

Report

Topical Peer Review

2023

Fire Safety

Technical

Specification for the

National Assessment

Reports

RHWG report to WENRA

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Table of Content

Topical Peer Review 2023

Fire Safety

Technical Specification for the

National Assessment Reports

ToC still to do!

00	General requirements	
00.1	Introduction	
00.2	Topic for the review – fire safety	
00.4	Scope of nuclear installations to be covered in the NAR	
00.4	Format and contents of the NAR	
00.5	Glossary	
01	General information	14
01.1	Nuclear installations identification	
01.2	Process to develop the NAR	
01.3	National regulatory framework	
01.4	Safety objectives	
01.5	Defence in depth principles	
02	Experience and research feedback and resulting major modifications	
02.1	Operating experience feedback	
02.2	Maintenance	
02.3	Feedback from fire safety related research	
03	Fire prevention	
03.1	NPPs	
03.2	RRs	
03.3	WDFs	

- 03.4** FCFs
- 04** Active fire protection
 - 04.1** NPPs
 - 04.1.1** Fire detection and alarm
 - 04.1.2** Fire suppression
 - 04.1.3** Administrative and organisational issues
 - 04.2** RRs
 - 04.2.1** Fire detection and alarm
 - 04.2.2** Fire suppression
 - 04.2.3** Administrative and organisational issues
 - 04.3** WDFs
 - 04.3.1** Fire detection and alarm
 - 04.3.2** Fire suppression
 - 04.3.3** Administrative and organisational issues
 - 04.4** FCFs
 - 04.4.1** Fire detection and alarm
 - 04.4.2** Fire suppression
 - 04.4.3** Administrative and organisational issues
- 05** Passive fire protection
 - 05.1** NPPs
 - 05.1.1** Prevention of fire spreading (barriers)
 - 05.1.2** Ventilation systems
 - 04.1.3** Access and escape routes
 - 05.2** RRs
 - 05.2.1** Prevention of fire spreading (barriers)
 - 05.2.2** Ventilation systems
 - 05.3** WDFs
 - 05.3.1** Prevention of fire spreading (barriers)
 - 05.3.2** Ventilation systems
 - 04.3.3** Access and escape routes
 - 05.4** FCFs
 - 05.4.1** Prevention of fire spreading (barriers)
 - 05.4.2** Ventilation systems

00 General requirements

00.1 Introduction

The general introduction has to be finalized after the rest of TS is completed and discussed with ENSREG.

The European Union's Nuclear Safety Directive 2014/87/EURATOM (NSD) requires the member states to undertake topical peer reviews (TPR) every 6 years with the first starting in 2017. For each review the directive requires the following:

- (a) a national assessment is performed, based on a specific topic related to nuclear safety of the relevant nuclear installations on their territory,
- (b) all other member states, and the Commission as observer, are invited to peer review the national assessment referred to in point (a),
- (c) appropriate follow-up measures are taken of relevant findings resulting from the peer review process,
- (d) relevant reports are published on the above mentioned process and its main outcome when results are available.

The member states, acting through the European Nuclear Safety Regulators Group (ENSREG), have decided that the topic for the second topical peer review is fire safety.

The **objectives of the Topical Peer Review (TPR) process**, as agreed by ENSREG, are to:

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

Whilst these objectives were initially established for nuclear power plants (NPPs) specifically, the scope of the TPR has been extended to include research reactors (RRs), waste and decommissioning facilities (WDFs) and fuel cycle facilities (FCFs) and these objectives apply equally to those.

The first stage of the peer review process is the **production of a national assessment report (NAR)** for each country participating in the topical peer review, as required under item (a) above. **This technical specification defines the structure and contents of the NARs to facilitate an effective peer review.** The other stages of the TPR are specified elsewhere (i.e. the Terms of Reference for TPR process).

The objectives of the NAR are to:

- describe the overall fire safety including:
 - o implementation of the overall fire safety programme,
 - o experience regarding fire safety activities,
- assess the outcomes to identify main strengths and weaknesses,
- identify actions to address any significant areas of improvement,
- describe different levels of the graded approach,
- produce a report in sufficient detail to a set format to allow a meaningful peer review.

The format and content of the NAR are further described in Chapter 00.4.

A list of abbreviations used within this specification is included in Annex 2 to this specification.

00.2 Topic for the review – fire safety

Fire safety is among the significant risks for many nuclear installations in Europe. Fires can occur at many locations in an installation and is capable of challenging multiple structures, systems and components (SSCs) simultaneously and affect signalling and power supply of multiple systems, being a possible cause of common cause failures. In addition to being an independent event itself, fire can be induced by other hazards or events. It can also itself induce internal hazards such as flooding as a result of the actuation of the fire protection system. Finally, fire is a very real hazard for which insights can be captured by actual fire incidents at nuclear reactors.

None of the previous evaluations and benchmarks initiated after Fukushima covered fire safety, thus it's a subject that can lead to new insights. The regulations for fire are relative mature, resulting in a good reference for the review. It is also a topic that is relevant for every nuclear installation.

As a technical topic, fire safety has a strong relation to both design but also operation. This means concrete questions and topics for review can be defined. Fire protection systems and measures are also an area where improvements are often reasonably practical, as not always large modifications to buildings are needed.

There are different practices in implementation of fire protection among plants, which gives the opportunity to learn from each other and share experiences. Besides, as fire hazard is relevant in many other sectors besides nuclear, different practices might have developed in different countries resulting from how fire hazards are handled in general.

The main safety benefits expected from the review of fire protection are:

- Increasing confidence in the adequacy and currency of hazard assessments;

- Increasing confidence in the safety of the plants against internal fires is harmonized within WENRA countries as required in the SRLs;
- Contribute to develop consistent approaches of fire protection across Europe;
- Identify whether fire safety can be improved. This specifically relates to the question if the Defence-in-Depth (DiD) concept for fire (prevent, detect, extinguish) is implemented.

00.3 Scope of nuclear installations to be covered in the NAR

1. All installations under the NSD should be considered:
 - nuclear power plants (NPPs),
 - research reactors (RRs)¹,
 - spent fuel storage facilities,
 - storage facilities for radioactive waste that are on the same site and are directly related to the types of nuclear installations listed above,
 - enrichment plants,
 - nuclear fuel fabrication plants,
 - reprocessing plants.
2. All stages in the lifecycle should be considered and the scope should cover facilities under construction, under operation and under decommissioning. More precisely, the scope should include:
 - All nuclear installations that on 31st December 2023:
 - are operating or in a state of “care and maintenance”,
 - are defueled or in the process of being decommissioned where
 - the possibility of fire cannot be disregarded, and
 - any such fire could have the potential to develop into an incident,
 - are under safe enclosure, excepting those from which all non-fixed radioactivity had been removed.
 - All nuclear installations for which construction permissions are granted by 31st December 2023. For these it is expected that fire protection will have been considered in design assumptions. Thus, some detailed parts of this specification would generally not be applicable at the current stage of their lifetime.
3. Facilities that, due to the radiological inventory that could be spread in case of fire, would not potentially create a significant radiological risk to the people and the environment,

¹ In line with the scope of the SRL for existing research reactors published in 2020, all research reactors independent of their type and thermal power with an exception of the critical, sub-critical assemblies, homogeneous zero-power reactors and accelerator driven systems are covered by the term “research reactor”.

should be excluded from the scope. This means for instance that installations at a late stage of decommissioning, when all free radioactivity has been removed, would be out of the scope. This is also the case for waste installations for which the waste product can be regarded as fire-resistant.

00.4 Format and contents of the NAR

For nuclear power plants, WENRA has developed SRLs regarding fire safety, mainly within Issue SV of the SRL document published in 2021, reflecting expected practices to be implemented in the WENRA countries. The relevant SRLs provide a framework for the NAR.

For research reactors, WENRA has developed SRLs regarding fire safety, mainly within Issue S of the SRL document published in 2020, reflecting expected practices to be implemented in the WENRA countries. The WENRA SRLs for research reactors have not yet been implemented in the national regulatory framework, and national action plans will be created based on a gap analysis. Selected SRLs provide a framework for the NAR.

Whereas the above RLs are specifically addressing different types of reactor facilities, WGWD has developed SRL reports for the thematic areas; Storage, Decommissioning, Disposal and Processing. Some/many of these SRLs – except SRLs for disposal are, as appropriate, applicable also for reactor facilities and fuel cycle facilities when it comes to these specific activities as integrated with the overall operation of those facilities.

WENRA has not yet developed SRLs for FCFs. Therefore, there is no equivalent set to the above for the expected practices relating to these facilities. In the absence of WENRA SRLs for FCFs, a selection and interpretation of guidance and practices from other facilities' SRLs and IAEA standards and guides has been developed to provide the framework for the NAR.

The NAR will be produced by the nuclear regulator to the format and content described in this specification with significant input from the licensees.

Each country will prepare its NAR in English.

Attention should be given to types and detail of the information in order to not compromise Nuclear Security issues. The report will be published in the public domain.

The NAR shall not contain specific technical information, which have to be classified as export controlled "Technology" according to Council Regulation for Dual-Use-Goods (EU 428/2009), i.e. manufacturing, developing and use of controlled technology. The processes for licensing of such specific technical information would not be commensurate with the scope of the TPR.

To ensure the NARs can be used for an effective peer review process, the titles and numbering of the main sections of the NARs will be as follows:

1 General information

- 2 Experience and research feedback and resulting modifications in the facilities
- 3 Fire prevention
- 4 Active fire protection
- 5 Passive fire protection
- 6 Fire safety analyses
- 7 Overall assessment and general conclusions
- 8 References

A detailed contents list of the NAR is presented in Annex 1. Each NAR should follow this template.

Annexes can be used to present detailed information if necessary. In addition, a preamble explaining the basis and goals of the NAR and/or an executive summary may be included.

Chapters 01 to 06 of this technical specification describe the contents of the NAR and the sections within each chapter, with the numbering consistent with the list above.

Chapter 01 should describe the national requirements and guidance for fire safety, safety objectives and how the defence in depth principle has been implemented with respect to fire safety in nuclear facilities.

Chapter 02 should describe how experience, including international operating experience relating to fires and research has been taken into account across the facilities in the scope. It is expected that this chapter will include examples of how the fire safety has been enhanced and improved over the last ten years.

Chapters 03 to 06 should provide information on the application of fire prevention, active fire protection, and passive fire protection as well as on fire safety analyses performed for those nuclear facilities in the scope.

An overall assessment and general conclusions are expected in **Chapter 07**.

If a chapter of the report is not applicable to a particular country or to nuclear facilities under scrutiny in the NAR, the NAR will still include the chapter, but just include the statement “not applicable” and a very short explanation.

Each member state shall report on the whole scope of the relevant nuclear facilities in its country. This may include a variety of reactor designs, different generations of designs and plants operated by different licensees. Subsections in Annex 1 provide an overview of how each chapter should be structured. There may be a need to use a further level of sub-sections. These should be structured as follows:

- Issues common to all installations

- Commonalities to all nuclear power plants
 - Further sub-sections grouping plants or licensees at the discretion of the member state, for example:
 - Light water reactors, and/or
 - PWRs, BWRs, PHWRs, other types of reactors, and/or
 - Licensees,
- Commonalities to all research reactors
 - Further sub-sections grouping plants or licensees at the discretion of the member state
- Commonalities to all fuel cycle facilities
 - Further sub-sections grouping plants or licensees at the discretion of the member state
- Commonalities to all waste and decommissioning facilities
 - Further sub-sections grouping plants or licensees at the discretion of the member state

The **level of detail** within the NAR will be:

- consistent with the stage of the lifecycle. In particular for those under construction it will be focused on integration of fire safety into the design,
- related to the safety significance.

00.5 Glossary

A glossary of terms internationally used in the context of nuclear fire safety or of this TPR is provided in this section. The NAR should follow this terminology in order to avoid misinterpretations.

Barrier (from [IAEA Glossary 2018]): A physical obstruction that prevents or inhibits the movement of people, radionuclides or some other phenomenon (e.g., fire), or provides shielding against radiation ().

Conversion Facilities (from [IAEA Glossary 2018]and [IAEA SSG-5]): Facilities used to generate uranium hexafluoride [from uranium concentrate]. Generally, in a conversion facility or an enrichment facility, only natural uranium or LEU that has a ²³⁵U concentration of no more than 6% is processed Typical process routes are outlined in Annex I of [IAEA SSG-5].

Criticality (from [IAEA Glossary 2018]): The state of a nuclear chain reacting medium when the chain reaction is just self-sustaining (or critical), i.e. when the reactivity is zero. Often used, slightly more loosely, to refer to states in which the reactivity is greater than zero). **Criticality accident** (from [IAEA Glossary 2018]): an accidental release of energy as a result of unintentionally producing a criticality in a facility in which fissile material is used. A criticality accident is also possible for fissile material in storage or in transport.

Fire barrier element (from [IAEA SSG-64]): Elements of the fire barrier, e.g., walls, ceilings, floors, doors, dampers, penetration seals.

Explanatory remark: Some elements are purely passive, such as walls, floors, or ceilings. However, elements with active functions, such as fire doors, fire or smoke dampers, etc., are also fire barrier elements.

Fire cell (from [IAEA NS-G-2.1]): Fire cells are separate areas in which redundant items important to safety are located. Since fire cells may not be completely surrounded by fire barriers, spreading of fire between cells should be prevented by other protection measures. These means include the following:

- (a) The limitation of combustible materials,
- (b) The separation of equipment by distance, without intervening combustible materials,
- (c) The provision of local passive qualified fire protection such as fire shields or cable wrap,;
- (d) The provision of fire detection and extinguishing systems.

Fire compartment (from [IAEA SSG-64] and formerly [NS-G-1.7]): A fire compartment is a building or part of a building that is completely surrounded by fire resistant barriers: all walls, the floor and the ceiling. The fire resistance rating of the barriers should be sufficiently high that total combustion of the fire load in the compartment can occur (i.e. total burnout) without breaching the fire barriers. (from [IAEA SSG-64]).

Fire Hazard Analysis (FHA) (from [OECD/NEA FIRE Database] and [IAEA SSG-64]): A analysis to evaluate potential fire hazards and appropriate fire protection means to mitigate the effects of fire in any plant location). According to [IAEA SSG-64], a FHA is a deterministic analysis and needs to formally meet specific requirements provided there.

Fire load (from [OECD/NEA FIRE Database] and [IAEA SSG-64]): The heat of combustion of the combustibles. The fire load [MJ] is calculated as product of mass of combustibles and corresponding calorific value.

Fire prevention (from [OECD/NEA FIRE Database] and description in [IAEA SSG-64]): Preventing the occurrence of any (incipient) fire

Fire protection feature (from [OECD/NEA FIRE Database] and [IAEA SSG-64]): Structural elements (passive such as walls, floors, ceilings, beams, and active such as doors, hatches, dampers, etc.) and technical equipment (fire detection and alarm systems and equipment, fire extinguishing systems and equipment, including their extinguishing media supplies)

Fire protection means (from [OECD/NEA FIRE Database]): Active and passive means to protect a target against effects from fires.

