far as possible, ensure access to the safety systems during an ongoing fire. Fire ventilation is also available in certain spaces for the purpose of exhausting combustion gases during a fire.

3.3.4.2.1 R: Ventilation system design: segregation and isolation provisions (as applicable)

Different fire compartments can be connected to the same ventilation system. This requires that the ventilation ducts are insulated when passing another fire compartment in addition to being provided with fire dampers. Insulation and dampers must have the same classification as the fire compartment fire barriers, usually El 60. Fire compartments with shared ventilation system have separate supply and exhaust air rooms.

For ducts insulated according to old building regulation with different temperature criteria a separation distance is required between the duct and the equipment/material in the room. The separation distance is dependent on the diameter of the duct.

In addition to insulation the ducts are suspended with methods securing they will not collapse within the required insulation time, 60 minutes.

Some fire compartments or groups of fire compartments have been provided with separate ventilation systems with a common release to the outside.

To prevent smoke spread between fire compartments and buildings the inlet and outlet openings have been placed as far as possible from each other.

The stairwells are provided with smoke extraction systems by over pressurization in order to ensure that egress paths are not blocked by smoke. This also acts as access paths for the internal fire brigade in the event of fire. Some compartments are also provided with smoke hatches or supply air fans in order to reduce temperature load and increase visibility.

3.3.4.2.2 R: Performance and management requirements under fire conditions

In the event of a fire in a compartment the fire detection system will detect the fire and the fire alarm system will activate. Following this there are automatic systems that will control the ventilation system:

- Closure of fire dampeners and recirculation dampeners.
- Activation of overpressure fans in stairwells to ensure the possibility of a safe egress path and access for the fire brigade.

In areas with smoke hatches manual opening of these hatches might be performed if the fire brigade personnel decides it is necessary.

3.3.5 R: Licensee's experience of the implementation of the fire protection concept

In order to maintain the fire protection of the facility, active work is required to monitor and maintain these systems. For this, clear instructions and procedures are required that describe what should be performed and how it should be carried out.

An important parameter is an understanding of how the fire protection is designed. This needs to be clearly described the plant's safety analysis report.

In the event of changes in the fire protection due to renovations or new regulations, it is important to document what has been done and why a particular solution has been chosen. Over the years, a number of improvements have been made in the fire protection against the original design. Most due to additional requirements and renewed regulations. Some improvements have been made following recommendations from insurance companies.

The physical separation of redundant trains of systems in fire compartments and the arrangements of fire cells in fire compartments are essential to achieve a robust fire protection concept.

The close cooperation and involvement of the internal fire brigade is a strength when it comes to the administrative fire protection and fire-fighting capabilities.

Secondary hazards from fire suppression systems are properly assessed within the plant design flood analyses and the pressure relief systems, demonstrating that the plant can accommodate flooding caused by sprinkler actuation and the overpressure caused by clean agent systems.

Systems making up the active fire protection are controlled and checked regularly in maintenance programs to secure expected behaviour in case of fire.

Preventing fires from occurring by reducing combustibles and ignition sources is an overall goal and should be strived for whenever possible, e.g. when making design changes. Procedures for management of fire load, ignition sources and temporary provisions are in place overviewed by personnel from the internal fire brigade and, when necessary, plant fire protection engineers. Providing appropriate prerequisites is essential to achieving desired effect in regards to fire protection.

Improvements to the fire protection concept are made continually based on risk assessments made onsite as well as in order to fulfil requirements set by regulators and insurance companies.

3.3.6 R: Regulator’s assessment of the fire protection concept and conclusions

RAB has a fire protection concept including fire prevention, fire detection and fire limitation and extinguishing. RAB provides a detailed description of the fire lines of defence where the protection is based on management and control of fire ignition and load sources, separation in compartment or by distance of safety related equipment, and eventually in case of fire, detection and limiting/extinguishing. RAB describes that as part of the Systematic Fire Protection Work regular inspections are performed in the facility to

ensure proper control of fire load and ignition sources. RAB also has rules for management of fire load and Hot Work are continually enforced during the mentioned inspections. RAB mentions that it is of key importance to provide personnel and contractors with the proper information of the importance of fire safety. It has been noted that an increased understanding of the importance of fire prevention will increase the likelihood of expected performance and another key factor is to make sure that the fire protection information is simple and easily available for proper fire prevention performance.
The fire limiting and extinguishing measures include fire compartments, fire alarms, automatic and manually actuated fire protection systems as well as the professional fire brigades.

By division into fire compartments it is secured that a maximum of one redundant part of a safety system can be affected by a fire. In those cases when redundant parts of a safety system are placed in the same fire compartment, these are protected by room separation, distance separation, barriers and/or sprinkling. The complete separation has not been possible due to original design and or conflicts between requirements for fire protection and other plant requirements.

Following the results of the FHA, see also chapter 2.1.3.6.2, vulnerabilities of the plant configuration has been identified and actions to improve the fire protection have been implemented. These includes encapsulation of oil systems, increased separation of the spent fuel pool pumps and improved fire protection in relay rooms.

RAB has a professional fire brigade on site, which lower the response time compared to an off-site fire brigade and ensures that the firefighters have appropriate knowledge of the facility and guidelines on how to handle different kinds of fires that can arise. The fire brigade and other staff are trained to extinguish the fires that may occur in Ringhals 3. Certain failures of the fire protection system as well as fires that affect components important to safety are reported to SSM as licensee event reports as they are included in the OLC. All these events are reviewed and assessed by SSM. SSM finds that the fire protections concept is adequate and works in practise, as has been shown when a fire do occur. SSM oversight activities regarding fire are limited. An inspection series in 2015 looked at house-keeping (in general) and concluded that requirements were fulfilled. As mentioned above, some other oversight activities have been carried out regarding Fire Hazard Analysis and fire-PSA. SSM also follows fire protection works via participation in the National Fire safety Forum (NBSG) where the licensees share experiences and initiate small R&D efforts focusing on practical fire protection issues. NBSG is also a common point of contact for the OECD/FIRE database project collecting and sharing information on fires as a basis for fire defences development and fire frequency estimations.

Strengths mentioned by RAB is that Ringhals 3 has good separation between the independent safety trains, ensuring that a fire on one train will not jeopardize the security of the other train. The electrical subdivisions in each safety train however is not fully separated. Instead the separation of the electrical subdivisions in some occasions depend on conditions set in analysis which should be noted as a weakness. In the latest versions of the Safe Shutdown analysis the analysis is performed primarily with the fire compartments as fire barriers. This has shown the strength of the fire compartmentalization since the plant can be safely shut down, in spite of the weakness in the electrical subdivisions separation mentioned above.

The close cooperation with the internal fire brigade is also a highly valued strength. The personnel gains proper knowledge of the plant layout and where for example temporary fire load is located which might complicate any potential rescue operation.

In addition to the strengths mentioned by RAB, SSM also want to mention the National Fire Safety Forum (NBSG) where the licensees and regulator are members. NBSG overall focus is to create increased knowledge in the field of fire safety at nuclear facilities and increased knowledge in the field of reactor safety-related fire safety.

The adherence to fire requirements are checked by not only SSM, but maybe more by other authorities and insurance companies. This contributes to a solid fire protection concept.

Observations and recommendations originating from internal analysis and checks as well as checks by external organisations have led to many improvements in fire protection, and is an ongoing effort.

Ringhals does also share experiences with others with regards to fire protection to spread and gain knowledge, see also section 3.3.1.3.2.

3.3.7 R: Conclusions on the adequacy of the fire protection concept and its implementation

SSM concludes that Ringhals 3 has an adequately fire protection concept implemented.

3.4 Westinghouse fuel factory

The fire protection policy forms the basis for the development of fire protection work in the total management system. An action plan for the company's fire protection activity has been drawn up to reach our goals.

- Management of fire protection
  - The company organization for fire protection work must be clearly set out. Within the company there must be a person who has overall responsibility for the management of fire protection as well as individuals who have been given written specifications of their duties
- Plans for training in fire protection
  - The aim is to make all personnel aware of fire safety issues in the workplace. They must be able to act on their own initiative and to play their part in ensuring that the company has proper fire protection. The fire protection manager and other responsible persons may need additional specialist training.
- Fire protection rules and routines
  - With the help of fire protection rules and routines, the fire risks can be limited or eliminated. The fire protection rules should explain what measures that everyone involved should do to reduce the risks. In case of a fire there should be well known and trained routines for necessary actions. The fire protection rules and routines are your tool in achieving the greatest possible fire safety at a place of work. Rules and routines should be constantly reviewed and be a part of the information in training activities.
- Business continuity planning

  - A business continuity plan is a plan to continue operations if a place of business is affected by adverse physical conditions, such as a storm, fire or crime. Such a plan typically explains how the business would recover its operations or move operations to another location. For example, if a fire destroys an office building or data centre, the people and business or data centre operations would relocate to a recovery site. The plan could include recovering from different levels of disaster which can be short term, localized disasters, to days long building wide problems, to a permanent loss of a building. More information about this item is published in CFPA E Guideline No 2 2013 N, business resilience.
- A description of buildings including fire protection
  - Westinghouse, in accordance with current regulations, needs to have relationship documents drawn up for fire protection. Examples of information that appears in the documents are fire separation, which spaces are equipped with fire and evacuation alarms and which spaces are equipped with automatic extinguishing systems.
- Operating and maintenance instructions for fire protection
  - Inspection and maintenance plan is in accordance with the manufacturer's instructions, regulations/standards or laws/regulations.
- A control system for fire protection
  - Fire safety is not achieved unless the fixed fire protection systems are controlled systematically and continuously. Control of the fire protection systems shall be carried out regularly and preferably by the fire protection surveyors appointed in the company. The control is to be based on the description of fire protection and the operating and maintenance instructions. Control implies that a large amount of data and information must be collected and effectively processed. Depending on the quantity of information and the control requirements, the tools you will use to have a proper overview of this information will vary. It is today increasingly common to use computers for the collection and processing of data. When you have established the inspection areas, inspection techniques and procedures, you can determine the inspection intervals. It is essential that the internal control activity should not become a matter of superficial routine. Control shall be carried out properly, and a lot of imagination and ingenuity may be needed to increase the interest and commitment of those who perform the inspections. In-house control of the electrical equipment should also form part of the regular inspections. It is at all times the duty of the owner of the plant to maintain his plant in such a condition that it provides the necessary safety for people, domestic animals, and property in accordance with the requirements of the appropriate authorities.
- Evaluation procedures for fire protection
  - This refers to a summary report on the inspections, both external and internal, which are carried out within the company. This summary is to be regarded as an aid for the chief fire protection officer and managing director in monitoring that these controls have been carried out, and it will also enable them to improve fire protection. It is appropriate for reports on incidents to

be included in this summary. Incident reporting means that information concerning the equipment in which fire incidents occur, and the causes of these incidents, is collected and compiled. The aim of incident reporting is to help the company to identify the risks in the company and to make it easier to assess the probability of occurrence of a certain event that may result in a fire. For these reasons, the fire investigation report should also be used that is typically carried out according to the international or national recognized approach and by the expert of responsible authority, such as police or fire department. This is particularly helpful when the location and the causes of fire, its spread including the concerning facility or/and process and the extent of damages are identified and documented

3.4.1 W: Fire prevention

Preventing fires from starting is the first level of defence in depth with respect to fire safety. Several internal measures are taken to minimize the likelihood of internal fires. These typically concern:

- fire loads (minimization and segregation of fixed and transient combustibles to the extent practical; location, spatial distribution, properties of combustibles, etc.),
- ignition sources (in particular, minimization of potential ignition sources to the extent practical, a strict control of any ignition sources and segregation of them from fire loads, management of hot work, etc.),
- oxygen (reduction of oxygen concentration, inert gas atmosphere, etc.).

This is primarily used in spaces with sensitive electronic equipment which are equipped with gas extinguishing systems.

3.4.1.1 W: Design considerations and prevention means

Fire prevention is designed and located to minimize the frequency and the effects of fire, to maintain capability for confinement of radioactive material and for criticality prevention.

The means of fire prevention are based on:

- Construction standards (Swedish national board of housing, Electrical safety council etc.) guaranteeing a period of fire resistance before a possible collapse of the building structures.
- Partitioning of space to prevent the spread of fire. Fire compartments are constructed according to risk analyses including technical installations. Ventilation ducts, for example, are designed in such a way that, in the event of a fire, they do not cause ignition of adjacent construction parts.
- The possibility of evacuating fire smoke from specific buildings.
- Specific equipment with automatic fire-detection system (activated by smoke or flame detection)
- Adapted device distribution for manual fire extinction.
- Training, both practical and theoretical, of the business's staff.
- Monitoring system, both visual monitoring, different types of operational alarms and different types of emergency alarms, including fire.

- Automatic extinguishing systems, both water mist and gas extinguishing systems. - Surveillance centre that is manned around the clock.
- Forwarded fire alarm that alerts the emergency services.
- Fire-technical separation between different spaces.
- Regular rounds.

3.4.1.2 W: Overview of arrangements for management and control of fire load and ignition sources

The fire load for each building in the factory has been determined based on the Swedish rules (Boverkets allmänna råd (2013:11), as well as Boverkets handbok om brandbelastning, rules to assess fire loads suitability). Compliance with this is checked by a hired security company several times a day when renderings are carried out. Other personnel report violations in the company's internal improvement programs ARC and CAP.

Every work on temporary places involving heat sources capable of initiating the start of a fire is controlled and monitored by personnel with skills in safety and fire protection.

Handling and installations concerning flammable goods are carried out in accordance with the Swedish authorities, Swedish Civil Contingencies Agency and local fire brigade.

3.4.1.3 W: Licensee's experience of the implementation of the fire prevention

Westinghouse works in close collaboration with the authorities to prevent the occurrence of an accident and, if necessary, limit its impact. To do so, several levels of collaboration are deployed.

3.4.1.3.1 W: Overview of strengths and weaknesses

Factory fire prevention is based on several general principles, recognized, and validated by a group of expert international players. The analysis of the risks specific to the plant activities is thus carried out and updated in partnership with:

- civil regulatory authorities (national and local)
- independent consulting firms
- the international level of the Westinghouse group

Compliance with international, national and local standards is reinforced by the use of independent experts and international feedback from Westinghouse. These three factors ensure the implementation of fire prevention policy adapted to the challenges of the different levels/activities of the company.

Within Westinghouse there is a culture of reporting the deviations that are seen in the business' continuous improvement systems CAP and ARC. The reports are then coded into categories and used for internal statistics and metrics for continued improvement work.

At the national level, strategic questions are investigated to develop a coordination between the various competent institutions (SSM, MSB for example).

At the regional level, strategic and tactical questions are studied to build a functional network.

At the local level, tactical questions are reflected to improve the quality of fire protection (coordination of local means, operational exercises, security audit).

3.4.1.3.2 W: Lessons learned from events, reviews fire safety related missions, etc.
Westinghouse aims at building an environment that continuously promotes learning from industry and experience to ensure that safety and quality are held to the highest and most current standards in the performed work.

This process is enriched by learning from our operating experience, post-job reviews, self assessment, benchmarking and much more.

Inspections carried out by insurance companies to see if Westinghouse complies with applicable insurance conditions are carried out every three years, while internal audits are carried out every two years.

3.4.1.3.3 W: Overview of actions and implementation status
Local organization works in close relationship with the global and international system of Westinghouse. This combination provides management, monitoring, and control of fire safety tools.

This approach makes it possible to exploit global trend analyses in order to update specific staff members on targeted dangers.

As of 2022, 13 cases have been reported that concern fire or related substances. An example is a blocked escape route where the following measures were taken:

- Experience feedback with affected personnel.
- Revision of procedures for handling goods in connection with the blocked escape route and signage.
- Updated instructions and routines for handling goods around escape routes.
- Escape routes within the relevant area must be marked more clearly.
- A responsible person within the department is appointed.
- Training for access to the area in question must be updated to include information on escape routes.

3.4.2 W: Regulator's assessment of the fire prevention

Requirements for fire prevention has historically been regulated by other authorities than SSM, see chapter 1.2.1. These requirements are generic for industrial buildings and not specific for nuclear power plants.

SSM do not have any specific requirements on fire prevention as shown in chapter 1.2.1 for other nuclear facilities. As such, there have not been any inspections and no formal lessons learned with regards to the fire prevention programs for the licensees. SSM is currently updating the regulations for nuclear facilities other than nuclear power plants.

3.4.2.1 W: Overview of strengths and weaknesses in the fire prevention

Westinghouse has an active fire prevention program that ensures that the fire loads are as low as reasonably achievable and lowers the probability of a fire occurring. This include routines to manage and control fire loads and ignition sources at the plant as well as personnel have the prerequisites to be able to identify and act on deviations in the fire prevention and in the event of fire. As a part of the systematic fire protection work, regular inspections are performed in the facility to ensure proper control of fire load and ignition sources. Every work on temporary places involving heat sources capable of initiating the start of a fire is controlled and monitored by personnel with skills in safety and fire protection.