Fire protection measure: Active means covering also human actions and procedures for protecting a target against the effects of fire.

Fire source: the component where the fire originated from, including the combustibles and the corresponding ignition source.

Fire suppression (from [NFPA 97] and [OECD/NEA FIRE Database]): The sum of all the work done to extinguish a fire from the time of its discovery.

Fitness for duty (from [IAEA NS-G-2.4]): an individual's suitability for duty, addressing adequate physical and mental fitness and aspects such as the illicit use of drugs or tobacco and alcohol abuse, in consonance with national regulations.

Fuel cycle facilities (from [IAEA SSR-4] and IAEA/NEA Fuel Incident Notification and Analysis System (FINAS) Guidelines [FINAS]): Nuclear fuel cycle facilities are nuclear installations, other than nuclear power plants, research reactors and critical assemblies, in which nuclear material and radioactive material are processed, handled, stored and prepared for disposal, in quantities or concentrations that pose potential hazards to personnel, the public and the environment. Nuclear fuel cycle facilities include facilities for:

- (a) mining and processing of uranium and thorium ores,
- (b) conversion and enrichment of uranium,
- (c) reconversion and fabrication of nuclear fuels of all types,
- (d) interim storage of fissile material and fertile material before and after irradiation,
- (e) production of nuclear energy for power, research and other purposes,
- (f) reprocessing of spent nuclear fuel and breeder materials from thermal reactors and fast reactors,
- (g) associated waste conditioning, effluent treatment and facilities for interim storage of waste that allow for retrieval of the waste for later disposal,
- (h) separation of radionuclides from irradiated thorium and uranium,
- (i) related research and development.

Ignition (from [NFPA 97] and [OECD/NEA FIRE Database]): The initiation of combustion evidenced by glow, flame, detonation, or explosion, either sustained or transient; the moment when a fire first occurs.

Ignition source (from [NFPA 97] and [OECD/NEA FIRE Database]): Any item or substance capable of an energy release of type and magnitude sufficient to ignite any flammable mixture of gases or vapours that could occur at the site (e).

Incipient fire (from [OECD/NEA FIRE Database]): Small or initial phase of fire, which can evolve to a fully developed fire if nothing is done.

Item important to safety (from [IAEA Glossary 2018]): An item that is part of a *safety group* and/or whose malfunction or *failure* could lead to *radiation exposure* of the *site personnel* or *members of the public*. Items important to safety include:

- Those structures, systems and components whose malfunction or failure could lead to undue radiation exposure of site personnel or members of the public,
- Those structures, systems and components that prevent anticipated operational occurrences from leading to accident conditions,
- Safety features (for design extension conditions),
- Those features that are provided to mitigate the consequences of malfunction or failure of structures, systems and components.

Nuclear fuel fabrication plants (from [IAEA Glossary 2018]): Facilities for the fabrication of nuclear fuel.

Reprocessing (from [IAEA Glossary 2018]): A process or operation, the purpose of which is to extract radioactive isotopes from spent fuel for further use.

Safety groups (from [IAEA Glossary 2018]): The assembly of equipment designated to perform all actions required for a particular initiating event to ensure that the limits specified in the design basis for anticipated operational occurrences and design basis accidents are not exceeded.

Uranium Enrichment Facilities: Facilities used to increase the ratio of U-235 isotope to others in order to produce fuel for nuclear reactors. At present, enrichment facilities use either the gaseous diffusion process or the gas centrifuge process, both of which require prior conversion of uranium oxide into a fluoride - see conversion facilities. Typical process routes for enrichment facilities are outlined in Annex II of [IAEA SSG-5].

01

General information

01.1 Nuclear installations identification

All nuclear installations that are operating or under construction as defined in section 00.3 should be listed. The key parameters for each of them should be described with, for research reactors and waste and decommissioning facilities, a clear statement concerning their inclusion or non-inclusion within the scope of the NAR. If necessary, this information can be presented in an annex to the report.

The key parameters should include for nuclear power plants and research reactors:

- Name,
- Licensee,
- Type of reactor,
- Thermal and electrical net power as applicable,
- Year of construction license (for reactor under construction),
- Year of first operation (for operating reactors),
- Scheduled shutdown date (if any).

The key parameters should include for fuel cycle facilities and waste and decommissioning facilities:

- Name,
- Licensee,
- Type of installation,
- Year of first operation,
- Scheduled shutdown date (if any).

For all nuclear installations included in the scope, the NAR should also include a brief characterisation of the site with all its radioactive (reactor and non-reactor) sources including the main characteristics of each reactor unit and/or other installation.

This also covers at least for reactor installations information on the phase of lifetime (construction, commissioning, operation, post-operation safe shutdown or other longer term shutdown, decommissioning) and the corresponding information on the fuel (in the reactor, in the spent fuel pool, other storage).

Research reactors operate at lower temperature and pressure levels than nuclear power plants. Also, the radioactive inventory is usually lower within a research reactor. Nevertheless, all research reactors have to fulfil the three fundamental safety functions. Where the regulatory framework considers a graded approach with respect to research reactors to meet these goals, a description of this approach should be provided.

For RRs in the scope, two categories are considered:

- **RRs with a higher risk profile:** RRs with a thermal power $\geq 1 \text{ MW}_{\text{th}}$ as well as RRs with a thermal power $< 1 \text{ MW}_{\text{th}}$ and with an important additional risk,
- **RRs with a lower risk profile:** RRs with a thermal power $< 1 \text{ MW}_{\text{th}}$, which do not have any significant additional risk.

For the first brief approximation of the risk profile, a threshold on thermal power is considered. Suitable value to define higher risk profile is thermal power of $\geq 1 \text{ MW}_{\text{th}}$. However, the thermal power itself may not be sufficient. For research reactors with a thermal power $< 1 \text{ MW}_{\text{th}}$, additional significant characteristics should then be taken into account such as: radiological source term, location (proximity to population and/or proximity to other facilities which can rise the external hazard), reactor specific features likely to affect safety (e.g., spent fuel storage areas, hot cells areas, high pressure systems, heating systems and the storage of flammables) and utilization of the reactor (experimental devices, tests, radioisotope production, reactor physics experiments). Further information may be found in Annex A of the SRL publication.

For fuel cycle and waste and decommissioning facilities, a brief description of the plant process with a particular focus on the major specific risks potentially affected by fire should be provided. If a graded approach is applied to fuel cycle and waste and decommissioning facilities, this approach should be described here.

Characterising the site, it is also important to provide information on the neighbourhood of the installation being reviewed, such as:

- Other nuclear installations collocated at the same site or in the direct vicinity of the site and, if this is the case, information if these are operated by the same or by different licensees,
- Commonly shared resources (e.g., electrical supplies, on site fire brigade, common drills, etc.) between these installations or with any other industrial installation in the neighbourhood,
- Plant external resources needed in particular for successfully firefighting and mitigating the consequences to nuclear safety.

01.2 Process to develop the NAR

The process used to develop the NAR should be described including the roles of:

- The regulator,
- Licensees,
- Other stakeholders.

01.3 National regulatory framework

The NAR should include a brief overview of the regulatory system relevant to fire safety to allow understanding of requirements and guidance and their implementation related to the development and implementation of the overall fire safety regime. It should identify key regulatory documents and guidance as well as technical standards used domestically.

These consider provisions made as part of

- the design and operation of those nuclear facilities in the scope of the NAR,
- the safety assessment of these facilities, including methods, data and analytical tools used.

The NAR should describe how international standards are used in developing the overall fire safety programme including:

- relevant WENRA Safety Reference Levels (SRLs),
- IAEA Safety Standards and other guidance, including the proven practices.

01.4 Safety objectives

The NAR should reflect the safety objectives provided hereafter being considered in the country for fire safety in nuclear installations. In the following, only the corresponding SRLs are given. Contributions in the NAR on the application of the safety objectives are expected in Section 6.

The following WENRA SRL corresponds to fire related safety objectives in NPPs:

***WENRA SV 1.1: Internal hazards shall be considered an integral part of the safety demonstration of the plant (including spent fuel storage) .
Threats from internal hazards shall be removed or minimised as far as reasonably practicable for all operational states.***

The following WENRA SRL corresponds to fire related safety objectives in RRs:

WENRA S 1.1: The licensee shall implement the defence in depth principle to fire protection, providing measures to prevent fires from starting, to detect and extinguish quickly any fires that do start and to prevent the spread of fires and their effects in or to any area that may affect safety.

The following WENRA SRLs correspond to fire related safety objectives in WDFs:

WENRA DI-35: The licensee shall establish a design basis for the facility taking into account normal operational conditions, anticipated operational occurrences and possible accidents derived from a relevant set of postulated initiating events (PIEs).

WENRA P-37: The licensee shall establish a design basis for the facility taking into account normal operation, anticipated operational occurrences and possible accidents derived from a relevant set of Postulated Initiating Events (PIEs).

Fire protection systems also belong to the safety-relevant SSCs (see, for example, WS-G-6.1, para 6.79).

For FCFs, the above WENRA SRLs can be considered in the absence of FCF-specific SRLs. IAEA Safety Requirements, as outlined in [SSR-4], i.e. Requirement 9 (general design considerations) and paragraphs 6.8 to 6.18, can also provide a framework for fire safety objectives in the design of these facilities.

01.5 Defence in depth principles

Fires could, simultaneously challenge more than one level of defence in depth, and increase, for example, the degree of dependency between the originator of initiating events and the failure of mitigation equipment.

In the following only the respective SRLs are given. Contributions in the NAR on the application of the safety objectives are expected in chapter 6.

The following WENRA SRLs correspond to the defence-in-depth principles typically applied in NPPs:

WENRA SV 5.1: A protection concept shall be established to provide a basis for the design of suitable protection measures.

WENRA SV 5.2: The licensee shall implement the defence in depth concept for protection against internal hazards. This shall include provisions to prevent the occurrence of events induced by internal hazards, to detect these events and, if relevant, control and/or mitigate their consequences.

WENRA SV 5.3: The protection concept shall be of sufficient reliability so that the fundamental safety functions are conservatively ensured for any direct and credible indirect effects of design basis events for internal hazards.

WENRA SV 5.4: The protection concept for internal hazards shall:

- (a) apply conservatism to provide safety margins in the design;***
- (b) rely primarily on passive measures as far as reasonably practicable;***
- (c) ensure adequate physical separation or segregation of redundant / diverse trains of safety systems, to prevent propagation of the effects of internal hazards to other trains. Exceptions shall be justified;***
- (d) ensure that procedures and means are available to verify the plant conditions during and following an impact initiated by a design basis event;***
- (e) minimize, as far as reasonably practicable, the event propagation within the site area;***
- (f) ensure that sufficient resources remain available at multi-unit sites considering the use of common equipment or services;***
- (g) not inadmissibly affect the protection against other design basis events (not limited to internal hazards);***

WENRA SV 5.5: SSCs identified as part of the protection concept with respect to design basis events shall be considered as important to safety (see G1.1).

WENRA SV 5.6 If there is a credible combination of the hazard under consideration with another internal or external event the SSCs for protection shall remain effective in this combination.

The following WENRA SRLs correspond to the defence-in-depth principles typically applied in RRs:

WENRA S 1.1: The licensee shall implement the defence in depth principle to fire protection, providing measures to prevent fires from starting, to detect and extinguish quickly any fires that do start and to prevent the spread of fires and their effects in or to any area that may affect safety.

WENRA S 2.4: Buildings that contain radioactive materials that could cause radioactive releases in case of fire shall be designed to minimize such releases.

The following WENRA SRLs correspond to the defence-in-depth principles typically applied in WDFs:

WENRA S-30 = P-38: The licensee shall make design arrangements for fire safety on the basis of a fire safety analysis and implementation of defence in depth (prevention, detection, control and mitigation of a fire).

WENRA S-26: The licensee shall establish operational limits and conditions (OLCs) in order to maintain the storage facility and waste and spent fuel packages or unpackaged spent fuel elements in a safe state during facility operation.

WENRA S-27: The defined OLCs (see S-26) shall consider, in particular, and as appropriate:

- (...)***
- potential aspects of gas generation from waste or spent fuel, in particular the hazards of fire ignition, explosion, waste and spent fuel package or unpackaged spent fuel element deformations and radiation protection aspects;***
- (...).***

For FCFs, WENRA SRLs SV 5.1 to 5.3, 5.5 and 5.6 can be applied. SV 5.4 considers reactor specific expectations. The FCFs subgroup considers that criteria under SV 5.4 could be interpreted as follows: *SSCs important to safety shall be located and designed in order to minimize the probability and effects from fire, taking into account criteria related to defence in depth, the design against single failure, redundancy and diversity.* In this context, the IAEA Specific Safety Requirements SSR-4 identify requirements on defence in depth in broad alignment with the WENRA SRLs' Requirements 10, 41 and 69. IAEA SSR-4 provides for FCFs' expectations that *Items important to safety shall be designed and located, subject to compliance with other safety requirements, so as to minimize the effects of fires and explosions, which could lead directly or indirectly to radiological consequences.* IAEA SSR-4, para 6.163 requires that internal fires shall not challenge redundant safety groups.

Prevention, control and mitigation of fire hazards in an installation requires the examination of credible fires and of items important to safety to be protected in order to achieve the safety objectives. Consistent with the defence in depth principles, the corresponding fire protection means implemented aim at:

- Minimizing the likelihood of fires by
 - removing, minimizing and segregating fixed and transient fire loads, as far as reasonably practicable,
 - eliminating potential ignition sources to the extent practicable; otherwise, strict control of any such sources,
 - segregating ignition sources from fuel sources.
- Mitigating the fire by
 - timely detection and extinguishing of fires,
 - preventing the spread of fires.
- Mitigating secondary fire effects and maintaining safety functions identified as necessary in case of fire, including mitigation of the radiological consequences of the fire (protecting relevant SSCs against the effects of the fire hazard and limiting its consequences to achieve the safety objectives).

These protective means are therefore implemented and organized in different successive levels that are as independent as possible. Each level of defence against fire shall prevent the situation from deteriorating and moving to the next level as well as mitigate the consequences of the failure of the previous level.

In line with the concept of defence in depth, protection against fire is provided in general by ensuring the high quality and reliability of SSCs (see section 02.2), by environmental qualification of these SSCs, by application of the principles of redundancy and diversity, and by physical separation, segregation, and design of appropriate barriers and other protective means.

Therefore, the design against the effects of fire is an iterative process. Proper maintenance, control, and in-service inspections of SSCs need to be in place for timely detection of the occurrence of a fire and implementation of necessary corrective actions to ensure protection against the fire. Identification of fire hazards at an early stage in the design is often used as a practical method to identify and prevent them.

Sections 03 to 05 of the NAR should describe how the defence in depth concept has been implemented with respect to fire safety in the nuclear installations, and that the impact of fire across the levels of defence in depth has been adequately considered. This includes adequate consideration to:

- prevent fires from starting,
- detect and extinguish quickly any fires that do start,
- prevent the spread of fires and their effects in or to any area that may affect safety.

It should be further described how the design and layout of fire protection means in place meet the objectives related to the aforementioned levels of defence in depth as far as reasonably practical.