3.4.2.2 W: Lessons learned from inspection and assessment on the fire prevention as part of its regulatory oversight

SSM:s main conclusion is that the fire preventing programs relies on everyone that enters a nuclear facility does their part to reduce the risk of a fire occurring and spreading. This is done by ensuring a limitation of combustible materials and lower the risk for ignition.

3.4.3 W: Active fire protection

3.4.3.1 W: Fire detection and alarm provisions

Fire detection takes place in all Westinghouse facilities with smoke detectors, heat detectors and even spark detectors in the ventilation system.

This system is completed by evacuation alarms with manual triggering.

3.4.3.1.1 W: Design approach

The building is equipped with an automatic fire alarm according to SBF 110, which constitutes a national guideline regarding the design of automatic fire alarms (components verified according to standard EN-54).

Certain parts of the buildings (particularly important) are equipped with an aspirating system that sucks air from the protected area (the air is continuously drawn through the precision detector where it is analysed to detect smoke particles, this system generates prewarning alarms to the monitoring Centre).

3.4.3.1.2 W: Types, main characteristics and performance expectations

The fire detection systems installed have been designed according to SBF 110:8. The amount of detectors, type of detectors, control panels and back-up power supply is designed to comply with what is called “Class A”- system, which means full coverage. The management, monitoring and status control of fire detection systems are driven by the surveillance and control centre.

3.4.3.1.3 W: Alternative/temporary provisions

The voluntary interruption of a fire detection capability must be justified, documented, controlled, and compensated in such a way as to avoid:
1. The risk of degradation of fire protection;
2. The increased risk of a fire occurring (e.g., when fire detection is deactivated to perform hot work).

All the actions leading to a modification of the capacities of the fire detection system are controlled and centralized to ensure an overall view of the system capabilities in real time. For example, if smoke detectors is temporarily turned off in order for hot works on temporary places to take place a fire guard is replacing the detector during and for a curtain amount of time after the job has been completed.

3.4.3.2 W: Fire suppression provisions

Some parts of the factory are equipped with automatic-extinction system and other parts in the factory’s site are equipped with manual extinguisher which are adapted to the type of fire risk. Areas where water is prohibited are equipped with no-water extinction means (gas automatic extinction system or manual extinguisher without water).

3.4.3.2.1 W: Design approach

The installation of fix and manual extinguishing systems considers all the risks inherent in the activity of each area. Therefore, the use of water as an extinguishing agent is totally excluded in certain parts of the plant where uranium is handled openly and is there replaced by a water free agent called Super K. For other parts of the operation, traditional extinguishing agents such as water, powder, foam and carbonic acid are used.

3.4.3.2.2 W: Types, main characteristics and performance expectations

Fixed automatic extinguishing systems aim to act quickly on an incipient fire, and appears with three types of agents. Hi fog, carbon dioxide and Novec.

These systems can be triggered by the detection of smoke in the protected area or by the direct detection of the extinguishing-agent diffusers to the heat.

3.4.3.2.3 W: Management of harmful effects and consequential hazards

The use of a fixed automated extinguishing system using a gas to inhibit the oxygen supply to an incipient fire can prove to be dangerous for the people and/or the intervention services in the zone where the oxygen lacks.

Trigger alert systems for these types of extinguishing systems are put in place to alert before entering the protected area. This can be characterized by the activation of a light signal positioned outside the room, for example.

Fixed automatic-extinction system must comply with national standards.

The water used by the hi fog system will remain in the culvert after the system has tripped where it is manually pumped up and disposed of.

3.4.3.2.4 W: Alternative/temporary provisions

The intentional interruption of an automated fire extinction system must be justified, documented, controlled, and compensated in such a way as to avoid:
1. The risk of degradation of fire protection.
2. The increased risk of a fire occurring.

All the actions leading to the modification of an automated fire extinction system are controlled and centralized to ensure an overall view of the system abilities in real time.

3.4.3.3 W: Administrative and organisational fire protection issues

In the event of changes in the business that affect or may affect the fire protection, has Westinghouse detailed instructions to follow. These instructions describe the responsibility for various functions in the organization, as well as which routines must be followed. The instruction applies to all employees, contractors, and consultants at all operations at Westinghouse in Västerås.

To ensure the smooth running of these operations, various functions and departments share responsibilities:

- equipment manager for fire technical equipment, e.g., fire alarm, extinguishing system, fire equipment, emergency lighting, etc., at factory.
- responsible function which works operationally with preventive fire protection throughout Westinghouse.

- function within the department for Planning, development and operational maintenance service system (Property) that works closely with operatives fire protection issues
- operationally responsible for following up the self-inspection of fire protection which fire security staff performs.
- a function that ensures that flammable goods are handled correctly in accordance with applicable laws and regulations
- Responsible for following up that rounding is performed according to control interval, mediate, or fix deviations.
- within Westinghouse, there is a contingency organization that is constantly prepared to act on unforeseen security-related events
- a special crisis management team with crisis managers on standby 24 hours a day, all year round. The crisis management organization is called in for extraordinary events

3.4.3.3.1 W: Overview of firefighting strategies, administrative arrangements and assurance

A first-action response plan is constantly updated at the factory to ease the emergency services action. It is drawn up in consultation with local fire department as well as regional, and national civil authorities. It is available in the surveillance and control centre. Local emergency services conduct ongoing orientation exercises at the facility. Responsible for coordinating this is the fire protection manager within Westinghouse. In exercises, relevant personnel from Westinghouse participate.

Uranium workshops cannot be equipped with water-based extinctors. Therefore, a strategy has been developed for firefighting in these parts of the factory. This strategy is described in our internal classified instruction.

3.4.3.3.2 W: Firefighting capabilities, responsibilities, organisation and documentation on-site and offsite

Fire and rescue department driving time is less than 8 minutes. Nearest fire station is triggered upon fire detection.

Firefighters and fire security staff on duty meet at the Surveillance Centre (the main entrance) to coordinate the fire intervention and is guided by Westinghouse staff on site.

Firefighters will never engage themselves to specifics areas where water would induce radiation risks. The factory has an IVPR group that is constantly on duty when production is in progress as well as a crisis preparedness group alert with a specific set-up time.

The factory and the local emergency services communicate with each other closely to develop a common knowledge basis. This involves regular exchanges on issues relating to the plant fire safety, but also visits and operational exercises. The rescue service conducts orientation exercises at approximately one-year intervals.

3.4.3.3.3 W: Specific provisions, e.g. loss of access

The fuel factory has an accessible road network within the factory area. Accessibility is ensured by the unit responsible for roads within the area. Rescue vehicles can get so close to the buildings that hose pulling does not exceed 50 meters.

3.4.4 W: Passive fire protection

3.4.4.1 W: Prevention of fire spreading (barriers)

Fire compartmentation is commensurate with the fire and radiological risks associated with the facilities. Objectives of fire building standards are to prevent the spread of fires, to ensure and maintain a safe state of the plant by maintaining the safety-function abilities and to limit the quantity of radioactive material involved or released during the fire. This shall minimize effects and consequences of fires not extinguished, particularly to avoid common cause failures and possible cliff-edge effects.

The general fire compartmentation is designed to withstand 60 minutes of fire.

3.4.4.1.1 W: Design approach

Westinghouse in Sweden is following the Swedish building standards applied at building time. Over the years, the plant has been expanded and renovated according to the building standards, applicable at each period. Westinghouse has a global fire protection description for all buildings at nuclear fuel factory, where the description of operations, building materials, and others describes (fire compartments, fire-load limits, etc.).

All fire-safety responsibilities and tasks are clearly defined and detailed by internal instructions. Westinghouse has a crisis management team designated to cooperate with fire brigade, depending on the scenario.

3.4.4.1.2 W: Description of fire compartments and/or cells design and key features

Fire compartments division refers to walls, windows, floor and technical sheath penetrations. Fire compartments are made in minimum EI 60 in workshops and labs, and EI 30 in offices (where "E" stands for Integrity and tightness, "I" stands for Isolation abilities). In glass sections between office spaces and workshop, the fire compartments is assessed to be EI 30.

Doors, hatches, glass sections and other comparable building equipment must be tested and approved.

Fire compartment separating walls must be connected to fire compartment separating floors and outer roof to ensure that building parts is maintained during the period which is stated in the requirements for the relevant building part, 30 or 60 minutes.

3.4.4.1.3 W: Performance assurance through lifetime

There are several aspects to consider when modifying or planning new buildings. The fire safety engineer and fire-safety coordinator must always be involved at an early stage in these projects. In case of major changes, an external fire engineer will reinforce the team to participate as an independent expert.

Westinghouse does not carry out special aging analyses for the fire protection without it being checked and tested regularly and replaced/serviced if necessary.

The fire documentation be updated by the project leader for every change.

3.4.4.2 W: Ventilation systems

The ventilation system is designed so that the spread of fire gas (smoke) is prevented.

3.4.4.2.1 W: Ventilation system design: segregation and isolation provisions (as applicable)

In the event of a fire, ventilation ducts are designed not to ignite nearby people and furniture buildings (during the time that the separation capability of the fire compartment must be maintained).

This is achieved by isolating channels where fire gases are allowed to flow through another fire compartment or by providing the channel with dampers in the fire compartment boundary.

3.4.4.2.2 W: Performance and management requirements under fire conditions

Routines are established for regular maintenances and conditions test. Each incident on where technical fire protection could be involved is reported and notified to ensure their expected use in the event of a fire incident.

3.4.5 W: Licensee's experience of the implementation of the fire protection concept

The fire compartmentation throughout the site is performed in a way that separates the different categories of operations on site, with aspect to uranium management.

To maintain the required level of the fire safety, and comply with regulatory requirements, the operations performs continuous rounding's on site, scheduled control and maintenance of the systems and conducting continuous performance enhancing work throughout the corrective action program.

The local fire brigade performs exercises on site and is joining the operations when training the crisis management staff.

Periodic review of governing instructions is handled annually and documented. It is continuously revised. This periodic review involves governing fire-protection.

Training plan for staff and special functions is available. The plan does not state who has attended which training. It does not mention either the next training opportunity. This is handled by a central function within the company and this is organized via our own education system.

3.4.6 W: Regulator's assessment of the fire protection concept and conclusions

Westinghouse has a fire protection concept including fire prevention, fire detection and fire limitation and extinguishing. The protection is based on management and control of fire ignition and load sources, separation in fire compartment, fire alarms, automatic and manually actuated fire protection systems as well as the first responders on site and the municipal fire brigade off-site. The municipal fire brigade and other staff are trained to extinguish fires that may occur at the fuel factory.

Westinghouse further has a fire protection policy being the basis for a fire protection work in the overall management system including:

- Management of fire protection,
- plans for training in fire protection,

- fire protection rules and routines,
- business continuity planning,
- description of buildings including fire protection,
- operating and maintenance instructions for fire protection, and
- evaluation procedures for fire protection.

Several measures for preventing fires or minimising frequency and effects are in place, e.g. regarding ignition sources, fire loads and use of oxygen reduction and inert atmosphere. Further, construction standards are used (e.g. fire resistance of doors and other structures) and separation in fire compartments as well as fire alarms, automatic fire extinguishing systems and adapted device distribution for manual fire extinction.

Every work on temporary places involving heat sources capable of initiating the start of a fire is controlled and monitored by personnel with skills in safety and fire protection.

Westinghouse mentions a close collaboration on several levels with various authorities to prevent the occurrence of an accident.

SSM oversight activities regarding fire hazards at Westinghouse are very limited. A fire occurred in the room for oxidation ovens on May 2, 2022. SSMs assessment (SSM2022-3901-1):

- Westinghouse personnel reacted swiftly
- Westinghouse personnel was experienced and with good knowledge about the operation.
- Personnel protection equipment was not used and WSE was advised to review the preconditions for personnel to have quick adequate access to such equipment.
- Operation was stopped in a controlled way and ventilation closed.

Westinghouse mentions a set of strengths:

- Compliance with international, national and local standards is reinforced by the use of independent experts and international feedback from Westinghouse.
- A Westinghouse culture of reporting the deviations that are seen in the business' continuous improvement systems CAP and ARC, that are used for continued improvement work.
- Coordination activities at several levels:
  - At the national level, investigation of strategic questions to develop a coordination between the various competent institutions, e.g. SSM and MSB.
  - At the regional level, strategic and tactical questions are studied to build a functional network.
  - At the local level, tactical questions are reflected to improve the quality of fire protection (coordination of local means, operational exercises, security audit).

Operating experience including post-job reviews is considered and also feedback from insurance companies inspections.

The adherence to fire requirements are mainly checked by other authorities than SSM and by insurance companies. This contributes to a solid fire protection concept.

3.4.7 W: Conclusions on the adequacy of the fire protection concept and its implementation

SSM concludes that the Westinghouse fuel factory has an adequate fire protection concept implemented. SSM finds that Westinghouse can improve its systematic fire preventing and fire protection by sharing experiences with other similar facilities.

3.5 Clab

3.5.1 C: Fire prevention

3.5.1.1 C: Design considerations and prevention means

Fire must primarily be prevented from occurring. If it does occur it must be quickly detected and prevented from spreading. If necessary, both automatic and manual firefighting measures must be available to fight the fire.

Fire safety is taken into account in the design of the facility, and also by limiting the fire load and through training of the personnel and by administrative control of work that may affect the risk of a fire. Early detection takes place with a monitoring system, which is supplemented by regular operational rounds in the facility.

Control of the spread of fire takes place, among other things, through fire cell division. Automatic firefighting functions are carried out in cooperation with the detection system. The facility is always staffed and the staff can take manual action in the event of a fire. The emergency services are close by and can be on the scene quickly to start an extinguishing operation.

Functions deemed to be of significant importance for the facility's defence in depth have high availability requirements and are equipped with duplicated active components. For these functions, requirements for physical separation between redundant parts apply so that a limited fire does not causes both parts to lose their function.

A fire is assumed to primarily damage components and devices in the facility. The spent nuclear fuel is protected by large volumes of pool water which means that the heating process is slow if the cooling system loses its function.

3.5.1.2 C: Overview of arrangements for management and control of fire load and ignition sources

The control room staff carry out daily rounds in the facility. At the control rounds, among other things, fire load are checked. The rounds take place according to instructions that regulates which rooms are to be rounded and what controls that should be done. If there are any anomalies discovered during the rounds, they are reported and rectified.

Special fire safety rounds are also carried out in the facility with a frequency so that all rooms have been inspected over the course of a year. In addition, occupational safety rounds are carried out at the facility which, among other things, look at fire load.

There are also regular occupational safety rounds in which the fire protection coordinator participates.

The safety culture at the plant is good, which means that the employees are observant of shortcomings and risks and report them in the system.

3.5.1.3 C: Licensee's experience of the implementation of the fire prevention

It is important to create a strong safety culture and a simple and user-friendly risk management system to make it easy to report defects and risks. It is also important that there are sufficient resources to inspect the facility frequently enough.

Since there are no hot systems in the facility the largest risk for fires at the facility is hot work. It is important to have several persons who have delegated permission responsibility to be able to carry out risk assessments of these works.

At Clab, there are dedicated staff responsible for permits for hot work. A forum is planned for those responsible for permit hot work. Those meetings are planned to be realized twice a year. During the meetings, for example, new rules, problems that arise, etc. will be handled.

3.5.1.3.1 C: Overview of strengths and weaknesses

The willingness to report is high; deficiencies are detected quickly and can be remedied. The rescue services are in the area and quickly arrives at the facility in the event of a fire. They also participate in exercises.

The fire systems require continuous maintenance and service. The fire alarm system has been upgraded to a new system during the period 2020-2021.

SKB have plans to assign more resources to further develop fire protection work.

3.5.1.3.2 C: Lessons learned from events, reviews fire safety related missions, etc.

SKB has experience from insurance inspections, supervision of the rescue service and WANO peer reviews. Discussions and recommendations result in improvement work at the facility.

For example, after the WANO peer review in 2013, SKB introduced indicators for fire protection that are measured every six months. SKB also developed fire protection cards placed on the outside of doors to rooms with important equipment. The cards indicate the fire load permitted in the room and the risks. SKB has also reduced the overall fire load in the facility.

After an insurance inspection, fire separation walls were introduced between transformers.

There has never been a fire at the facility.

3.5.1.3.3 C: Overview of actions and implementation status

Work is ongoing to produce rescue cards for the facility's rooms together with the fire brigade. Today there are 5 rescue cards produced. The purpose of the cards is to help the rescue service during an operation.

A fire protection program is developed at the facility with a number of improvements.

The following measures are now being prepared to be introduced at the facility:

- improve the fire ventilation in the fuel elevator compartment.
- installation of extinguishing systems in the storage buildings.
- installation of two new backup power diesels redundant through fire separation in two different fire cells.
- introduce fire separation of all incoming cables
- installation of new independent cooling system that cools with air that will give us a stronger reliability and durability of the cooling of the storage basins.

3.5.2 C: Regulator's assessment of the fire prevention

Requirements for fire prevention has historically been regulated by other authorities than SSM, see section 1.2.1. These requirements are generic for industrial buildings and not specific for nuclear power plants.

SSM do not have any specific requirements on fire prevention as shown in section 1.2.1 for other nuclear facilities. As such, there have not been any SSM-inspections and no formal lessons learned with regards to the fire prevention programs for the licensees.