At least some brief information should be provided that and how the defence in depth principles mentioned in the WENRA SRLs before are met in each nuclear installation.

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02

Experience and research feedback and resulting major modifications

In order to assess the suitability, effectiveness and reliability of fire protection means in place or being replaced, experience feedback as well as new insights from fire related research activities are essential. Therefore, the NAR should provide recent insights, e.g. from the operating experience (“OPEX”) feedback, from maintenance as well as results from research activities (experiments and calculations).

02.1 Operating experience feedback

The NAR should describe how the licensee organisations monitor their internal, national and international operating experience with respect to fires, including fire incidents, how they implement proactive measures to improve fire safety and spread knowledge in the organisation.

In the NAR should also include examples of how fire safety has developed/improved in the installations within the scope of the NAR over the last ten years.

The following WENRA SRLs correspond to the operating experience and its application. In this context, it is noted that the following WENRA SRLs are in principle applicable to NPPs in the scope of the TPR.

WENRA J 3.1: The licensee shall report events of significance to safety in accordance with established procedures and criteria.

WENRA J 4.3: Event investigation shall be conducted on a time schedule consistent with the event significance. The investigation shall:

- ***Establish the complete event sequence;***
- ***Determine the deviation;***
- ***Include direct and root cause analysis;***
- ***Assess the safety significance including potential consequences; and***
- ***Identify corrective actions;***

The following WENRA SRLs correspond to the operating experience and its application. In this context, it is noted that the following WENRA SRLs are in principle applicable to RRs in the scope of the TPR.

WENRA J 4.3: Event investigation shall be conducted on a time schedule consistent with the event significance. The investigation shall:

- ***Establish the complete event sequence;***
- ***Determine the deviation;***

- **Include direct and root cause analysis, including causes relating to equipment design, operation and maintenance, or to human and organizational factors;**
- **Assess the safety significance including potential consequences; and**
- **Identify corrective actions;**

Additions for WDFs and FCF have to be checked by the WGWD and WGFCF

In line with the above SRLs, fire events in nuclear facilities have the potential to give rise to significant nuclear safety consequences and should therefore be reported (see criteria in IAEA SSG-50, Appendix). This includes NPPs, RRs, FCFs and WDFs, hence the above mentioned SRLs apply to all of these facilities.

With respect to fire events reporting and analysis, the following information should be provided (to the extent possible with details in a table) in the NAR as far as reliable information is available:

- number of fire events occurred in nuclear facilities in the scope of the TPR during the last 10 years,
- fire source (turbine generator, MV/LV transformer, HV transformer, rectifier/inverter, pump, hydrogen vessel/equipment, component ignited by hot work, heater, electrical cabinet, diesel generator, cables, breaker, other components),
- plant operational state (e.g., power operation, shutdown mode, start-up mode, hot stand-by, construction phase) when the fire started,
- the potential for fires (e.g., in fuel cycle facilities) to result in releases of hazardous substances (e.g., HF),
- root causes (equipment failure, human factor, inadequate maintenance or testing, procedures, management),
- location where the fire started (inside building, if yes, type of building, type of room, outside buildings on the site, offsite),
- briefly presentation of some fire events (description, causes, consequences, corrective actions).

The NAR should identify the fire deficiencies and/or non-compliances after fire event investigations, or other activities such as Periodic Safety Review (PSR), inspections against national fire regulations or international standards. Importantly, the NAR should describe how the fire deficiencies and/or fire non-compliances could be resolved, including brief descriptions of the improvements and modifications planned and implemented.

02.2 Maintenance

One important aspect, also for experience feedback from nuclear installations are inspection and maintenance activities and their insights. Therefore, these aspects are considered here.

The following WENRA SRLs correspond to the operating experience and its application. In this context, it is noted that the following WENRA SRL is in principle applicable to NPPs and RRs in the scope of the TPR.

WENRA K 1.1: The licensee shall prepare and implement documented programmes of maintenance, testing, surveillance, and inspection of SSCs important to safety to ensure that their availability, reliability, and functionality remain in accordance with the design over the lifetime of the plant. They shall take into account operational limits and conditions and be re-evaluated in the light of experience.

The following WENRA SRLs correspond to fire related safety objectives in WDFs:

- ***WENRA DE-42: The licensee shall prepare, and implement documented programmes for maintenance, testing, surveillance and inspection of SSCs and other equipment significant to safety to ensure that their availability, reliability and functionality remain in accordance with the safety case for decommissioning. The programmes shall take into account operational limits and conditions (OLCs) and be re-evaluated in the light of experience and the continuous changes of the facility during decommissioning.***
- ***WENRA DI-65: The licensee shall establish and implement programs for maintenance, periodic testing and inspection, based on written procedures in order to ensure and confirm that structures, systems and components (SSCs) are able to function in accordance with the requirements for operational and post-closure safety.***
- ***WENRA DI-61: The licensee shall plan, assess, document and implement any modifications of design, waste acceptance criteria, structures, systems and components (SSCs), operational limits and conditions (OLCs) and operational procedures and methods using arrangements consistent with the importance to safety of the modifications.***

For FCFs, the above SRLs can be considered in the NAR, as they can be considered transferable. Fire detection and alarm systems, other alarm systems, extinguishing systems, and passive fire barrier elements with active functions such as fire doors or dampers should be checked as a part of recurring in-service inspections and the logs of recurring tests should be inspected. Further control aspects are, for example, fire protection when storing flammable substances (e.g. in the area of cable crossings) as well as the introduction and storage of impermissible fire loads. During Periodic Safety Reviews, e.g. every 10 years, the arrangements and documents (including those relating to fire protection) of the nuclear facility should be checked.

If compensatory measures are implemented in case the implemented fire protection features are unavailable (failure, maintenance, etc.) these measures shall provide an equivalent level of safety.

The NAR should therefore at least provide information regarding the following aspects:

- controls, inspection and maintenance carried out for fire protection features,
- process and tools used to verify adequacy and reliability of maintenance and periodic testing to ensure the required performance of fire protection features over the lifetime of the installation,
- consideration of ageing of fire protection features.

02.3 Feedback from fire safety research

This chapter is applicable to all facilities in scope of the TPR. The NAR should describe if and how insights from fire related research have resulted in modifications to the facilities, as applicable.

The NAR should also include information on the need to determine and consider direct fire effects (temperature, thermal flux, pressure, soot, etc.), failure criteria of SSCs and performance criteria of fire protection features by means of research and development to establish as applicable.

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WENRA S 2.3: Buildings that contain equipment that is important to safety shall be subdivided into compartments that segregate such items from fire loads and segregate redundant or diverse trains of a safety system from each other. When a fire compartment approach is not practicable, fire cells shall be used, providing a balance between passive and active means, as justified by fire hazard analysis.

WENRA S 2.4: Buildings that contain radioactive materials that could cause radioactive releases in case of fire shall be designed to minimize such releases.

WENRA S 5.1: In order to prevent fires, procedures shall be established to control and minimize the amount of combustible materials and minimize the potential ignition sources that may affect items important to safety. In order to ensure the operability of the fire protection measures, procedures shall be established and implemented. They shall include inspection, maintenance and testing of fire barriers, fire detection and extinguishing systems.

Further relevant aspects corresponding to fire prevention are specified in WENRA SRL S2.2 for RRs.

The general aspects to be considered for fire prevention are the same for all research reactors, regardless of their power. The extent, level of detail and effort used by the licensee for the reporting should be adequate depending on the potential risks of the research reactor. The description in the NAR should include

- the design features in the research reactor for minimizing the likelihood and the effects of fire on SSCs, (e.g., construction materials used, separation of combustible materials and ignition sources),
- the operational provisions and procedures to control and minimize the amount of combustible materials, flammable liquids, pyrophoric materials and minimize the potential ignition sources that may affect items important to safety, including
 - the prevention aspect around experiments in the reactor hall (including oversight and instructions for experimenters and students),
 - the process in the research reactor to strengthen the awareness of personnel in managing any activities with flammable materials, fire loads, etc.

03.3 WDFs

To be added by WGWD

03.4 FCFs

WENRA SRLs have not yet been specifically developed for FCFs.

The following WENRA SRLs specifically correspond to fire prevention in RRs:

WENRA S 2.1: SSCs important to safety shall be designed and located so as to minimize the frequency and the effects of fire and to maintain capability for shutdown, residual heat

removal, confinement of radioactive material and monitoring of state of the research reactor during and after a fire event.

However, the above provided SRL S 2.1 provided for RRs could be more generally applied to all facilities stating “SSCs important to safety shall be designed and located so as to minimize the frequency and the effects of fire and to maintain capability for meeting the safety goals during and after a fire event.” For FCFs, this interpretation should be considered to reflect the appropriate safety goals and functions, that is, SSCs shall be 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 NAR should describe:

- the process in the facility’s design for minimizing the likelihood and the effects of fire on SSCs,
- the fire prevention means including specific needs due to the installation’s operation and processes (flammable liquids, pyrophoric materials, etc.),
- procedures for management and control of “hot work” to handle maintenance or other work where there are risks of fire ignition or measures to prevent false alarms.

04

Active fire protection

Detecting and extinguishing quickly those fires which do start, thus limiting the damage is the second level of defence-in-depth with respect to nuclear fire safety and covered by the term “active fire protection”.

Following detection, the fire has to be extinguished and the installation has to be put into a safe condition.

04.1 NPPs

04.1.1 Fire detection and alarm

The following WENRA SRLs correspond to fire detection and alarm in NPPs:

WENRA SV 5.8: Where appropriate, detection and monitoring equipment shall be part of the protection concept to cope with internal hazards. Where appropriate, thresholds shall be identified and intervention values shall be defined to facilitate the timely initiation of protection measures.

WENRA SV 6.8: Fire detection and alarm features, with detailed annunciation of the location of a fire to the control room personnel, shall be installed at the plant and their adequacy shall be supported by results of the fire hazard assessment. These features shall be provided with non-interruptible emergency power supplies and failures of the cable connections shall be announced to the main control room.

The NAR should describe

- the fire detection and alarm provision to identify and notify occupants and fire emergency responders of any incipient fires, including the guidelines applied in their design, the system’s key features / technology and the locations covered,
- the approaches to assure that the systems are capable to withstand the relevant ambient / hazard conditions,
- to the extent practical, how independence between fire detection systems of adjacent compartments is achieved and maintained under hazard conditions,
- alternative arrangements applied when temporary works require fire detection to be disabled locally or globally,
- arrangements and training in place to ensure the operator’s situational awareness (on the status and actions prompted by fire detection and alarm features).

04.1.2 Fire suppression

Following detection, the fire has to be extinguished and the installation has to be put into a safe condition.

The following WENRA SRLs correspond to fire extinguishing in NPPs:

WENRA SV 6.9: Suitable fire extinguishing features shall be in place according to the fire hazard assessment. They shall be designed and located such that their rupture, spurious or inadvertent operation does not inadmissibly impair the SSCs important to safety.

WENRA SV 6.10: The fire water distribution network for fire hydrants outside buildings and the internal standpipes shall provide adequate coverage of all plant areas. The coverage shall be justified by the fire hazard assessment.

The NAR should describe:

- the approaches applied in the selection, design and location of fire extinguishing systems, according to the relevant fire hazard challenge in the fire compartments/cells with SSCs important to safety,
- key design characteristics of the fire extinguishing provision (e.g. pressure, flow, overall inventory, seismic and frost resistance, etc.) and how adequate capacity and coverage of all relevant plant areas is achieved,
- how inadvertent operation is avoided, and system reliability is assured. This includes consideration of the single failure criterion in the context of fire extinguishing features,
- how secondary hazards from actuation (flooding, challenges to radiological containment, criticality, etc.) have been considered in the safety demonstration and operational arrangements,
- how environmental effects from deployment/actuation have been considered,
- how independence of fire extinguishing systems (including support systems, e.g. ventilation and drainage systems) between adjacent compartments has been achieved,
- the balance between fixed fire extinguishing and manual firefighting that may be applied at the facility. This should include accessibility considerations during manual firefighting.
- the firefighting strategies and how they are assured (written procedures, training provision, frequency of emergency exercises, key learning from past events, exercises, etc., to the extent practical).

04.1.3 Administrative and organisational fire protection issues

The administrative and organisational aspects of fire safety are important considerations in addition to design provisions and physical measures. Specifically, fire protection can significantly rely on organisational and administrative arrangements, for example, in fire detection and suppression.

The following WENRA SRLs correspond to administrative and organisational fire protection issues in NPPs:

WENRA SV 5.10: Adequate organisational arrangements, including minimum staffing levels, equipment, fitness for duty, skills and training, and procedures shall be in place to ensure safety, as identified by the hazard assessment.

WENRA SV 6.11: In order to prevent fires, procedures shall be established to control and minimize the amount of combustibles and the potential ignition sources. In order to ensure the operability of the fire protection measures, procedures shall be established and implemented. They shall include examination, inspection, maintenance and testing of fire barriers, fire detection, alarm features and extinguishing systems.

WENRA SV 6.12: Written procedures that clearly define the responsibility and actions of staff in responding to any fire in the plant shall be in place and kept up to date. A firefighting strategy shall be developed, kept up-to date, and appropriate training provided, to cover each area in which a fire might affect SSCs important to safety.

WENRA SV 6.13: If plant internal firefighting capability is supported by offsite resources, there shall be proper coordination between the plant personnel and the offsite response group, in order to ensure that the latter is familiar with the hazards of the plant. Emergency training, drills and exercises shall be performed.

WENRA SV 6.14: If plant personnel are required for firefighting, their organization, minimum staffing level, equipment, fitness requirements, skills and training shall be documented and their adequacy shall be confirmed by a competent person.

The NAR should briefly describe

- the firefighting strategy in place, how it is kept up-to date, and how appropriate training is provided, in order to adequately fight any fire that might affect SSCs important to safety in any fire compartment,
- written procedures in place clearly defining responsibility and actions of staff in responding to any fire in the installation and how it is kept up to date,
- the means by which proper coordination between the plant personnel and the offsite response group is achieved, if the plant internal firefighting capability is supported by offsite resources. This includes ensuring that offsite resources are familiar with the hazards of the plant. The activities may involve e.g. conducting emergency training, drills and exercises.
- firefighting capability, responsibilities and organization (plant internal fire brigade, organisation between onsite and offsite firefighters, etc.)²,
- minimum staffing level for firefighting,
- availability of suitable firefighting equipment,
- fitness requirements, familiarisation, skills and training for firefighters³,

² This includes prioritisation of the different responsibilities of onsite firefighting resources, if these resources are expected to also carry out other work.

³ This includes e.g. how it is ensured that offsite resources are familiar with the hazards of the nuclear installations and if and how often there are periodic drills with offsite firefighting resources.

- firefighting documentation (e.g., building cards with important information about the building, topographical scheme etc.), eventually checklists for chief officer (so that during firefighting the fire brigade does not miss important information about the building).
- how the “design bases” applicable to the fire response organisation are met to ensure the achievement of the fire safety objectives in the facility, including the description of any thresholds that may be applied when considering the deployment (or not) of offsite firefighting capability,
- specific provisions in place for management of a fully developed fire in situations with total loss of access to the installation (e.g. in the event of an external hazard).

04.2 RRs

Active fire protection represents the second level of defence-in-depth with respect to nuclear fire safety following the principles of defence-in-depth mentioned in Section 1.

04.2.1 Fire detection and alarm

The following WENRA SRL corresponds to fire detection in research reactors.

WENRA S 4.1: Each fire compartment or fire cell shall be equipped with fire detection and alarm features, with detailed annunciation for the control room staff of the location of a fire. These features shall be provided with non-interruptible emergency power supplies and appropriate fire resistant supply cables.

It should be described in the NAR:

- that suitable and reliable fire detection and alarm features (automatic and/or manual) are in place for detecting any incipient fire and providing a detailed annunciation of the fire and its location to occupants and fire emergency organisations, including the arrangements if the automatic system fails.
- that fire detection systems are, as far as practicable, independent of their counterparts in other fire compartments in order to maintain the operability of such systems in adjacent fire compartments.

Research facilities usually base their detection and alarm strategy on the requirements for conventional buildings. Reference to these requirements should be given, but do not need to be described in detail. Any additional nuclear requirements should be described in more detail including specific provisions on detection and alarm systems resulting from those requirements. Also, if specific provisions are taken, based for example on the outcome of nuclear safety analyses, these should be described in more details.

Examples could be the use of particular fire detection systems in areas with higher radiation dose rates (radiation protected cameras, detectors), reduced use of water suppression system if criticality risk is identified, etc.

04.2.2 Fire suppression

Following detection, the fire has to be extinguished and the installation has to be put into a safe condition.

The following WENRA SRLs correspond to fire extinguishing in research reactors.

WENRA S 4.2: Fixed or mobile, automated or manual extinguishing systems shall be installed. They shall be designed and located so that their rupture, spurious or inadvertent operation does not significantly impair the capability of SSCs important to safety to carry out their safety functions.

WENRA S 4.3: The distribution loop for fire hydrants outside building and the internal standpipes shall provide adequate coverage of areas of the research reactor relevant to safety. The coverage shall be justified by the fire hazard analysis.

It should be described in the NAR:

- how the control of fire is achieved through a combination of fixed fire suppression and extinguishing systems and equipment and manual firefighting capabilities including justification that they are designed and located such that their rupture, spurious or inadvertent operation does not inadmissibly impair SSCs important to safety.
- active fire protection specific to experiments if these are different than for other parts of the installation.
- that, if relevant, fire extinguishing features do not simultaneously affect redundant equipment and thereby cause the measures taken to meet the single failure criterion to become ineffective.
- that, if any, the fire water distribution network for fire hydrants outside buildings and the internal standpipes provides adequate coverage of all research reactor site areas;

The NAR should provide information on:

- the guidelines for the arrangement (location) and types of extinguishing systems and equipment implemented in the installation (fixed or mobile, automatically or manually actuated) [not for **RRs with a lower risk profile**],
- the process for defining the type of extinguishing agent compliant with safety (confinement function, criticality hazard, etc.),

As fire detection and extinguishing means can cause secondary effects after their actuation, e.g. flooding. the following information should be provided:

- which and how such secondary effects are considered in the safety demonstration,

- the specific provisions in place to deal with the effluents released by extinguishing features if this could generate contamination or criticality risks.

04.2.3 Administrative and organisational fire protection issues

Active fire protection also concerns organisational and administrative aspects of fire detection and suppression.

The following WENRA SRLs correspond to administrative and organisational fire protection issues in research reactors.

WENRA S 5.1: In order to prevent fires, procedures shall be established to control and minimize the amount of combustible materials and minimize the potential ignition sources that may affect items important to safety. In order to ensure the operability of the fire protection measures, procedures shall be established and implemented. They shall include inspection, maintenance and testing of fire barriers, fire detection and extinguishing systems.

WENRA S 6.1: The licensee shall implement adequate arrangements for controlling and ensuring fire safety, as identified by the fire hazard analysis.

WENRA S 6.2: Written emergency procedures that clearly define the responsibility and actions of site personnel in responding to any fire in the research reactor shall be established and kept up to date. A fire fighting strategy shall be developed, kept up-to date, and trained for, to cover each area in which a fire might affect items important to safety and protection of radioactive materials.

WENRA S 6.3: When reliance for manual fire fighting capability is placed on an offsite resource, there shall be proper coordination between the licensee's response group and the off-site response group, in order to ensure that the latter is familiar with the hazards of the research reactor.

WENRA S 6.4: If site personnel is required to be involved in fire fighting, their organization, minimum staffing level, equipment, fitness requirements, and training shall be documented and their adequacy shall be confirmed by a competent person.

According to the above mentioned WENRA SRLs it should be ensured

- that suitable written procedures clearly defining responsibility and actions of staff in responding to any fire in the installation are in place and kept up to date,
- that a firefighting strategy is in place, kept up-to date, and appropriate training is provided, to cover each area where a fire might affect SSCs important to safety,
- that and by which means, in case that research reactor internal firefighting capability, if any, is supported by offsite resources, proper coordination between the research reactor personnel and the offsite response group is ensured, in order to ensure that the latter is familiar with the hazards of the research reactor, including conducting emergency training, drills and exercises.

Therefore, the following information should be provided in the NAR:

- Either, if there is a professional research reactor internal fire brigade present at the site, there is there a need to involve in addition an external fire brigade. If yes, it should be described how the fire response is organised between on-site and off-site brigade.
- Or, if there are only non-professional research reactor firefighters present at the site, how the responsibilities are distributed for firefighting (off-site professional vs. on-site non-professional ones),
- different responsibilities of on-site firefighting resources, prioritisation of their work (firefighting vs. other shift work).
- if the internal non-professional resources are able to fight a fully developed fire in the installation,
- if and how often there are periodic drills with off-site firefighting resources,
- which types of personnel or staff are instructed/qualified to use the manual firefighting capabilities or actuate an automatic system manually, if any.

4.3 WDFs

04.3.1 Fire detection and alarm

Text to be added by WGWD

04.3.2 Fire suppression

Following detection, the fire has to be extinguished and the installation has to be put into a safe condition.

No specific SRLs for WDFs; therefore, the following texts should be checked and if necessary modified by WGWD

The following WENRA SRLs correspond to fire extinguishing provisions in NPPs:

WENRA SV 6.9: Suitable fire extinguishing features shall be in place according to the fire hazard assessment. They shall be designed and located such that their rupture, spurious or inadvertent operation does not inadmissibly impair the SSCs important to safety.

WENRA SV 6.10: The fire water distribution network for fire hydrants outside buildings and the internal standpipes shall provide adequate coverage of all plant areas. The coverage shall be justified by the fire hazard assessment.

In addition, the following WENRA SRLs correspond to fire extinguishing provisions in research reactors:

WENRA S 4.2: Fixed or mobile, automated or manual extinguishing systems shall be installed. They shall be designed and located so that their rupture, spurious or inadvertent operation does not significantly impair the capability of SSCs important to safety to carry out their safety functions.

WENRA S 4.3: The distribution loop for fire hydrants outside building and the internal standpipes shall provide adequate coverage of areas of the research reactor relevant to safety. The coverage shall be justified by the fire hazard analysis.

For waste and decommissioning facilities, the above SRLs should be considered as appropriate. It should be noted, as highlighted in IAEA SSR-4, para. 6.79 that fire extinguishing systems shall be demonstrated not to increase the criticality risk. For example, the use of water in certain areas may be prohibited or subject to specific authorisation procedures.

The NAR should therefore describe:

- the approaches applied in the selection, design and location of fire extinguishing systems, according to the relevant fire hazard challenge in the fire compartments/cells with SSCs important to safety,
- key design characteristics of the fire extinguishing provision (e.g. pressure, flow, overall inventory, seismic and frost resistance, etc.) and how adequate capacity and coverage of all relevant plant areas is achieved,
- how inadvertent operation is avoided, and system reliability is assured. This includes consideration of the single failure criterion in the context of fire extinguishing features,
- how secondary hazards from actuation (flooding, challenges to radiological containment, criticality, etc.) have been considered in the safety demonstration and operational arrangements,
- how environmental effects from deployment/ actuation have been considered,
- how independence of fire extinguishing systems (including support systems, e.g. ventilation and drainage systems) between adjacent compartments has been achieved.,
- the balance between fixed fire extinguishing and manual firefighting that may be applied at the facility. This should include accessibility considerations during manual firefighting.
- the firefighting strategies and how they are assured (written procedures, training provision, frequency of emergency exercises, key learning from past events, exercises, etc., to the extent practical).

04.3.3 Administrative and organisational fire protection issues

The administrative and organisational aspects of fire safety are important considerations in addition to design provisions and physical measures. Specifically, fire protection can significantly rely on organisational and administrative arrangements, for example, in fire detection and suppression.

The NAR should therefore briefly describe as far as applicable:

- the firefighting strategy in place, how it is kept up-to date, and how appropriate training is provided, in order to adequately fight any fire that might affect SSCs important to safety in any fire compartment,
- written procedures in place clearly defining responsibility and actions of staff in responding to any fire in the installation and how it is kept up to date,
- the means by which proper coordination between the plant personnel and the offsite response group is achieved, if the plant internal firefighting capability is supported by offsite resources. This includes ensuring that offsite resources are familiar with the hazards of the plant. The activities may involve e.g. conducting emergency training, drills and exercises.
- the firefighting capability, responsibilities and organization (plant internal fire brigade, organisation between onsite and offsite firefighters, etc.)⁴,
- the minimum staffing level for firefighting,
- the availability of suitable firefighting equipment,
- fitness requirements, familiarisation, skills and training for firefighters⁵,
- the firefighting documentation (e.g., building cards with important information about the building, topographical scheme etc.), eventually checklists for chief officer (so that during firefighting the fire brigade does not miss important information about the building),
- how the “design bases” applicable to the fire response organisation are met to ensure the achievement of the fire safety objectives in the facility, including the description of any thresholds that may be applied when considering the deployment (or not) of offsite firefighting capability,
- specific provisions in place for management of a fully developed fire in situations with total loss of access to the installation (e.g. in the event of an external hazard).

04.4 FCFs

04.4.1 Fire detection and alarm

WENRA SRLs have not yet been developed specifically for fire detection and alarm issues in fuel cycle facilities.

The following WENRA SRLs correspond to fire detection and alarm provisions in NPPs:

WENRA SV 5.8: Where appropriate, detection and monitoring equipment shall be part of the protection concept to cope with internal hazards. Where appropriate, thresholds shall

⁴ This includes prioritisation of the different responsibilities of onsite firefighting resources, if these resources are expected to also carry out other work.

⁵ This includes e.g. how it is ensured that offsite resources are familiar with the hazards of the nuclear installations and if and how often there are periodic drills with offsite firefighting resources.

be identified and intervention values shall be defined to facilitate the timely initiation of protection measures.

WENRA SV 6.8: Fire detection and alarm features, with detailed annunciation of the location of a fire to the control room personnel, shall be installed at the plant and their adequacy shall be supported by results of the fire hazard assessment. These features shall be provided with non-interruptible emergency power supplies and failures of the cable connections shall be announced to the main control room.

In addition, the following WENRA SRL corresponds to fire detection and alarm provisions in research reactors:

WENRA S 4.1: Each fire compartment or fire cell shall be equipped with fire detection and alarm features, with detailed annunciation for the control room staff of the location of a fire. These features shall be provided with non-interruptible emergency power supplies and appropriate fire resistant supply cables.

For FCFs, the above reference levels for reactors should be considered in the NAR, where they are transferable and proportionate to the facilities' safety justification. IAEA SSR-4 Requirement 22 (analysis of fire and explosion) and para. 6.77 expect the analysis to cover all means of fire prevention and control including fire detection and extinction, para 8.9 expects demonstration of systems for fire detection and control during commissioning. IAEA SSG-5 expects that all rooms with both fire loads and significant amounts of fissile and/or toxic chemical material should be equipped with fire detection and alarms (except where the permanent presence of operators is sufficient). Para. 4.56 expects that to fulfil requirements of SSR-4, para 6.28 an emergency power supply should be provided for fire detection and alarm systems.

The NAR should therefore describe

- the fire detection and alarm provisions to identify and notify occupants and fire emergency responders of any incipient fires, including the guidelines applied in their design, the system's key features / technology and the locations covered.
- the approaches to assure that the systems are capable to withstand the relevant ambient / hazard conditions,
- to the extent practical, how independence between fire detection systems of adjacent compartments is achieved and maintained under hazard conditions,
- alternative arrangements applied when temporary works require fire detection to be disabled locally or globally,
- arrangements and training in place to ensure operators' situational awareness (on the status and actions prompted by the fire detection and alarm systems).

04.4.2 Fire suppression

Following detection, the fire has to be extinguished and the installation has to be put into a safe condition.

WENRA SRLs have not yet been developed specifically for fire extinguishing issues in fuel cycle facilities.

The following WENRA SRLs correspond to fire extinguishing provisions in NPPs:

WENRA SV 6.9: Suitable fire extinguishing features shall be in place according to the fire hazard assessment. They shall be designed and located such that their rupture, spurious or inadvertent operation does not inadmissibly impair the SSCs important to safety.

WENRA SV 6.10: The fire water distribution network for fire hydrants outside buildings and the internal standpipes shall provide adequate coverage of all plant areas. The coverage shall be justified by the fire hazard assessment.

In addition, the following WENRA SRLs correspond to fire extinguishing provisions in research reactors:

WENRA S 4.2: Fixed or mobile, automated or manual extinguishing systems shall be installed. They shall be designed and located so that their rupture, spurious or inadvertent operation does not significantly impair the capability of SSCs important to safety to carry out their safety functions.

WENRA S 4.3: The distribution loop for fire hydrants outside building and the internal standpipes shall provide adequate coverage of areas of the research reactor relevant to safety. The coverage shall be justified by the fire hazard analysis.

For FCFs, the above SRLs should be considered as appropriate. It should be noted, as highlighted in IAEA SSR-4, para 6.79, that fire extinguishing systems shall be demonstrated not to increase the criticality risk. For example, the use of water in certain areas may be prohibited or subject to specific authorisation procedures.

The NAR should therefore describe

- the approaches applied in the selection, design and location of fire extinguishing systems, according to the relevant fire hazard challenge in the fire compartments/cells with SSCs important to safety,
- key design characteristics of the fire extinguishing provision (e.g. pressure, flow, overall inventory, seismic and frost resistance, etc.) and how adequate capacity and coverage of all relevant plant areas is achieved,
- how inadvertent operation is avoided, and system reliability is assured. This includes consideration of the single failure criterion in the context of fire extinguishing features,
- how secondary hazards from actuation (flooding, challenges to radiological containment, criticality, etc.) have been considered in the safety demonstration and operational arrangements,
- how environmental effects from deployment/ actuation have been considered,
- how independence of fire extinguishing systems (including support systems, e.g. ventilation and drainage systems) between adjacent compartments has been achieved,

- the balance between fixed fire extinguishing and manual firefighting that may be applied at the facility. This should include accessibility considerations during manual firefighting.
- the firefighting strategies and how they are assured (written procedures, training provision, frequency of emergency exercises, key learning from past events, exercises, etc., to the extent practical).