3.5.2.1 C: Overview of strengths and weaknesses in the fire prevention

SKB has an active fire prevention program at Clab that ensures that the fire loads are as low as reasonably achievable and lowers the probability of a fire occurring. This include routines to manage and control fire load and ignition sources at the plant as well as that personnel have the prerequisites to be able to identify and act on deviations in the fire prevention and in the event of fire. As a part of the systematic fire protection work, regular inspections are performed in the facility to ensure proper control of fire load and ignition sources. In case of hot work, specific training and a work specific permit is required.

There are several national and international forums where the licensees and regulator share information and experiences from events. One forum is Norderf, which provides the Nordic nuclear power plants with external experience from the nuclear industry in the world. Another is the NEA project OECD-FIRE, that have collected information from over 500 events that have occurred at NPP:s.

FKA, RAB, OKG, SSM and SKB are members in NBSG. The overall focus with NBSG is to create increased knowledge in the field of fire safety at nuclear facilities and increased knowledge in the field of reactor safety-related fire safety. The group's work will lead to synergies in the field of fire safety by jointly funding research, testing and dissemination of information.

3.5.2.2 C: Lessons learned from inspection and assessment on the fire prevention as part of its regulatory oversight

SSM:s main conclusion is that the fire preventing programs relies on everyone that enters a nuclear facility does their part to reduce the risk of a fire occurring and spreading. This is done by ensuring a limitation of combustible materials and lower the risk for ignition. One lesson learned is that this is of importance when spent fuel arrives to Clab and is handled before it is moved to the spent fuel pool, this is done by inspections by the licensee.

3.5.3 C: Active fire protection

3.5.3.1 C: Fire detection and alarm provisions

3.5.3.1.1 C: Design approach

The fire alarm detects and presents fire events and status and sends an alarm to the central control room. It also provides an automatic alarm to the rescue force. The fire alarms system signals connected ventilation- gas extinguishing- and sprinkler systems. The system also provides signals to automatically close doors to contain the fire.

In the event of a fire alarm in the personal staff building, an optical/acoustic alarm starts where the fire is detected. In all other parts of the facility the fire alarm goes to the control room and the control room staff order evacuation by the speaker system.

In the event of internal errors in the system, an error alarm is given in the central control room.

3.5.3.1.2 C: Types, main characteristics and performance expectations

The system complies with the regulation from the Swedish Fire Protection Association (SBF110).

The fire alarm system is made up of three units that communicate in a so-called delta connection. The three units have six fire alarm centres, a PLC control system and a presentation unit. Four detector loops are connected to each of the six fire alarm centres.

The main fire alarm system consists of six central devices, five with associated service units and one without. The operator obtains in the event of a fire in the main fire alarm system, information on the operating unit about alarming detector, room, fire cell, if there are several alarms and a reference to disturbance instructions. Additional information can be obtained via the control panel, for example the status of the fire detectors, disconnections of detectors and alarm outputs. There is also a possibility to test the status of the fire alarm centre.

The wiring network of the fire alarm systems consists of loop cables. The loop wires connect the detectors (measuring stations) in a loop with the central units.

The fire alarm has comprehensive detection. The fire alarm system uses combi detectors, heat detectors and there are also some rooms with sampling detectors. Combi detectors contain both an optical smoke detector part and a heat detector part. Choice of detector type is based on which type is suitable in respective part of the facility. Via the presentation unit or operating units at fire alarm centres can the smoke detection can be disabled, maintaining heat detection, or the entire detector can be disabled. In the main fire alarm system there is also a zener barrier, to the detectors in the gas storage, as well as a loop repeater placed in the tunnel. The repeater is used to compensate for length of the cable in the tunnel. In the other fire alarm centres, smoke detectors of the optical type are used, but also heat detectors are present.

The operator's attention is called in the event of a fire alarm or fault in the system by an acoustic signal in the control room and the control equipment (system 506) receives information about the triggered fire alarm or disturbance in the fire alarm system. The operator receives further information via the presentation unit such as information of the fire cell, room description, attack path, radiation classes etc.

In presentation unit fixed and temporary disconnections of individual or groups of detectors are created. These are activated manually or with time control.

In the presentation unit it is also possible to retrieve event logs on detectors, sprinkler valves and events.

The system monitors itself for errors in the system. Communication between fire alarm, presentation units and control systems are also monitored.

The fire alarm centrals are fed from the battery-backed 230V AC mains and are not affected by external grid failure. The control system is powered from the battery-backed direct voltage network and is not affected by external grid failure. The system's equipment in building (L) is powered with uninterrupted and interference-free power and is not affected by external power outages. Some of the system's objects such as fire alarm control panels, aspirating detectors, the zener barrier and the loop repeater in the tunnel have their own battery back-up in case of failure of external network must supply these with power for at least 24 hours.

The presentation system's server is powered from a UPS and becomes independent of external power failure. Information on the status of the system can be found in the fire alarm centres and the status of the control system is indicated on LEDs in the KME 105 and in the presentation system.

3.5.3.1.3 C: Alternative/temporary provisions

Before work start is allowed in the system, analysis of work is undertaken, PJB (Pre Job Briefing) and the rescue service is contacted when necessary and action is discussed.

Compensatory measures are regulated in instructions and requirements in "Operational limit and condition" (OLC).

3.5.3.2 C: Fire suppression provisions

3.5.3.2.1 C: Design approach

For fire extinguishing there are fire water systems, water sprinkler systems and gas extinguishing systems at the facility. The fire water for the facility is supplied from Oskarshamn's nuclear power plant. The system is placed in the ground as a ring line for feeding all fire hydrants indoors and outdoors and the water sprinkler systems.

Water sprinklers are located in cable floors, cable culverts, shafts, transport locks, garbage container spaces and in an escape route in the auxiliary system building. The system shall constrain a fire in those parts of the facility.

The gas extinguishing systems task is to limit the consequences of a fire in the computer hall which is the only one with a gas extinguishing system.

3.5.3.2.2 C: Types, main characteristics and performance expectations

Fire water system

The system must have a water flow of totally 58 kg/s and a pressure of 0,88-1,0 Mpa. The water supply must be at least 1200 m^3. The system is filled with water and pressurized up to the fire hydrants valves.

Fire hydrants in the above-ground part, with the exception of the garage building, are equipped with an extra outlet for the rescue service's equipment at each fire hydrant.

The fire hydrant on the roof of the reception building is not normally pressurized, but can be pressurized by opening a valve. The fire hydrant is equipped with a normal connection for the rescue service hose.

The outdoor fire hydrants are located at the outer ring pipe, which is equipped with sectioning valves. Indoor fire hydrants are generally located near stairwells.

Water sprinkler system
The system is designed for a water denseness of 5 mm/min. The largest sprinkler section water flow is 40 kg/s.

When a fire alarm is triggered, the system comes into operation and sprinkles for 3 minutes. Additional sprinkling can be initiated manually from the operation centre, sprinkling centre or from the attack path. In the transport lock the system is manually initiated when it is a fire in the transport vehicle or other vehicles that temporarily is located in the room.

The system is designed as a dry pipe system, which means that the pipes after the sprinkler valves within cable floors, culverts and shafts are not normally filled with water. The sprinkler nozzles are of an open construction.

Gas extinguishing systems
The extinguishing system consists of a central unit, two high-pressure cylinders and piping system. Detection takes place from an aspirating smoke detector in the fire alarm system and at a predetermined level of this detector, the extinguishing system comes into operation and opens valves on the gas cylinders.

Two pipe systems with nozzles are connected to each gas cylinder and serve rooms and hidden spaces under the installation floor.

Detection of smoke takes place in 2 levels from the fire alarm system. Level 1 triggers fire alarms only. In case of stronger smoke development, level 2 is activated, which triggers the extinguishing system. The system has a 10 second built-in time delay after level 2 is triggered.

3.5.3.2.3 C: Management of harmful effects and consequential hazards
An extinguishing water investigation has been carried out at the facility and measures will be implemented to take care of extinguishing water.

3.5.3.2.4 C: Alternative/temporary provisions
Before work starts in the systems an analysis of work is undertaken, PJB (Pre Job Briefing) and the rescue service is contacted when necessary and an action is discussed.

Compensation measures are regulated in instructions and requirements in “Operational limit and condition” (OLC).

3.5.3.3 C: Administrative and organisational fire protection issues

Fire protection checks and measures are controlled by using a maintenance system (GDU) and working permits. All work that affects fire protection requires a permission given by the fire protection coordinator.

The fire protection coordinator at the facility does the fire technical assessment of the work that is planned at the facility. At the daily operation meeting all work, ongoing and planned, is discussed.