04.4.3 Administrative and organisational fire protection issues

The administrative and organisational aspects of fire safety are important considerations in addition to design provisions and physical measures. Specifically, fire protection can significantly rely on organisational and administrative arrangements, for example, in fire detection and suppression.

The following WENRA SRLs correspond to administrative and organisational fire protection issues in NPPs:

WENRA SV 5.10: Adequate organisational arrangements, including minimum staffing levels, equipment, fitness for duty, skills and training, and procedures shall be in place to ensure safety, as identified by the hazard assessment.

WENRA SV 6.11: In order to prevent fires, procedures shall be established to control and minimize the amount of combustibles and the potential ignition sources. In order to ensure the operability of the fire protection measures, procedures shall be established and implemented. They shall include examination, inspection, maintenance and testing of fire barriers, fire detection, alarm features and extinguishing systems.

WENRA SV 6.12: Written procedures that clearly define the responsibility and actions of staff in responding to any fire in the plant shall be in place and kept up to date. A firefighting strategy shall be developed, kept up-to date, and appropriate training provided, to cover each area in which a fire might affect SSCs important to safety.

WENRA SV 6.13: If plant internal firefighting capability is supported by offsite resources, there shall be proper coordination between the plant personnel and the offsite response group, in order to ensure that the latter is familiar with the hazards of the plant. Emergency training, drills and exercises shall be performed.

WENRA SV 6.14: If plant personnel are required for firefighting, their organization, minimum staffing level, equipment, fitness requirements, skills and training shall be documented and their adequacy shall be confirmed by a competent person.

In addition, the following WENRA SRLs correspond to administrative and organisational fire protection issues in research reactors:

WENRA S 5.1: In order to prevent fires, procedures shall be established to control and minimize the amount of combustible materials and minimize the potential ignition sources that may affect items important to safety. In order to ensure the operability of the fire protection measures, procedures shall be established and implemented. They

shall include inspection, maintenance and testing of fire barriers, fire detection and extinguishing systems.

WENRA S 6.1: The licensee shall implement adequate arrangements for controlling and ensuring fire safety, as identified by the fire hazard analysis.

WENRA S 6.2: Written emergency procedures that clearly define the responsibility and actions of site personnel in responding to any fire in the research reactor shall be established and kept up to date. A fire fighting strategy shall be developed, kept up-to date, and trained for, to cover each area in which a fire might affect items important to safety and protection of radioactive materials.

WENRA S 6.3: When reliance for manual fire fighting capability is placed on an offsite resource, there shall be proper coordination between the licensee's response group and the off-site response group, in order to ensure that the latter is familiar with the hazards of the research reactor.

WENRA S 6.4: If site personnel is required to be involved in fire fighting, their organization, minimum staffing level, equipment, fitness requirements, and training shall be documented and their adequacy shall be confirmed by a competent person.

For FCFs, the above SRLs can be considered in the NAR, as they can be considered transferable. Furthermore, IAEA SSR-4, para. 9.44 outlines IAEA expectations for FCFs that “*specific training and drills for operating personnel, internal and external firefighters and other personnel relevant for emergency response shall be provided relevant to their assigned response functions in the event of a fire or explosion at the facility!*” (see requirement 25 of GSR Part 7 [6]). The extent of the fitness for duty, skills, training and retraining programmes shall be in accordance with the potential hazards of the facility and its processes. IAEA SSR-4, para 9.109 to 9.115 provide requirements for FCFs on the expected licensee arrangements for ensuring fire safety, covering but not limited to:

- (a) Application of the principle of defence in depth,
- (b) Control of combustible materials and ignition sources,
- (c) Inspection, maintenance and testing of fire protection measures,
- (d) Establishment of a firefighting capability at the facility,
- (e) Establishment of an emergency response capability and a firefighting capability for the site that is commensurate with the size, complexity and diversity of the site and the hazard potential of the facility,
- (f) Assignment of responsibilities and training and exercising of personnel,
- (g) Assessment of the impact of modifications on fire safety measures.

The NAR should therefore briefly describe

- the firefighting strategy in place, how it is kept up-to date, and how appropriate training is provided, in order to adequately fight any fire that might affect SSCs important to safety in any fire compartment,
- written procedures in place clearly defining responsibility and actions of staff in responding to any fire in the installation and how it is kept up to date,

- the means by which proper coordination between the plant personnel and the offsite response group is achieved, if the plant internal firefighting capability is supported by offsite resources. This includes ensuring that offsite resources are familiar with the hazards of the plant. The activities may involve e.g. conducting emergency training, drills and exercises.
- the firefighting capability, responsibilities and organization (plant internal fire brigade, organisation between onsite and offsite firefighters, etc.)⁶,
- the minimum staffing level for firefighting,
- the availability of suitable firefighting equipment,
- fitness requirements, familiarisation, skills and training for firefighters⁷,
- the firefighting documentation (e.g., building cards with important information about the building, topographical scheme etc.), eventually checklists for chief officer (so that during firefighting the fire brigade does not miss important information about the building),
- how the “design bases” applicable to the fire response organisation are met to ensure the achievement of the fire safety objectives in the facility., including the description of any thresholds that may be applied when considering the deployment (or not) of offsite firefighting capability,
- specific provisions in place for management of a fully developed fire in situations with total loss of access to the installation (e.g. in the event of an external hazard).

⁶ This includes prioritisation of the different responsibilities of onsite firefighting resources, if these resources are expected to also carry out other work.

⁷ This includes e.g. how it is ensured that offsite resources are familiar with the hazards of the nuclear installations and if and how often there are periodic drills with offsite firefighting resources.

05 Passive fire protection

Preventing the spread of those fires which have not been extinguished, thus minimizing their effects on essential plant functions is the third level of defence according to the defence-in-depth principles of nuclear fire safety as covered by the term “passive fire protection”.

The third level of the defence in depth concept is to assume both that fire extinguishing systems fail and that the firefighters do not respond quickly enough which causes fire development. Objectives of this level are to prevent the spread of fires and to limit the quantity of radioactive material involved in the fire. This shall minimize effects and consequences of fires not extinguished, particularly to avoid common cause failures and possible cliff-edge effects.

05.1 NPPs

05.1.1 Prevention of fire spreading (barriers)

The following WENRA SRLs correspond to the prevention of fire spreading through fire barriers in NPPs by passive fire protection means:

WENRA SV 6.4: In accordance with the fire hazard assessment, buildings that contain SSCs important to safety shall be suitably fire resistant and shall maintain their structural integrity after a fire.

WENRA SV 6.5: Use of a fire compartment approach is preferred. The fire resistance rating of the fire barriers of the fire compartment shall be sufficiently high so that the total combustion of the fire load in the compartment can occur without breaching the barriers taking into account the fire hazard analysis. If a fire compartment[1] approach is not practicable, fire cells shall be used and duly justified by the fire hazard analysis. For fire barrier resistance assessment oxygen availability within and oxygen supply to the fire compartment shall be conservatively considered and justified.

According to the safety goals, information should be provided in the NAR on the approach

- for determining the fire barriers forming fire compartment or fire cell boundaries, and
- for assuring thermal and mechanical integrity of the structures.

In addition, the NAR should describe:

- compensatory measures taken to prevent spreading of fire and smoke between adjacent fire cells (HVAC systems, combustible free areas, etc.), and

- the process for justification that the fire barriers remain efficient under temporary operations increasing fire load and/or ignition sources (maintenance, modifications, etc.).

05.1.1.1 Ventilation systems

Ventilation systems are needed in most nuclear installations. They often require penetrations through fire barriers and can therefore undermine their performance.

In the event of fire, changes in pressure and temperature can disrupt this circulation of air and give a rise to uncontrolled transfers of radioactive material within the installation and even into the environment. Furthermore, a fire can damage filters and ventilation ducts and facilitate the transport of radioactive aerosols within the installation and/or to the environment.

The management of ventilation for fire safety therefore requires specific consideration. Objectives are to avoid, on the one hand, the spreading of fire and the risks associated with pyrolysis gases and other unburned material and, on the other hand, to facilitate intervention and control of fire consequences, retaining confinement of radioactive materials. These objectives must be analysed in some specific areas to demonstrate that they do not unacceptably conflict with other safety requirements (e.g., keeping depressurisation, atmosphere circulation patterns, radiological confinement (filters), etc.).

Ventilation issues strongly depend on the operation and processes in a nuclear facility and therefore should be considered in the NAR.

The following WENRA SRLs correspond specifically to ventilation systems in NPPs:

WENRA SV 6.6: Ventilation systems shall be arranged such that each fire compartment fulfils its segregation purpose in case of fire and designed such that the ventilation of other fire compartments which contain other trains of the safety system is maintained as far as required to fulfil their safety functions.

WENRA SV 6.7: If parts of the ventilation systems (such as connecting ducts, fan rooms and filters) are located outside fire compartments they shall have a fire resistance consistent with the fire hazard analyses or be capable of isolation from fire effects by appropriately rated fire dampers.

The following information on ventilation systems should be provided in the NAR:

- the ventilation systems are suitable and do not compromise building compartmentation nor the availability of redundant trains of safety systems or safety groups,
- each fire compartment containing a redundant train of a safety system or safety group should have ventilation designed such that a fire in one compartment will not propagate fire effects that induce loss of ventilation in another compartment,

- if ventilation features in an adjacent fire compartment s have the same fire resistance rating as the compartment or, alternatively, the fire compartment penetrations should be isolatable by suitably rated fire dampers operating automatically, where appropriate,
- which provisions are in place to maintain segregation between fire compartments in case that a ventilation system serves more than one fire compartment. The means available to prevent the spread of fire and dangerous substances, e.g., toxic, corrosive and/or radioactive fire by-products, to other fire compartments should also be considered.

05.1.2 Access and escape routes

Access and escape provision in the event of fire is another essential aspect for consideration in nuclear installations' fire safety. Access and escape routes often rely on passive fire protection and are needed for firefighting and/or to bring the plant to a safe state.

The following WENRA SRL corresponds to access and escape routes in NPPs:

WENRA SV 5.7: Access and escape routes identified as necessary to bring and maintain the plant in a safe state for the considered design basis event shall be available and safe to use.

With respect to access and escape routes implementation, the NAR should describe:

- the approach and criteria applied to ensure adequate access and escape routes, including those for external fire brigades and plant shift personnel, if necessary/required,
- the provisions to ensure that these routes remain accessible as well as suitably and reliably protected during a fire event.

05.2 RRs

05.2.1 Prevention of fire spreading (barriers)

The following WENRA SRLs correspond to the prevention of fire spreading through fire barriers in research reactors by passive fire protection means:

WENRA S 2.2: Buildings that contain SSCs important to safety shall be suitably fire resistant.

WENRA S 2.3: Buildings that contain equipment that is important to safety shall be subdivided into compartments that segregate such items from fire loads and segregate redundant or diverse trains of a safety system from each other. When a fire compartment approach is not practicable, fire cells shall be used, providing a balance between passive and active means, as justified by fire hazard analysis.

For RRs with a lower risk profile: The NAR should include a global description of the fire compartments and/or cells formed and a description of fire barriers and other means to prevent or delay the spreading of fire.

For RRs with a higher risk profile: According to the safety goals, information should be provided in the NAR on the approach

- for determining the fire barriers forming fire compartment and/or fire cell boundaries, and
- for assuring thermal and mechanical integrity of the structures.

In addition, all research reactors regardless of their profile should provide information on:

- the design and installation of fire barrier elements and improvements that were made over the lifetime of the installation,
- compensatory measures taken to prevent spreading of fire and smoke between adjacent fire cells (HVAC systems, combustible free areas, etc.), and
- the process for justification that the fire barriers remain efficient under temporary operations increasing fire load and / or ignition sources (maintenance, modifications, etc.).

05.2.2 Ventilation systems

Ventilation systems are needed in various nuclear installations, often affecting the strict passive fire protection and therefore need to be considered as an important aspect as well.

In the event of fire, variations of pressure and temperature can disrupt the circulation of air and give rise to uncontrolled transfers of radioactive material within the installation and even to the environment. Furthermore, a fire can cause damage to filters and ventilation ducts and can facilitate the transport of radioactive aerosols within the installation and the release to the environment.

The management of ventilation systems in case of fire therefore requires a specific study and pre-established rules specific to the installation. Objectives are to avoid the spreading of the fire and the risks associated with pyrolytic gases and other unburned material and to facilitate intervention and control of fire consequences in the concerned areas, especially in terms of confinement.

The following WENRA SRLs correspond specifically to ventilation systems in research reactors within the scope of the NAR:

WENRA S 4.4: Ventilation systems shall be arranged such that each fire compartment fully fulfils its segregation purpose in case of fire.

WENRA S 4.5: Parts of ventilation systems (such as connecting ducts, fan rooms and filters) that are located outside fire compartments shall have the same fire resistance as the compartment or be capable of isolation from it by appropriately rated fire dampers.

The following information should be provided: in the NAR:

- information on the design and installation of ventilation systems (e.g., fire dampers have the same fire resistance as fire compartment, are fire dampers fully functional, ...) which compromise neither building compartmentation nor availability of redundant trains of safety systems, including improvements that were made over the lifetime of the installation,
- [not for **RRs with a lower risk profile**] information showing that fire compartments containing redundant trains of a safety system have a ventilation system designed such that a fire in one safety related fire compartment will not propagate fire effects that induce a loss of ventilation of another safety related fire compartment and that parts of the ventilation system located in an adjacent fire compartment have the same fire resistance rating as the compartment or, alternatively, the fire compartment penetrations are isolated by suitably rated fire dampers operating automatically, where appropriate;
- Information showing that for those ventilation systems serving more than one fire compartment,
 - provisions are in place to maintain the segregation
 - in between fire compartments and
 - for which means are in place to prevent the spread of fire and dangerous material to other fire compartments (e.g. control room), (mainly gaseous fire by-products, e.g. toxic, corrosive, radioactive, etc.).

05.3 WDFs

05.3.1 Prevention of fire spreading (barriers)

Text to be added by WGWD

05.3.1.1 Ventilation systems

Text to be added by WGWD

05.3.2 Access and escape routes

Access and escape provision in the event of fire is another essential aspect for consideration in nuclear installations' fire safety. Access and escape routes often rely on passive fire protection and are needed for firefighting and/or to bring the plant to a safe state.

The following texts should be checked and modified for WDFs

For the different types of nuclear facilities in the scope of the TPR, the corresponding WENRA SRLs are provided in the following for nuclear reactor installations, but are in principle also applicable to non-reactor installations, including WDFs.

The following WENRA SRLs correspond to access and escape routes in NPPs:

WENRA SV 5.7: Access and escape routes identified as necessary to bring and maintain the plant in a safe state for the considered design basis event shall be available and safe to use.

In addition, the following WENRA SRLs correspond to access and escape routes in research reactors:

WENRA S 2.5: Access and escape routes for fire fighting and operating personnel shall be available.

For WDFs, the above SRLs SV 5.7 and S 2.5 should be considered in the NAR.

With respect to access and escape routes implementation, the NAR: should describe:

- the approach and criteria applied to ensure adequate access and escape routes, including those for external fire brigades and plant shift personnel, if necessary/required,
- the provisions to ensure that these routes remain accessible as well as suitably and reliably protected during a fire event.

05.4 FCFs

05.4.1 Prevention of fire spreading (barriers)

WENRA SRLs have not yet been developed specifically with respect to prevention of fire spreading for fuel cycle facilities.

The following WENRA SRLs correspond to the prevention of fire spreading through fire barriers in NPPs by passive fire protection means:

WENRA SV 6.4: In accordance with the fire hazard assessment, buildings that contain SSCs important to safety shall be suitably fire resistant and shall maintain their structural integrity after a fire.

WENRA SV 6.5: Use of a fire compartment approach is preferred. The fire resistance rating of the fire barriers of the fire compartment shall be sufficiently high so that the total combustion of the fire load in the compartment can occur without breaching the barriers taking into account the fire hazard analysis. If a fire compartment[1] approach is not practicable, fire cells shall be used and duly justified by the fire hazard analysis. For fire barrier resistance assessment oxygen availability within and oxygen supply to the fire compartment shall be conservatively considered and justified.

For FCFs, the WENRA SRLs SV 6.4 and SV 6.5 should be considered: buildings that contain SSCs important to safety shall be suitably fire resistant and shall maintain their structural integrity after a fire. The interpretation and provision of fire compartmentation in FCFs should be commensurate with the fire and radiological risks associated with the facilities.

According to the safety goals, information should be provided in the NAR on the approach

- for determining the fire barriers forming fire compartment or fire cell boundaries, and
- for assuring thermal and mechanical integrity of the structures.

In addition, the NAR should describe:

- compensatory measures taken to prevent spreading of fire and smoke between adjacent fire cells (HVAC systems, combustibles free areas, etc.), and
- the process for justification that the fire barriers remain efficient under temporary operations increasing fire load and/or ignition sources (maintenance, modifications, etc.).

05.4.1.1 Ventilation systems

Ventilation systems are needed in most nuclear installations. They often require penetrations through fire barriers and can therefore undermine their performance.

In the event of fire, changes in pressure and temperature can disrupt this circulation of air and give a rise to uncontrolled transfers of radioactive material within the installation and even into the environment. Furthermore, a fire can damage filters and ventilation ducts and facilitate the transport of radioactive aerosols within the installation and/or to the environment.

The management of ventilation for fire safety therefore requires specific consideration. Objectives are to avoid, on the one hand, the spreading of fire and the risks associated with pyrolysis gases and other unburned material and, on the other hand, to facilitate intervention and control of fire consequences, retaining confinement of radioactive materials. These objectives must be analysed in some specific areas to demonstrate that they do not unacceptably conflict with other safety requirements (e.g., keeping depressurisation, atmosphere circulation patterns, radiological confinement (filters), etc.).

Ventilation issues strongly depend on the operation and processes in a nuclear facility and therefore should be considered in the NAR.

WENRA SRLs have not yet been developed specifically with respect to issues concerning ventilation systems for fuel cycle facilities.

The following WENRA SRLs correspond to preventing fire spreading through ventilation systems in NPPs by passive fire protection means:

WENRA SV 6.6: Ventilation systems shall be arranged such that each fire compartment fulfils its segregation purpose in case of fire and designed such that the ventilation of other fire compartments which contain other trains of the safety system is maintained as far as required to fulfil their safety functions.

WENRA SV 6.7: If parts of the ventilation systems (such as connecting ducts, fan rooms and filters) are located outside fire compartments they shall have a fire resistance consistent with the fire hazard analyses or be capable of isolation from fire effects by appropriately rated fire dampers.

For FCFs, WENRA SRLs SV 6.6 and SV 6.7 should be interpreted in the context of the fire compartmentation that may be practicable and the provision of safety measures as redundant safety groups in these facilities.

Information on ventilation systems should be provided in the NAR to demonstrate that:

- the ventilation systems are suitable and do not compromise building compartmentation nor the availability of redundant trains of safety systems or safety groups,
- each fire compartment containing a redundant train of a safety system or safety group should have ventilation designed such that a fire in one compartment will not propagate fire effects that induce loss of ventilation in another compartment,
- if ventilation features in an adjacent fire compartment s have the same fire resistance rating as the compartment or, alternatively, the fire compartment penetrations should be isolatable by suitably rated fire dampers operating automatically, where appropriate,
- which provisions in place to maintain segregation between fire compartments in case that a ventilation system serves more than one fire compartment. The means available to prevent the spread of fire and dangerous substances e.g. toxic, corrosive and/or radioactive fire by-products to other fire compartments should also be considered.

05.4.2 Access and escape routes

Access and escape provision in the event of fire is another essential aspect for consideration in nuclear installations' fire safety. Access and escape routes often rely on passive fire protection and are needed for firefighting and/or to bring the plant to a safe state.

For the different types of nuclear facilities in the scope of the TPR, the corresponding WENRA SRLs are provided in the following for nuclear reactor installations, but are in principle also applicable to non-reactor installations, including FCFs.

The following WENRA SRLs correspond to access and escape routes in NPPs:

WENRA SV 5.7: Access and escape routes identified as necessary to bring and maintain the plant in a safe state for the considered design basis event shall be available and safe to use.

In addition, the following WENRA SRLs correspond to access and escape routes in research reactors:

WENRA S 2.5: Access and escape routes for fire fighting and operating personnel shall be available.

For FCFs, the above SRLs SV 5.7 and S 2.5 should be considered in the NAR.

With respect to access and escape routes implementation, the NAR: should describe:

- the approach and criteria applied to ensure adequate access and escape routes, including those for external fire brigades and plant shift personnel, if necessary/required,
- the provisions to ensure that these routes remain accessible as well as suitably and reliably protected during a fire event.

06

Fire safety analyses

Fire safety analyses are an important part of a nuclear facility's safety demonstration.

For nuclear power plants, there are formal requirements for conducting both, deterministic fire hazard analyses (FHA) and probabilistic fire risk assessment (Fire PSA).

For research reactors there are formal requirements for conducting deterministic fire hazard analyses (FHA). There are no formal requirements for a Fire PSA for research reactors, but for some RRs with a higher risk profile a Fire PSA is still applied.

For fuel cycle and waste and decommissioning facilities, only general requirements for conducting fire safety analyses do exist. PSA as such is not currently applied. However, in this context, it is important to note that IAEA SSR-4 requirement 20 applies. This requirement states that *a comprehensive safety analysis shall be carried out in the design process for a nuclear fuel cycle facility. Systematic and recognized methods of deterministic analysis shall be used, complemented by probabilistic assessments where appropriate, in accordance with a graded approach. The purpose of the analysis shall be to ensure that the design provides an adequate level of safety and meets the required design acceptance criteria.*

06.1 NPPs

06.1.1 General

The following WENRA SRL specifically corresponds to fire safety analyses for NPPs:

WENRA SV 2.1: All internal hazards that might affect SSCs important to safety shall be identified. Justification shall be provided that the compiled list of internal hazards to be considered is complete and relevant to the design of the nuclear power plant. Any location where permanent or temporary hazard sources are present shall be taken into account.

Control and mitigation of fire hazards in a nuclear installation requires examination of credible fires. Structures, systems and components (SSCs) important to safety should be protected against fire in order to achieve the safety objectives.

Consistent with the defence in depth principles, fire protection means implemented according to fire safety analyses should address the defence in depth objectives stated in Chapter 3.

The fire safety analysis should provide justification of the fire protection means implemented in order to meet the applicable technical criteria. Based on the functional requirements

associated with those SSCs to be protected, the licensee should therefore justify that the technical performance of the fire protection features ensures that the safety objectives will be met.

The NAR should provide to the extent practical and as far as required information on the scope of the fire analyses, e.g. a formal deterministic fire hazard analysis (FHA), probabilistic fire risk assessment (Fire PSA), the use of a combination of both, or others (e.g., engineering judgement). In line with chapter 01.4 and 01.5, for any of these approaches, the following should be briefly summarised:

- The safety objectives and the SSCs to be protected against fire, including:
 - the specific safety objectives to be met and the safety functions that have to be protected,
 - the methodology used to identify SSCs necessary to fulfil the required safety functions,
 - for each safety function, the key SSCs to be protected,
 - the requirements for SSCs to ensure their required safety functions and the related fire damage criteria.
- Fire phenomena and their analysis:
 - Methods, tools and data used for the quantification of direct (e.g., temperature, pressure, soot) and indirect fire effects (e.g. by fire suppression), their impact on nuclear safety⁸.

The following information should be provided in the NAR as applicable:

- Performance criteria and treatment of uncertainties, including: the approach for defining such performance criteria according to the fire phenomena considered and the state-of-the art,
- a description of performance criteria (e.g., thermal resistance, behaviour under pressure) applied to fire protection features (e.g., fire doors, fire dampers, cable protections).

Information on the following aspects with respect to uncertainty and sensitivity considerations should be given in the NAR:

- Consideration of uncertainties when selecting fire protection means to be implemented,
- description on how sensitivities of different parameters are provided within the analysis.

If fire modelling tools such as computational codes are used to adequately simulate a fire scenario, validation and verification (V&V) of the tool(s) applied and its (their) applicability to

⁸ The methods and tools applied for quantification of fire effects should be appropriate to the fire phenomena's complexity and the severity of the potential consequences.

representative scenarios in the nuclear installation being investigated are required to ensure e.g. the reliability of the results, the related uncertainties, and to identify limitations of the model(s).

As far as applicable, the following information on the V&V of modelling tools applied should be briefly provided in the NAR:

- Use of feedback for definition of fire scenarios and calculation of reliability data,
- Identification of research and development needs for determining fire properties, SSC failure criteria, or fire protection features performance criteria,
- Description of the fire research and development results used in support of fire safety analyses,
- If computational fire analysis tools (e.g. fire simulation codes) have been applied in support studies, the reliability of the results, related uncertainties, and consideration of model limitations.

06.1.1.1 Event combinations

Following the Fukushima nuclear accidents, consideration of event combinations including fire has been recognised as a key part of a nuclear facility's safety demonstration.

The following WENRA SRL corresponds to the consideration of event combinations:

WENRA E 6.1: Credible combinations of individual events, including internal and external hazards, that could lead to anticipated operational occurrences or design basis accidents, shall be considered in the design. Deterministic and probabilistic assessment as well as engineering judgement can be used for the selection of the event combinations.

As outlined in IAEA SSG-64, fires may not only occur as single (individual) events, but also in combination with other hazards (this is often referred to as 'combined hazards'). Three types of such hazard combinations are in principle possible:

- **Consequential (subsequent) events:** An initial event, e.g. an external or internal hazard, results in another event, e.g. an internal hazard. Examples involving fire are a seismic event and subsequent internal fire, or internal fire and subsequent internal flooding.
- **Correlated events:** Two or more events, at least one of them representing an internal fire, which occur as a result of a common cause. The common cause can be any anticipated event including an external hazard or might be due to an unanticipated dependency. The two or more events connected by this common cause could occur simultaneously. Examples include a tsunami as the common cause for external flooding, internal flooding and internal fire as three potential correlated events, and electromagnetic interference as the common cause for station blackout and internal fire as the two correlated events.

- **Unrelated (independent) events:** An initial event, e.g. an external or internal hazard, occurs independently from an internal fire without any common cause. These events occur simultaneously or affect the installation at the same time interval⁹.

The following information on the treatment of combined fire events in fire safety analyses should be provided in the NAR:

- The event combinations considered in the fire safety analysis.
- The rules and/or criteria applied to consider such event combinations.

06.1.2 Deterministic fire hazard analysis (FHA)

For nuclear reactor facilities in the scope of the TPR, the corresponding WENRA SRLs are provided in the following with respect to the (deterministic) fire hazard analysis (FHA) issue:

The following WENRA SRLs specifically correspond to the deterministic FHA for NPPs:

WENRA SV 6.1: A fire hazard analysis shall be developed on a deterministic basis, covering at least:

- *all plant operational states of normal operating and shutdown, a single fire and consequential spread;*
- *any plant location where fixed or transient combustible material is present;*
- *credible combinations (see RL E6.1) of fire and other events (including external hazards).*

The deterministic analysis shall be complemented by PSA in order to evaluate the fire protection arrangements and to identify risks caused by fires.

WENRA SV 6.2: The extent of reliance on on-site or off-site fire brigades shall be shown to be adequate in the fire hazard analysis.

It is important to consider all plant operational states, including shutdown states in the FHA.

The analysis should prove that the technical performance levels are fulfilled. The licensee should identify the required safety functions to be protected, the associated requirements, the technical performance levels of protection measures against fire and describe the following in the NAR:

- the requirements on the scope, assumptions and methodologies applied to perform the FHA,
- the adequacy of the performance levels in relation to the safety objectives,
- how the performance levels are achieved through the adopted design and layout.

The different modes of transfer and deposition mechanisms inside buildings and ventilation systems need to be considered with specific attention given to leakages into the environment.

⁹ Damages caused by the first event still affect the installation when the second event occurs.
RHWG Report to WENRA – TPR II Technical Specification

At least the approach and data used for quantification of radiological releases due to the fire should be provided.

The performance level of fire protection features is defined according to specific conditions. The analysis shall be reviewed in case of any changes to conditions and/or assumptions. It shall be updated in line with changes to the installation and within safety reassessments required by regulations.

The NAR should therefore describe

- the management of changes to the fire safety analysis in the context of Periodic Safety Reviews (PSRs),
- the approach to ensure that the FHA is updated to reflect any significant modifications to the nuclear facilities.

06.1.3 Probabilistic fire risk analysis (Fire PSA)

The following WENRA SRL specifically corresponds to PSA for NPPs:

WENRA O 1.1: For each plant design, a specific PSA shall be developed for level 1 and level 2, considering all relevant operational states, covering fuel in the core and in the spent fuel storage and all relevant internal and external initiating events. External hazards shall be included in the PSA for level 1 and level 2 as far as practicable, taking into account the current state of science and technology. If not practicable, other justified methodologies shall be used to evaluate the contribution of external hazards to the overall risk profile of the plant.

Internal fires in a nuclear facility can damage plant components and initiate accident sequences that might lead to radioactive releases internally to the plant or to the environment. A probabilistic safety analysis (PSA) aims at calculating the frequency of fire accidents that might lead to severe consequences. For nuclear power plants, it is good practice to assess safety on the basis of studies performed regarding core and fuel damage frequency (CDF and FDF) in Level 1 PSA and frequencies for large or large and early radioactive releases (LRF/LERF) in Level 2 PSA. Fire PSA is part of PSA according to the state of the art.

Fire PSAs and their results provide an opportunity to verify that provisions (prevention and mitigation) against fire accidents are sufficient to reduce the risks induced by fire in the installation. In general, insights from Fire PSA provide indications on weaknesses in the fire safety of the installation and the benefits of potential improvements.