3.5.3.3.1 C: Overview of firefighting strategies, administrative arrangements and assurance

All personnel participate in regular firefighting exercises. The staff in the control room is trained to guide the rescue service in the facility during a dispatch.

Seven exercises for the control room staff and rescue service are performed yearly. The training and exercises are based on 3 years rolling program (the first year is dedicated to training and years 2 and 3 are dedicated to drills).

The rescue service is trained in knowledge of the facility 8 times yearly. Work is ongoing to produce rescue cards for the facility's rooms. Today there are 5 rescue cards produced. The purpose of the cards is to help the rescue service during an operation.

Printouts can be produced from the fire alarm computer where you can see the layout and risks etc.

The fire protection coordinator at the facility holds regular operational meetings to discuss fire protection with the rescue services.

The facility is insured via Nordic Nuclear Insurance (NNI). NNI carries out regular inspections (every three years) where they make recommendations for improvements in the area of fire protection.

3.5.3.3.2 C: Firefighting capabilities, responsibilities, organisation and documentation on-site and offsite

There is always a rescue team in service in the area. They remain on the plant for first intervention (station at ~800 m distance). If this force is out on other missions in the area, a replacement force will enter. This take maximum 30 minutes. Availability of a "general-purpose" fire-truck, a truck for foam extinguishing and a jeep for general purposes. First firefighting attempts relies on this crew plus the aid of the plant personnel.

3.5.3.3.3 C: Specific provisions, e.g. loss of access

The fire water supply comes from OKG, which has both diesel-powered and electric-powered pumps. There are two ring lines from OKG. There is diesel powered backup power at Clab that powers equipment needed to go to safe mode. The fire alarm control panels have a battery backup for 48 hours.

3.5.4 C: Passive fire protection

3.5.4.1 C: Prevention of fire spreading (barriers)

To prevent the spread of fire, the facility is divided into fire cells.

The integrity of the fire cells must always be maintained, which they are considered to be, if the fire technical class in separating building constructions is intact, no openings between fire cells occur. Doors, gates and hatches are closed except when passing. If any of these requirements is not met, compensatory measures are introduced.

3.5.4.1.1 C: Design approach

The fire cell division is made with regard to the type of functions that is conducted in respective room.

The classification of the fire cell boundaries depends on what type of building part it is. Rooms with important equipment have a higher fire protection class.

3.5.4.1.2 C: Description of fire compartments and/or cells design and key features

Building parts separating fire cells are made in fire technical class EI60 or A60.

The two storage buildings have different fire classes on fire separating parts. The older storage building, Clab 1, has class A60 while the new one, Clab 2, has class EI60. This is because the classification has been changed since the first storage building was constructed.

Storage buildings 1 and 2 form the same fire cell, but are divided into two fire gas cells. The fire gas cells are separated from each other with building parts in class E60.

The transport tunnel forms its own fire cell. Separating construction between the tunnels and the storage buildings are made in fire-technical class A60.

Fire seals is carried out in the same class as the rest of the construction.

Doors, gates or hatches in the fire cell boundary are made in class EI60-C. As the fire load in the plant usually has a maximum of 60 MJ/m^2, class A 60 is accepted in some cases as doors to stairwells, gates to transport tunnels and hatches to rock crevices.

Ventilation ducts are laid out and designed so that in case of a fire they do not give rise to ignition of nearby building parts and fixed furnishings outside the fire cell in which they are placed in, for the time specified by the fire cell requirement.

Air treatment installations that are located in common areas and that supply different fire cells are designed so that the fire separation ability between the fire cells is maintained. Air treatment installations passing through fire-separating building elements are designed so that the fire separation ability is maintained.

3.5.4.1.3 C: Performance assurance through lifetime

Clab has an aging program where system analyses are performed. The purpose of the analyses is to, in a structured way, collect facts about a part of the facility, process the facts and make a qualified assessment of the status of the current system from a 1, 5, 10 and 20-year perspective. With emphasis on 1 and 5 years.

Analysis and proposals for measures must:

- Result in maintained security, availability and competence for the facility's important parts.

- Provide input to plan short and long-term measures so that these can be implemented in the form of changes, modernizations, exchanges, etc. and if possible synchronize these with ongoing and planned projects or facility modifications.

The process includes systematically:

- Analyse the equipment with regard to function, mode of operation and management from a broad perspective.
- Provide support for the facility's strategic planning process. That is, proposals for facility modifications and modifications.
- Submit documents to the line managers to manage the need for competence, spare parts, maintenance changes, tests, inspections, etc.
- Evaluate the impact of the aging program by analysing the results of measures introduced through aging management analysis.
- Analyse the system with regard to technological aging. With technological aging means that the equipment in question can still function, but that it cannot be maintained, as spare parts, tools or expertise no longer is available.
- Consider the long-term nuclear safety of the systems that must act as a final repository and it´s barriers.

The work is a continuous process carried out every five years. Assessment of, for example, needs, access and changes regarding competence, spare parts and documentation must therefore primarily be done over a future period of five years. In addition, an assessment must be made of measures that can be required during the remaining operating time, as well as a rough estimate of when in the time these measures need to be implemented.

3.5.4.2 C: Ventilation systems

3.5.4.2.1 C: Ventilation system design: segregation and isolation provisions (as applicable)

The ventilation system is equipped with fire dampers in the fire cell boundaries to limit the spread of fire within the facility. This by automatically isolating fire cells in the event of a fire. The function of the fire damper is tested every 48 hours by the fire alarm system.

The system also contains fire ventilation fans with associated dampers for overpressure maintenance of certain stairwells and elevators from the storage buildings for evacuation, as well as smoke ventilators.

The facility is also equipped with smoke hatches for fire gas evacuation.

3.5.4.2.2 C: Performance and management requirements under fire conditions

In the event of a fire in the facility, the fire dampers are automatically closed in the fire cell where the fire was detected.

In some rooms, the fire gas ventilation starts automatically and, in some rooms, it is started manually. In the stairwells and escape routes, the fire gas ventilation always starts automatically.

There are also a number of flue gas hatches in the facility. These are opened manually but have melting sheets that cause the hatches to open when a certain temperature occurs.

3.5.5 C: Licensee's experience of the implementation of the fire protection concept

The fire protection at Clab is at a satisfactory level. It is important to continue to document and report risks and errors as well as continue developing fire protection. This includes working further with the aging program to have control over when systems need to be replaced. An ongoing development and upgrade regarding separation and redundancy/separation that will further enhance fire safety.

The risk profile of the facility can be considered lower than that of a nuclear power plant with regard to the fact that nuclear material is always in a subcritical state and that pressures and temperatures in the process systems are low.

SKB has gained some experience from completed exercises. For example, the availability of fire hoses has been too poor in the tunnel and the audibility of evacuation alarms have been poor in some places.

It is important to have a good reporting system so that deficiencies are identified and can be remedied. It is also important to have structured development work.

Clab has first responders on site which lowers the response time. They also have appropriate knowledge of the facility and guidelines on how to handle different kinds of fires that can arise. They are aided by the off-site fire brigade.

3.5.6 C: Regulator's assessment of the fire protection concept and conclusions

SKB has a fire protection concept including fire prevention, fire detection and fire limitation and extinguishing. The fire protection measures include fire compartments, fire alarms, automatic and manually actuated fire protection systems as well as the professional fire brigades.

By division into fire compartments it is secured that a maximum of one redundant part of a system important to safety. In those cases when redundant parts of a safety system are placed in the same fire compartment, these are protected by room separation, distance separation, barriers and/or sprinkling. It is also important to recognize that it takes considerable time to heat up and boil off water in the Clab storage pools, i.e. before the spent fuel can be damaged and release radioactivity. This time window is available to extinguish a fire and repair or replace the affected components.

Daily control rounds include, among other things, checks of fire loads. Special fire safety rounds are planned so that all rooms are inspected over the course of a year. Clab experience is that a strong safety culture together with ease of reporting on defects and risk is important. Clab describes that the largest risk for fires is hot work and clarifies that it is important with dedicated staff responsible for such works. Clab has a special forum for these persons for experience exchange etc.

Regarding strengths, Clab reports that willingness to report is high; deficiencies are detected quickly and can be remedied. The rescue services are in the area and quickly arrives at the facility in the event of a fire. They also participate in exercises. Further, the fire alarm system has been upgraded to a new system during the period 2020-2021.

An improvement area is more resources and the Clab report mentions that SKB have plans to assign more resources to further develop fire protection work.

Following the results of the FHA, see also chapter 2.4.5.1, vulnerabilities of the plant configuration has been identified and actions to improve the fire protection. These includes repositioning of redundant components and installation of heat radiation protection between in the cooling system. These improvements have increased Clab:s ability to withstand a fire.