The following information should be provided with respect to Fire PSA in the NAR as far as applicable:

- Has a Fire PSA performed for the installation, and up to which level?
- As far as applicable, which global methodology has been applied (short description)?
- If applicable, are the following issues considered in Fire PSA (with a short description):

- Collection of operating experience on internal fires,
- As built / as operated plant: identification of fire sources, plant walkdowns, etc.,
- Identification of buildings and fire compartments relevant for Fire PSA,
- Fire development, including fire detection and suppression (systems and manual actions),
- Fire spreading to multiple fire compartments,
- Combinations of fires and other events,
- Fire impact on SSCs and on human resources,
- Fire specific accident procedures,
- If applicable, what criteria are applied for assessing the acceptability of the Fire PSA results?
- If applicable, are the Fire PSA results reviewed by the safety authority and when?
- If applicable are there examples of Fire PSA results and insights and plant modifications based on Fire PSA?
- If no Fire PSA has been developed yet, is it planned in near future?

06.2 RRs

06.2.1 General

Since there are no equivalent SRL in Issue S, in this Section the SRL from Issue SV will be used.

The following WENRA SRLs specifically correspond to fire safety analyses for RRs:

WENRA SV 2.1: All internal hazards that might affect SSCs important to safety shall be identified. Justification shall be provided that the compiled list of internal hazards to be considered is complete and relevant to the design of the nuclear power plant. Any location where permanent or temporary hazard sources are present shall be taken into account.

Control and mitigation of fire hazards in a nuclear installation requires examination of credible fires and of structures, systems and components (SSCs) important to safety to be protected in order to achieve the safety objectives.

Consistently with the defence in depth principles, fire protection means implemented based on this examination is aiming at:

- Minimizing the likelihood of fires by
 - removing, minimizing and segregating fire loads (fixed and transient ones), as far as reasonably practicable,
 - eliminating potential ignition sources to the extent practicable; otherwise, strict control of any such sources,
 - segregating of ignition sources from fuel sources,
- Mitigating the fire by

- timely detection and extinguishing of fires,
- preventing the spread of fires,
- Mitigating secondary fire effects and maintain safety functions identified as necessary in the event of fire including mitigation of the radiological consequences of the fire (protecting relevant SSCs against the effects of the hazard and limiting its consequences to achieve the safety objectives).

WENRA SV 3.1: For all internal hazards that might affect SSCs important to safety, hazard assessments shall be performed using deterministic and, as far as practicable, probabilistic methods as well as engineering judgement. Assessment shall account for all individual hazard sources and corresponding direct and credible indirect effects.

WENRA SV 3.2: Internal hazard sources shall, as far as reasonably practicable, be removed or minimised until it can be shown that:

- *the most severe physically possible impact is incapable of posing a threat to SSCs important to safety or*
- *the occurrence of an event induced by a hazard source is extremely unlikely with a high degree of confidence.*

WENRA SV 3.3: The hazard assessment, applied methods and input data as well as the utilization of the results, including implementation of actions, shall be justified, documented and kept up to date.

The fire safety analysis should provide justification of the fire protection means implemented for meeting justified technical criteria. Based on the functional requirements associated with those SSCs to be protected, the licensee should therefore justify that the technical performance of the fire protection features ensures that the safety objectives will be met.

Information on the scope of the fire safety analyses based on a deterministic fire hazard analysis (FHA) or, as a minimum, an engineering assessment (**for lower risk RRs**) should be provided. The following relevant information for any of these approaches should be briefly described:

- Safety objectives and SSCs to be protected
 - The safety objectives to be met and the safety functions that have to be protected against fire should be provided.
 - The methodology used to identify SSCs necessary to fulfil the required safety functions that have to be protected against fire should be described.
 - For each safety function, a list of the main SSCs to be protected from fire should be provided.
 - The requirements for SSCs to ensure their required safety functions and the related fire damage criteria should be provided.
- Fire phenomena considered and quantification

In the location where a fire starts, it can cause direct and indirect effects (e.g., temperature increase, a pressure rise, turbulent flows, release of fire by-products such as hot gases,

(toxic or corrosive) smoke and soot). Even far from the fire, such fire by-products can cause SSC malfunction different from that caused by the thermal fire effects. It is important to consider the entire direct and indirect fire effects,

- a) to assess the vulnerability of SSCs needed to be protected from fire and,
- b) for a suitable design and layout of fire protection means.

Therefore, the following information should be provided as far as applicable:

- Description of the fire phenomena considered in fire safety analyses considered for to analysis of direct and indirect fire effects,
- Consideration of these fire effects in the safety demonstration.

The methods and tools applied for fire effects quantification need to be appropriate to the studied phenomena complexity. Fire simulation tools should be used within their fields of validation.

If fire effect quantification is based on experimental results, these results shall be obtained under conditions sufficiently representative of the scenarios to be quantified. Conclusions drawn from experimental results should be analysed to ensure they match the scenario.

In some specific cases (e.g., if neither adapted calculation methods nor experimental data are available), expert judgment may be considered.

The following information should be provided as applicable:

- Description of methods, tools and data used for the quantification of fire effects (e.g. temperature, pressure, soot);
 - Description the validation and verification (V&V) process applied to ensure qualification and adequacy of tools applied to quantify fire effects.
- Performance criteria to be met and uncertainties, as applicable, when fire calculations are performed.

Given the vulnerability of the targets to direct and indirect fire effects, performance criteria to be met with respect to the fire protection features should be provided:

- Approach for defining such performance criteria according to the fire phenomena considered and the state-of-the art,
- Performance criteria (e.g., thermal resistance, behaviour under pressure) applied to fire protection features (e.g., fire doors, fire dampers, cable protections).

The risk analysis approach requires to assess the effects of a fire and to compare them with the fire protection features' performance criteria while notably considering the failure conditions of target SSCs to protect.

Modelling fire scenarios and the assessment of the scenarios' consequences involve uncertainties related to input data used to model the scenarios, values associated with these data, tools used to determine fire effects, models implemented, etc. These uncertainties shall be assessed and considered.

When sensitivity analyses have been performed, information regarding the following aspects should be given:

- Consideration of uncertainties when selecting fire protection means to be implemented,
- Description on how sensitivities of different parameters are provided within the analysis.

If fire modelling tools such as computational codes are used to adequately simulate a fire scenario, validation and verification (V&V) of the tool(s) applied and its (their) applicability to representative scenarios in the nuclear installation being investigated are required to ensure e.g. the reliability of the results, the related uncertainties, and to identify limitations of the model(s).

As far as applicable, the following information on the V&V of modelling tools applied should be briefly provided in the NAR:

- the use of feedback for definition of fire scenarios and calculation of reliability data,
- the identification of research and development needs for determining fire properties, SSC failure criteria, or fire protection features performance criteria,
- a description of the fire research and development results used in support of fire safety analyses,
- if computational fire analysis tools (e.g. fire simulation codes) have been applied in support studies, the reliability of the results, related uncertainties, and consideration of model limitations.

06.2.1.1 Event Combinations

Following the Fukushima nuclear accidents, consideration of event combinations including fire has been recognised as a key part of a nuclear facility's safety demonstration.

The following WENRA SRL corresponds to the consideration of event combinations:

WENRA E 6.1: Credible combinations of individual events, including internal and external hazards, that could lead to anticipated operational occurrences or design basis accidents, shall be considered in the design. Deterministic assessment and probabilistic methods as well as engineering judgement can be used for the selection of the event combinations.

Fires do not only occur as single (individual) events, but also as an event combination of hazards (so called combined hazards). Three types of such event combinations of hazards are in principle possible to be considered:

- **Consequential (subsequent) events:** An initial event, e.g. an external or internal hazard, results in another event, e.g. an internal hazard. Examples involving fire are a seismic event and subsequent internal fire, or internal fire and subsequent internal flooding.
- **Correlated events:** Two or more events, at least one of them representing an internal fire, which occur as a result of a common cause. The common cause can be any anticipated event including an external hazard or might be due to an unanticipated dependency. The two or more events connected by this common cause could occur simultaneously. Examples include a tsunami as the common cause for external flooding, internal flooding and internal fire as three potential correlated events, and electromagnetic interference as the common cause for station blackout and internal fire as the two correlated events.
- **Unrelated (independent) events:** An initial event, e.g. an external or internal hazard, occurs independently from an internal fire without any common cause. These events occur simultaneously or affect the installation at the same time interval¹⁰.

The following information on the treatment of combined fire events in fire safety analyses should be provided in the NAR:

- which combinations of events are considered in fire safety analysis,
- rules/criteria applied to consider such event combinations.

06.2.2 Deterministic fire hazard analysis (FHA) [RRs with a higher risk profile]

The following WENRA SRLs specifically correspond to the FHA for research reactors:

WENRA S 3.1: A fire hazard analysis shall be carried out and kept updated to demonstrate that the fire safety objectives are met, that the fire design principles are satisfied, that the fire protection measures are appropriately designed and that any necessary administrative provisions are properly identified.

WENRA S 3.2: The fire hazard analysis shall be developed on a deterministic basis, covering at least:

- ***For all normal operating and shutdown states, a single fire and consequential spread, anywhere that there is fixed or transient combustible material;***
- ***Consideration of credible combination of fire and other PIEs likely to occur independently of a fire;***
- ***fire hazards due to experiments.***

¹⁰ Damages caused by the first event still affect the installation when the second event occurs.
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WENRA S 3.3: The fire hazard analysis shall demonstrate how the possible consequential effects of fire and extinguishing systems operation have been taken into account.

Ensuring that safety in the event of fire in a nuclear installation is based on the defence in depth approach, which shall be applied for all research reactor operational states, including shutdown states. It is therefore necessary to describe the provisions considered to meet the safety objectives and to verify whether they are sufficient.

The fire safety analysis shall be based on the verification that the technical performance levels, justified through a hazard analysis, are fulfilled. The licensee should identify the required safety functions to be protected, the associated requirements, the technical performance levels of protection measures against fire and to demonstrate:

- the adequacy of these performance levels in relation to the safety objectives, and
- how they are achieved by the adopted design and layout: Justification of the provisions, therefore compliance with technical performance criteria with calculation of the potential radiological consequences of a fire only for verification.

The following information regarding the FHA should be provided in the NAR:

- guidance used, if applicable
- when and how often FHA is performed,
- the different steps of the FHA,
- elements required to perform the FHA in addition to the description of the installation's characteristics (dimensions, organization of premises, layout, processes, etc.),
- rules and justifications used to consider the absence of fire in specific situations,
- scenarios analysed in the FHA and the technical elements used to justify that they are the most relevant (bounding scenarios),
- use of experience feedback in the frame of the FHA,
- in case fire spreading from an initial fire compartment to adjacent ones is not prevented to the extent practical by suitable and reliable fire protection means in place, how the consequences are mitigated to ensure that the required safety functions are not inadmissibly impaired.

The different modes of transfer and deposition mechanisms inside buildings and ventilation systems need to be considered with specific attention given to leakages into the environment. At least the approach and data used for quantification of radiological releases due to the fire should be provided.

The performance level of fire protection features is defined according to specific conditions. The analysis shall be reviewed in case of any condition change. It shall be updated in line with changes to the installation and within safety reassessments required by regulations.

The NAR should describe:

- how changes regarding fire safety analysis are considered within Periodic Safety Reviews,
- how the FHA is updated to reflect any significant modifications that occur.

06.2.3 Probabilistic fire risk analysis (Fire PSA)

There are no formal requirements for a Fire PSA for research reactors, but for some RRs with a higher risk profile a Fire PSA is still applied.

The following information should be provided with respect to Fire PSA in the NAR as far as applicable:

- Has a Fire PSA performed for the installation, and up to which level?
- As far as applicable, which global methodology has been applied (short description)?
- If applicable, are the following issues considered in Fire PSA (with a short description):
 - Collection of operating experience on internal fires,
 - As built / as operated plant: identification of fire sources, plant walkdowns, etc.,
 - Identification of buildings and fire compartments relevant for Fire PSA,
 - Fire development, including fire detection and suppression (systems and manual actions),
 - Fire spreading to multiple fire compartments,
 - Combinations of fires and other events,
 - Fire impact on SSCs and on human resources,
 - Fire specific accident procedures,
 - If applicable, what criteria are applied for assessing the acceptability of the Fire PSA results?
 - If applicable, are the Fire PSA results reviewed by the safety authority and when?
 - If applicable are there examples of Fire PSA results and insights and plant modifications based on Fire PSA?
 - If no Fire PSA has been developed yet, is it planned in near future?

06.3 WDFs

06.3.1 General

Text to be added by WGWD

06.3.1.1 Event Combinations

The following texts to be checked and modified by WGWD

Following the Fukushima nuclear accidents, consideration of event combinations including fire has been recognised as a key part of a nuclear facility's safety demonstration.

The following WENRA SRLs specifically correspond to the consideration of event combinations:

WENRA E 6.1: Credible combinations of individual events, including internal and external hazards, that could lead to anticipated operational occurrences or design basis accidents, shall be considered in the design. Deterministic and probabilistic assessment as well as engineering judgement can be used for the selection of the event combinations.

For WG facilities, the above SRL should be considered as appropriate.

As outlined in IAEA SSG-64, fires may not only occur as single (individual) events, but also in combination with other hazards (this is often referred to as 'combined hazards'). Three types of such hazard combinations are in principle possible:

- **Consequential (subsequent) events:** An initial event, e.g. an external or internal hazard, results in another event, e.g. an internal hazard. Examples involving fire are a seismic event and subsequent internal fire, or internal fire and subsequent internal flooding.
- **Correlated events:** Two or more events, at least one of them representing an internal fire, which occur as a result of a common cause. The common cause can be any anticipated event including an external hazard or might be due to an unanticipated dependency. The two or more events connected by this common cause could occur simultaneously. Examples include a tsunami as the common cause for external flooding, internal flooding and internal fire as three potential correlated events, and electromagnetic interference as the common cause for station blackout and internal fire as the two correlated events.
- **Unrelated (independent) events:** An initial event, e.g. an external or internal hazard, occurs independently from an internal fire without any common cause. These events occur simultaneously or affect installation at the same time interval¹¹.

The following information on the treatment of combined fire events in fire safety analyses should be provided in the NAR:

- The event combinations considered in the fire safety analysis,
- The rules and/or criteria applied to consider such event combinations.

06.3.2 Deterministic fire hazard analysis (FHA)

The following texts need to be modified by WGWD, perhaps the chapter should be titled only "fire safety analysis"

¹¹ Damages caused by the first event still affect the installation when the second event occurs.
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The following WENRA SRLs specifically correspond to FHA for NPPs:

WENRA SV 6.1: A fire hazard analysis shall be developed on a deterministic basis, covering at least:

- all plant operational states of normal operating and shutdown, a single fire and consequential spread;***
- any plant location where fixed or transient combustible material is present;***
- credible combinations (see RL E6.1) of fire and other events (including external hazards).***

The deterministic analysis shall be complemented by PSA in order to evaluate the fire protection arrangements and to identify risks caused by fires.

WENRA SV 6.2: The extent of reliance on on-site or off-site fire brigades shall be shown to be adequate in the fire hazard analysis.

The following WENRA SRLs specifically correspond to FHA for RRs:

WENRA S 3.1: A fire hazard analysis shall be carried out and kept updated to demonstrate that the fire safety objectives are met, that the fire design principles are satisfied, that the fire protection measures are appropriately designed and that any necessary administrative provisions are properly identified.

WENRA S 3.2: The fire hazard analysis shall be developed on a deterministic basis, covering at least:

- For all normal operating and shutdown states, a single fire and consequential spread, anywhere that there is fixed or transient combustible material;***
- Consideration of credible combination of fire and other PIEs likely to occur independently of a fire;***
- Fire hazards due to experiments.***

WENRA S 3.3: The fire hazard analysis shall demonstrate how the possible consequential effects of fire and extinguishing systems operation have been taken into account.

The following WENRA SRLs specifically correspond to fire safety analyses for WDFs:

WENRA S- 24: The licensee shall identify and classify structures, systems and components important to safety (SSCs), applying a graded approach.

WENRA S-28: The design of the facility shall take into account all relevant postulated initiating events (PIEs), depending on the storage characteristics. A list of potential PIE is provided in the appendix.

WENRA DE-46: No decommissioning activity shall be undertaken without a prior assessment of its impact on safety taking into account the postulated initiating events with internal causes included in the safety case for decommissioning. Due consideration shall be given to different decommissioning activities executed in parallel which might adversely affect safety of each other.

WENRA S-25: The licensee shall address the ageing of SSCs and safety features of facilities for the storage of spent fuel and waste by establishing, if necessary, provisions for their maintenance, testing and inspection. Results derived from this program shall be used to review the adequacy of the design at appropriate intervals.

WENRA P-40: The licensee shall make design provisions for maintenance, testing, and inspection of Structures, Systems and Components (SSCs).

WENRA P-39: The licensee shall identify and classify Structures, Systems and Components (SSCs) in accordance with their importance for both operational safety and product quality, applying a graded approach.

WENRA P-53: The licensee shall conduct a maintenance, periodic testing and inspection programme according to written procedures in order to ensure that SSCs are able to function in accordance with the design intents and safety requirements.

WENRA P-54: The licensee shall ensure that the programme for maintenance, periodic testing and inspection of SSCs is in accordance with the facility safety case

WENRA DE-30: SSCs may be re-classified as they change in importance to safety in the course of decommissioning activities. The licensee shall reflect this re-classification in the safety case.

The analysis should prove that the technical performance levels are fulfilled. The licensee should identify the required safety functions to be protected, the associated requirements, the technical performance levels of protection measures against fire and describe in the NAR:

- the requirements on the scope, assumptions and methodologies applied to perform the FHA,
- the adequacy of the performance levels in relation to the safety objectives,
- how the performance levels are achieved through the adopted design and layout.

The different modes of transfer and deposition mechanisms inside buildings and ventilation systems need to be considered with specific attention given to leakages into the environment. At least the approach and data used for quantification of radiological releases due to the fire should be provided.

The performance level of fire protection features is defined according to specific conditions. The analysis shall be reviewed in case of any changes to conditions and/or assumptions. It shall be updated in line with changes to the installation and within safety reassessments required by regulations. The NAR should describe:

- the management of changes to the fire safety analysis in the context of Periodic Safety Reviews (PSRs),
- the approach to ensure that the FHA is updated to reflect any significant modifications to the nuclear facilities.

06.4 FCFs

06.4.1 General

WENRA SRLS have not yet been specifically developed regarding fire safety analyses for fuel cycle facilities.

The following WENRA SRLs correspond to fire safety analyses for NPPs:

WENRA SV 2.1: All internal hazards that might affect SSCs important to safety shall be identified. Justification shall be provided that the compiled list of internal hazards to be considered is complete and relevant to the design of the nuclear power plant. Any location where permanent or temporary hazard sources are present shall be taken into account.

Control and mitigation of fire hazards in a nuclear installation requires examination of credible fires. Structures, systems and components (SSCs) important to safety should be protected against fire in order to achieve the safety objectives.

Consistent with the defence in depth principles, fire protection means implemented according to fire safety analyses should address the defence in depth objectives stated in Chapter 01.4.

WENRA SV 3.1: For all internal hazards that might affect SSCs important to safety, hazard assessments shall be performed using deterministic and, as far as practicable, probabilistic methods as well as engineering judgement. Assessment shall account for all individual hazard sources and corresponding direct and credible indirect effects.

WENRA SV 3.2: Internal hazard sources shall, as far as reasonably practicable, be removed or minimised until it can be shown that:

- ***the most severe physically possible impact is incapable of posing a threat to SSCs important to safety or***
- ***the occurrence of an event induced by a hazard source is extremely unlikely with a high degree of confidence.***

WENRA SV 3.3: The hazard assessment, applied methods and input data as well as the utilization of the results, including implementation of actions, shall be justified, documented and kept up to date.

For FCFs, the above WENRA SRLs should be considered proportionately in the NAR, recognising that the analyses may be based on engineering judgement and/or specific risk assessments. IAEA SSR-4 requirement 22 on analysis of fire and explosion should be considered. This requires that the potential for external and internal fires shall be analysed and the related potential initiating events shall be identified for use in the safety analysis. It also states that specific controls required for fires shall be identified clearly. IAEA SSR-4 paras. 6.77 to 6.79 outline the expectations on postulating initiating events, the consideration of common cause failure, the identification of appropriate limits on flammable materials, fire prevention, protection and control, fire extinguishing systems in the context of criticality hazards, and the availability of items important to safety.

IAEA Safety Guide SSG-5 “Safety of Conversion Facilities and Uranium Enrichment Facilities”, paras. 4.38 to 4.41 provide expectations on fire analyses for uranium conversion, gaseous diffusion and gas centrifuge enrichment facilities.

The fire safety analysis should provide justification of the adopted fire protection means to meet the applicable technical criteria. Based on the functional requirements associated with those SSCs to be protected, the licensee should therefore justify that the technical performance of the fire protection features ensures that the safety objectives will be met.

The NAR should provide to the extent practical and as far as required information on the scope of the fire safety analyses, e.g. a formal deterministic fire hazard analysis (FHA), or others (e.g. engineering judgement). In line with chapters 01.4 and 01.5, for any of these approaches, the following should be briefly summarised in the NAR:

- The safety objectives and the SSCs to be protected against fire, including:
 - the specific safety objectives to be met and the safety functions that have to be protected,
 - the methodology used to identify SSCs necessary to fulfil the required safety functions,
 - for each safety function, the key SSCs to be protected,
 - the requirements for SSCs to ensure their required safety functions and the related fire damage criteria,
- Fire phenomena and their analysis:
 - methods, tools and data used for the quantification of direct (e.g., temperature, pressure, soot) and indirect fire effects (e.g. by fire suppression), their impact on nuclear safety¹².

The following information should be provided in the NAR as applicable:

- Performance criteria and treatment of uncertainties, including: the approach for defining such performance criteria according to the fire phenomena considered and the state-of-the art,
- a description of performance criteria (e.g., thermal resistance, behaviour under pressure) applied to fire protection features (e.g., fire doors, fire dampers, cable protections).

Information on the following aspects with respect to uncertainty and sensitivity considerations should be given in the NAR:

- Consideration of uncertainties when selecting fire protection means to be implemented,
- description on how sensitivities of different parameters are provided within the analysis.

¹² The methods and tools applied for quantification of fire effects should be appropriate to the fire phenomena's complexity and the severity of the potential consequences.

If fire modelling tools such as computational codes are used to adequately simulate a fire scenario, validation and verification (V&V) of the tool(s) applied and its (their) applicability to representative scenarios in the nuclear installation being investigated are required to ensure e.g. the reliability of the results, the related uncertainties, and to identify limitations of the model(s).

As far as applicable, the following information on the V&V of modelling tools applied should be briefly provided in the NAR:

- the use of feedback for definition of fire scenarios and calculation of reliability data,
- the identification of research and development needs for determining fire properties, SSC failure criteria, or fire protection features performance criteria,
- a description of the fire research and development results used in support of fire safety analyses,
- if computational fire analysis tools (e.g. fire simulation codes) have been applied in support studies, the reliability of the results, related uncertainties, and consideration of model limitations.

06.4.1.1 Event Combinations

Following the Fukushima nuclear accidents, consideration of event combinations including fire has been recognised as a key part of a nuclear facility's safety demonstration.

The following WENRA SRL corresponds to the consideration of event combinations:

WENRA E 6.1: Credible combinations of individual events, including internal and external hazards, that could lead to anticipated operational occurrences or design basis accidents, shall be considered in the design. Deterministic and probabilistic assessment as well as engineering judgement can be used for the selection of the event combinations.

For FCFs, the above SRL should be considered as appropriate.

As outlined in IAEA SSG-64, fires may not only occur as single (individual) events, but also in combination with other hazards (this is often referred to as 'combined hazards'). Three types of such hazard combinations are in principle possible:

- **Consequential (subsequent) events:** An initial event, e.g. an external or internal hazard, results in another event, e.g. an internal hazard. Examples involving fire are a seismic event and subsequent internal fire, or internal fire and subsequent internal flooding.
- **Correlated events:** Two or more events, at least one of them representing an internal fire, which occur as a result of a common cause. The common cause can be any anticipated event including an external hazard or might be due to an unanticipated dependency. The two or more events connected by this common cause could occur

simultaneously. Examples include a tsunami as the common cause for external flooding, internal flooding and internal fire as three potential correlated events, and electromagnetic interference as the common cause for station blackout and internal fire as the two correlated events.

- **Unrelated (independent) events:** An initial event, e.g. an external or internal hazard, occurs independently from an internal fire without any common cause. These events occur simultaneously or affect the installation at the same time interval¹³.

The following information on the treatment of combined fire events in fire safety analyses should be provided in the NAR:

- The event combinations considered in the fire safety analysis,
- The rules and/or criteria applied to consider such event combinations.

06.4.2 Deterministic fire hazard analysis (FHA)

To be improved by WGFC, perhaps the chapter should be titled only “fire safety analysis”

The following WENRA SRLs specifically correspond to FHA for NPPs:

WENRA SV 6.1: A fire hazard analysis shall be developed on a deterministic basis, covering at least:

- *all plant operational states of normal operating and shutdown, a single fire and consequential spread;*
- *any plant location where fixed or transient combustible material is present;*
- *credible combinations (see RL E6.1) of fire and other events (including external hazards).*

The deterministic analysis shall be complemented by PSA in order to evaluate the fire protection arrangements and to identify risks caused by fires.

WENRA SV 6.2: The extent of reliance on on-site or off-site fire brigades shall be shown to be adequate in the fire hazard analysis.

The following WENRA SRLs specifically correspond to FHA for NPPs:

WENRA S 3.1: A fire hazard analysis shall be carried out and kept updated to demonstrate that the fire safety objectives are met, that the fire design principles are satisfied, that the fire protection measures are appropriately designed and that any necessary administrative provisions are properly identified.

WENRA S 3.2: The fire hazard analysis shall be developed on a deterministic basis, covering at least:

- *For all normal operating and shutdown states, a single fire and consequential spread, anywhere that there is fixed or transient combustible material;*
- *Consideration of credible combination of fire and other PIEs likely to occur*

¹³ Damages caused by the first event still affect the installation when the second event occurs.
RHWG Report to WENRA – TPR II Technical Specification

- independently of a fire;*
- *Fire hazards due to experiments.*

WENRA S 3.3: The fire hazard analysis shall demonstrate how the possible consequential effects of fire and extinguishing systems operation have been taken into account.

The following WENRA SRLs specifically correspond to FHA for WDFs:

WENRA S- 24: The licensee shall identify and classify structures, systems and components important to safety (SSCs), applying a graded approach.

WENRA S-28: The design of the facility shall take into account all relevant postulated initiating events (PIEs), depending on the storage characteristics. A list of potential PIE is provided in the appendix.

WENRA S-25. The licensee shall address the ageing of SSCs and safety features of facilities for the storage of spent fuel and waste by establishing, if necessary, provisions for their maintenance, testing and inspection. Results derived from this program shall be used to review the adequacy of the design at appropriate intervals.

WENRA P-40: The licensee shall make design provisions for maintenance, testing, and inspection of Structures, Systems and Components (SSCs).

WENRA P-39: The licensee shall identify and classify Structures, Systems and Components (SSCs) in accordance with their importance for both operational safety and product quality, applying a graded approach.

WENRA P-53: The licensee shall conduct a maintenance, periodic testing and inspection programme according to written procedures in order to ensure that SSCs are able to function in accordance with the design intents and safety requirements.

WENRA P-54: The licensee shall ensure that the programme for maintenance, periodic testing and inspection of SSCs is in accordance with the facility safety case.

For FCFs, the above WENRA SRLs for nuclear reactors and waste and decommissioning facilities should be considered to the extent practicable, recognising that the fire analysis in FCFs may at times be based on engineering judgement and/or specific risk assessments. Credible hazard effects for FCFs differ from nuclear power reactors, and reactor operational states may not have a direct read across to FCFs' operational states. As discussed, IAEA SSR-4 requirement 22, paras 6.77 to 6.79 and IAEA Safety Guide SSG-5 paras. 4.38 to 4.41 provide expectations on fire analyses.

It is important to consider all plant operational states, including shutdown states in the FHA.

The analysis should prove that the technical performance levels are fulfilled. The licensee should identify the required safety functions to be protected, the associated requirements, the technical performance levels of protection measures against fire and describe in the NAR:

- the requirements on the scope, assumptions and methodologies applied to perform the FHA,
- the adequacy of the performance levels in relation to the safety objectives,

- how the performance levels are achieved through the adopted design and layout.

The different modes of transfer and deposition mechanisms inside buildings and ventilation systems need to be considered with specific attention given to leakages into the environment. At least the approach and data used for quantification of radiological releases due to the fire should be provided.

The performance level of fire protection features is defined according to specific conditions. The analysis shall be reviewed in case of any changes to conditions and/or assumptions. It shall be updated in line with changes to the installation and within safety reassessments required by regulations. The NAR should describe:

- the management of changes to the fire safety analysis in the context of Periodic Safety Reviews (PSRs),
- the approach to ensure that the FHA is updated to reflect any significant modifications to the nuclear facilities.

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References

International Atomic Energy Agency (IAEA): Fire Safety in the Operation of Nuclear Power Plants, Safety Guide No. NS-G-2.1, IAEA Safety Standards Series, Vienna, Austria, 2000.

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Nuclear Energy Agency FIRE (Fire Incidents Records Exchange) Database Project:
OECD/NEA FIRE Coding Guideline (OECD/NEA FIRE-CG 2019:01), Paris, France, October 2020.

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Annex 1

Detailed contents list for the NARs

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Annex 2

Abbreviations used in this specification

FCF	fuel cycle facility
FHA	fire hazard analysis
NAR	national assessment report
NPP	nuclear power plant
PSR	periodic safety review
PSA	probabilistic safety analyses
RR	research reactor
TPR	technical peer review
V&V	validation and verification
WDF	waste and decommissioning facility