Clab has a professional fire brigade on site which lower the response time compared to an off-site fire brigade and ensures that the firefighters have appropriate knowledge of the facility and guidelines on how to handle different kinds of fires that can arise. The fire brigades and other staff are trained to extinguish the fires that may occur at Clab. The first responding off-site brigade is also trained in the same for a fire occurring at Clab, as they are a part of the same municipal fire brigade.

Certain failures of the fire protection system as well as fires that affect components important to safety are reported to SSM as licensee event reports as they are included in the OLC. All these events are reviewed and assessed by SSM. SSM finds that the fire protections concept is adequate.

Clab does also share experiences with others with regards to fire protection to spread and gain knowledge, see 3.5.2.1.

SKB has experience from insurance inspections, supervision of the rescue service and WANO peer reviews. Discussions and recommendations result in improvement work at the facility. After the WANO peer review in 2013, SKB introduced indicators for fire protection that are measured every six months. SKB also developed fire protection cards placed on the outside of doors to rooms with important equipment. The cards indicate the fire load permitted in the room and the risks. SKB has also reduced the overall fire load in the facility. After an insurance inspection, fire separation walls were introduced between transformers.

SSM oversight activities regarding fire are limited. SSM follows fire protection works via participation in the National Fire safety Forum (NBSG) where the reactor licensees and SKB share experiences and initiate small R&D efforts focusing on practical fire protection issues.

In addition to the strengths mentioned by Clab, SSM also want to mention the National Fire Safety Forum (NBSG) where the reactor licensees, SKB and SSM are members. NBSG overall focus is to create increased knowledge in the field of fire safety at nuclear facilities and increased knowledge in the field of reactor safety-related fire safety.
The adherence to fire requirements are checked mainly by not only SSM, but maybe more by other authorities and insurance companies. This contributes to a solid fire protection concept.

Observations and recommendations originating from internal analysis and checks as well as checks by external organisations have led to many improvements in fire protection, and is an ongoing effort.

3.5.7 C: Conclusions on the adequacy of the fire protection concept and its implementation

SSM concludes that Clab has an adequate fire protection concept implemented.

4 Overall assessment and general conclusions

Regulators assessment and conclusions on fire protection concepts

Overall assessment and general conclusions for NPP:s
As a consequence of the requirements issued in 2004 (SKIFS 2004:2)[13] the licensees had to re-examine their existing fire protection and revise their initial SAR fire analyses. The resulting design changes lead to major safety enhancements, especially for the six oldest reactors that have stopped operation and are currently under dismantling and decommissioning. All NPP licensees have performed FHA but the scope and approaches differ somewhat. Forsmark 2 and Ringhals 3 have chosen the approach to use their PSA models to verify that the reactors can be brought to a safe state following a fire. The PSA models include detailed mapping of plant cable routing for example, which ensures that potential dependencies can be accounted for. The FHA methodologies are similar for Forsmark 2 and Ringhals 3, with some differences in basic analysis assumptions. In the Forsmark 2 FHA the fire compartments are divided into fire cells based on a number of criteria defined specifically for analysis purposes, while the Ringhals 3 FHA is based on fire compartments. For cases where redundant trains can be affected by a fire, Ringhals 3 has verified that distance separation or equipment fire protection is sufficient. Neither Forsmark 2 nor Ringhals 3 have performed FHA for refuelling outage. The Oskarshamn 3 FHA covers both power operation and refuelling outage, with the assumptions for refuelling outages being less conservative.

When revising the initial SAR fire analyses some weaknesses revealed mainly for the older designs, such as redundant safety-related equipment placed in the same fire compartment, resulted for example in plant modifications to protect this equipment through distance separation. Due to the original design, or conflicts between fire protection requirements and other requirements, separation was not always possible to achieve. This was typically managed by introducing fire extinguishing equipment or by additional administrative procedures. Especially the oldest, now closed, Swedish NPP:s underwent extensive modernization programs which included measures for fire issues. NPPs of more recent design, such as Oskarshamn 3, were proven less sensitive to fires due to the high degree of redundancy and physical separation in their basic design.

SSM:s reviews of the revised FHA:s were mainly focused on the NPP:s of older design as well. FHA reviews for Forsmark 2 (SSM2014-6031-8) (SSM2018-916-3) (SSM2021-475-8) and Ringhals 3 (SSM2016-5327-6) (SSM2020-7843-7) were hence more detailed than for Oskarshamn 3 (SSM2016-1192-4). There are still some remaining issues related to certain basic analysis assumptions, to acceptance criteria used, and to analyses and documentation of fire during refuelling outages that will need to be handled by SSM.

All NPP licensees have also performed fire PSA (level 1 and 2) and the methodologies used differ for these as well. Both Forsmark 2 and Ringhals 3 have analysed fires as initiating events and presents an overall CDF and release frequency for all fires. OKG has performed a simplified type of assessment for Oskarshamn 3 where the total fire initiating

[13] Superseded by SSMFS 2008:17 following the formation of the Swedish Radiation Safety Authority, and since then included in new regulations for nuclear power plants in force from 1st march 2022, with interim provisions for existing facilities.

event frequency has been estimated and then evenly distributed between the fire compartments analysed, i.e. the fire compartments that houses system and components credited in the PSA model. OKG claims that estimated CDF for fire during power operation (including transition between cold shutdown reactor and power operation) does not exceed 10^{-7} per year and that it thereby can be neglected in comparison with the result of the overall PSA study.

SSM has not reviewed the fire PSA:s in detail for any of the NPP licensees in recent years. Conclusions from PSA reviews on a general level for FKA (SSM2021-2041-12) (SSM2022-4627-10) and RAB (SSM2022-6289-12) are that the PSA:s are full scope and are being kept up to date. The review of the OKG area event methodology (SSM2013-541-16) resulted in a number of remarks that have not yet been resolved. SSM can also conclude that the statement that contribution from fire events can be neglected in comparison with the result of the overall PSA study could be questioned. In recent years the CDF presented has decreased significantly due to plant modifications and less conservative assumptions.

SSM concludes that all NPP licensees handle the fire prevention and fire protection in similar ways. The physical separation of redundant trains of systems in fire compartments and the arrangements of fire cells in fire compartments are essential for the fire protection. This is fully developed in Oskarshamn 3 with four trains but also well performed at both Forsmark 2 and Ringhals 3 with less strict separation.

All NPP:s work actively with fire prevention and fire protection. Workers on site must complete a fire safety training course to be allowed access. The fire prevention programs include for example hot work management, and ignition source and fire load control. As part of the systematic fire protection work, plant personnel perform walk-downs on a regular basis to verify actual fire loads and presence of ignition sources. SSM inspections of the licensee's housekeeping practices generally shows good compliance with requirements.

The active fire protection concept includes detection and alarm, active fire suppression and manual firefighting. Fire protection has historically been regulated and inspected by other authorities than SSM. Furthermore, insurance companies have made recommendations for improvement in fire protection. SSM considers as a strength that all NPP:s have professional fire brigades on site as this results in shorter response times compared to relying on off-site fire brigades only. Firefighters stationed on site will also gain valuable knowledge about the facility and how to handle the different kinds of fires that may arise. The extensive sharing of experiences and insights related to fire safety between licensees, e.g. in NBSG is considered a good practice.

In conclusion, the result of the assessment in this report is that SSM considers the fire protection concepts at the Swedish NPP:s to be adequate. All licensees have performed FHA, with partly different methods adapted to their designs, demonstrating that fires will not prevent safety functions and barriers from bringing and maintaining the reactors in safe shutdown conditions. The remaining issues resulting from regulatory oversight performed are mainly to be seen as areas for improvement and will be followed-up in coming oversight activities. For fire-PSA:s there are some issues that need to be addressed further, given the large decrease in overall PSA level 1 and PSA level 2 results (Core damage frequency and radioactive release frequencies) presented in recent years, mainly as a result of the introduction of the Independent Core Cooling System required by SSM in the aftermath of Fukushima.

Regarding fire protection relating to the three lines of defence, prevention - detection – contain / extinguish, the result of the assessment is that all Swedish NPPs have an adequate fire defence in place.

Overall assessment and general conclusions for Westinghouse fuel factory
SSM assesses that the radiological consequence to the public in case of a fire in the nuclear fuel fabrication facility is limited. As such, SSM has not performed specific reviews on the FHA in recent years.

Westinghouse works in similar ways as the NPP:s with fire prevention and fire protection. Workers who will perform tasks on site must complete a fire safety training course to be allowed access. The fire prevention programs include for example hot work management, and ignition source and fire load control. As part of the systematic fire protection work, plant personnel perform walk downs on a regular basis to verify actual fire load and presence of ignition sources.

The active fire protection concept includes detection and alarm, active fire suppression and manual firefighting. Fire protection has historically been regulated and inspected by other authorities than SSM. Also insurance companies have made recommendations for improvement in fire protection. The municipal fire brigade is trained specifically for fires at Westinghouse.

SSM:s overall assessment is that the FHA performed by Westinghouse shows the associated risk with a fire in the fuel factory and its potential consequences to the public, is acceptable. Regarding fire prevention and fire protection, SSM emphasizes the importance of sharing experiences with other similar facilities.

The regulations for nuclear facilities such as the Westinghouse fuel factory are currently being updated. Once finalized, further oversight activities will be implemented to ensure compliance with requirements for fire analysis.

Overall assessment and general conclusions for Clab
The Swedish Nuclear Inspectorate's regulations and general advice (SKIFS 2004:1)[14] concerning the design and construction of Nuclear Power Reactors included new requirements compared to those applicable when the Swedish reactors were designed and commissioned. The new requirements were intended to develop and maintain safety in the plant design. These requirements were applied in an adapted fashion to nuclear facilities in general when SKB applied to expand Clab with an encapsulation plant for spent nuclear fuel. Therefore SKB had to re-examine their existing fire protection and revise their original fire analysis for Clab.

In reviewing the analyses, SSM concluded that SKB demonstrated a sufficiently robust design with extensive time available for performing corrective actions in case of a fire in Clab. Observed weaknesses includes that systems and components important to safety are not fully separated. SKB has improved the separation of components important to safety in recent years, but due to characteristics of the original design, or conflicts between fire protection requirements and other requirements, full separation was not always possible

[14] Superseded by SSMFS 2008:1 following the formation of the Swedish Radiation Safety Authority

to achieve. This was typically managed by introducing fire extinguishing equipment and by additional administrative procedures.

SKB works in a similar way as the NPP:s with fire prevention and fire protection. Workers who will perform tasks on site must complete a fire safety training course to be allowed access. The fire prevention programs include for example hot work management, and ignition source and fire load control. As part of the systematic fire protection work, plant personnel perform walk downs on a regular basis to verify actual fire loads and presence of ignition sources.

The active fire protection concept includes detection and alarm, active fire suppression and manual firefighting. Fire protection has historically been regulated and inspected by other authorities than SSM. Also insurance companies have made recommendations for improvement in fire protection. SSM considers as a strength that SKB has on site access to a professional fire brigade trained specifically for Clab (shared with OKG) as this results in shorter response times compared to relying on off-site fire brigades only. Firefighters stationed on site will also gain valuable knowledge about the facility and how to handle different kinds of fires that may arise as part of their daily work.

The extensive sharing of experiences and insights related to fire safety between licensees for NPP and SKB in different national and international forums is also considered good practice.

The regulations regarding nuclear facilities such as Clab are currently being updated. Once finalized, it further oversight activities will be implemented to ensure compliance with requirements for fire analysis.

5 References

[1] SSM2022-1269-36 FKA response on WENRA Topical Peer Review 2023 – Fire. FKA report F-0192500, 2023-09-22.

[2] SSM2022-1269-32 Response on WENRA Topical Peer Review 2023-Fire Protection, OKG 2022-12788 rev 2, 2023-09-05

[3] SSM2022-1269-33 RAB TPR Fire report, 2023-09-05

[4] SSM2022-1269-35 WENRA Topical Peer Review Fire Protection - NAR Clab, SKB 2003340, 2023-09-14

[5] SSM2022-1269-36 Westinghouse TPR-II NAR, 2023-09-19

6 Acronyms and Abbreviations

ANS	American National Standard
ANSI	American National Standards Institute
AUC	Ammonium uranium carbonate
BBR	The National Board of Housing, Building and Planning
BBRAD	The National Board of Housing, Building and Planning Rules on the bearing capacity of buildings in the event of fire
BBRBE	The National Board of Housing, Building and Planning general advice on fire load
BLC	Fire Alarm Center (Swedish: Brandlarmcentral)
BRAK	Fire safety inspections at OKG
BWR	Boiling Water Reactor
CAP and ARC	Westinghouse systems for continuous improvement
CCF	Common Cause Failure
CDF	Core Damage Frequency
CFAST	Software for fire analysis
CFD	Computational fluid dynamics
CFPA	Confederation of Fire Protection Associations (Europe)
CFR	Code of Federal Regulations
CGT	Combustion Gas Turbine
Clab	Central Interim Storage for Spent Fuel (Swedish: Centralt lager för an-vänt kärnbränsle)
CRD	Control Rod Drive
DBA	Design Basis Accident
DEC	Design Extension Condition
DFA	The Delegation for Atomic Energy Affairs (Swedish: Delegationen för Atomenergifrågor)
DiD	Defence-in-Depth
EDG	Emergency Diesel Generator
EKS	European construction standards
ELAP	Extended loss of AC power
ENSREG	European Nuclear Safety Regulators Group
FCV	Filtered Containment Venting
FDS	Fire Dynamics Simulator
FHA	Fire Hazard Analysis
FKA	Forsmark Kraftgrupp AB
IAEA	International Atomic Energy Agency
ICCS	Independent Core Cooling System
KSU	Nuclear Training and Safety Centre (Swedish: Kärnkraftsäkerhet och ut-bildning)
LCO	Limiting condition for Operation
LED	Light emitting diode
LER	Licensee Event Report
LONF	Loss of normal feed water
LOOP	Loss of Offsite Power
LPG	Liquid Propane Gas
MCR	Main Control Room
MSB	Swedish Civil Contingencies Agency (Swedish: Myndigheten för Sam-hällsskydd och Beredskap)
NAR	National Assessment Report

NBSG	National fire safety Forum (Swedish: Nationella BrandSäkerhetsGrup-pen)
NEA	Nuclear Energy Agency
NEI	Nuclear Energy Institute
NFPA	National Fire Protection Agency (US)
NNI	Nordic Nuclear Insurance
NOG	Nordic Owners Group
NordErf	Nordic organisation for exchange of information and experience of events of importance for nuclear safety
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
NSD	Nuclear Safety Directive
NSSS	Nuclear Steam Supply System
OECD	Organisation for Economic Co-operation and Development
OECD/FIRE	OECD/NEA Fire Database project
OEM	Original equipment manufacturer
OKG	OKG AB
OLC	Operational limits and conditions
OSART	Operational Safety Review Team (IAEA service)
PIE	Postulated Initiating Event
PJB	Pree Job Briefing
PLC	Programmable logic controller
PRA	Probabilistic Risk Assessment (used interchangeably with PSA)
PS	Presentation system
PSA	Probabilistic Safety Assessment (used interchangeably with PRA)
PSR	Periodic Safety Review
PWR	Pressurised Water Reactor
RAB	Ringhals AB
RCP	Reactor coolant pump
RCS	Reactor Coolant System
RHWG	Reactor Harmonisation Working Group (WENRA)
RIS	Rescue on call information support officer
RPS	Reactor Protection System
RPV	Reactor Pressure Vessel
Rw/B	Radwaste Building
SAR	Safety Analysis Report
SEWS	Screening Evaluation Work Sheet
SFP	Spent Fuel Pool
SFP	Systematic Fire Protection
SFR	SKB repository for low- and intermediate-level short-lived radioactive waste
SKB	Swedish Nuclear Fuel and Waste Management Company (Swedish: Svensk Kärnbränslehantering AB)
SKI	The Swedish Nuclear Safety Inspectorate (Swedish: Statens Kärnkraftin-spektion, predecessor to SSM until 2008)
SLA	Service Level Agreement
SMA	Seismic Margin Assessment
SRL	Safety Reference Level
SSC	Structures, Systems and Components
SSM	Swedish Radiation Safety Authority (Swedish: Strålsäkerhetsmyn-digheten)

SSMFS	SSM Regulations
SSR	Specific Safety Requirement
TMI	Three Mile Island
TPR	Topical Peer Review
TS	Technical Specifications
TVO	Teollisuuden Voima Oyj (operator of Olkiluoto NPP; Finland)
UPS	Uninterruptible power supply
WANO	World Association for Nuclear Operators
WANO AFI	WANO Area for Improvement
WENRA	Western Europe Nuclear Regulators Association
WSE	Westinghouse Electric Sweden AB
WWER	water-water energetic reactor (from Russian)

The Swedish Radiation Safety Authority (SSM) works proactively and preventively with nuclear safety, radiation protection, nuclear security, and nuclear non-proliferation to protect people and the environment from the harmful effects of radiation, now and in the future.

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