ETSON EUROPEAN TECHNICAL SAFETY ORGANISATIONS NETWORK

Fontenay-aux-Roses, February 5th, 2021

To the attention of: Gisela STOPPA
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**IRSN-DG/2021-00048**

Subject : WENRA/ETSON Collaboration – Draft specification of the Topical Peer Review on Fire protection

Dear Gisela,

I am pleased to send you the document elaborated by ETSON experts on possible specifications of the next Topical Peer Review (TPR) on fire protection.

This document is structured according to the defense-in-depth approach and based on the applicable WENRA reference levels. From our point of view, it should help structuring the analysis of countries' reports and learning pragmatic lessons from the TPR.

As mentioned during my presentation of the Technical Board on Reactor Safety activities to the WENRA/Reactor Harmonisation Working Group, ETSON experts are available for discussions on the attached document.

Yours sincerely,

Karine HERVIOU Signature numérique de Karine HERVIOU Date : 2021.02.05 14:41:36 +01'00'

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# TPR Specification: FIRE PROTECTION

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# 1- Scope

The Technical Specification for the Topical Peer Review (TPR) should cover NPP reactor units and spent fuel pools (SFP), research reactors over 1 $MW_{th}$ and fuel cycle facilities. Nuclear waste facilities, especially those with contaminated combustible waste (e.g., plastic, bitumen, etc.) could also be involved in the process because contaminants of these wastes can be easily suspended in the air in the event of fire.

A fire safety analysis in industrial installations may be conducted using a large range of approaches. The Technical Specification is focused on fire protection in nuclear installations by specifying the fire hazard analysis (FHA) process and the fire protection means implemented according to both, defence in depth principles and WENRA Safety Reference Levels (SRLs). The requirements for design, layout, inspection and maintenance of fire protection features should also be specified.

The current specification proposes to review these two aspects: the first one regarding the fire hazard analysis (§ 4), the second one regarding the fire protection defence in depth concept (§ 5). Both approaches are consistent; thus, there may be redundancies in terms of expected information in the different chapters since fire protection is justified by the FHA.

The fire is supposed to occur within the site boundaries of the facility.

# 2- General Information on the Nuclear Facilities

For all facilities, the site with all its radioactive (reactor and non-reactor radioactive sources) shall be briefly characterised and the main characteristics of each facility shall be reflected.

For NPPs, the report shall provide separate information for each type of reactor or unit. Safety significant differences between reactor types or series shall be highlighted.

For fuel cycle facilities and research reactors, the report shall provide a brief description of the plant process. Concerning the fuel cycle facilities, it should particularly focus on the main specific risks (criticality, exothermic reactions, etc.) potentially impaired by fire.

When describing the site characteristics, information on the facility's neighbourhood shall be provided:

- Does the facility's neighbourhood include other facilities (on-site or off-site the site boundary)?
- Are these facilities operated by different licensees?
- Are there any common resources (fire protection features, electrical supplies, firefighting personnel, etc.) shared between these installations or with any industrial installation in the neighbourhood?

# 3- National Regulatory Contexts and Guidance Available

The national report should include a brief overview of the regulatory system relevant to fire safety:

- Regulatory regulations and guidance available for the design and operation of nuclear facilities in the respective country;
- Methods, data and analytical tools used.

It should also be briefly described how international standards are applied including:

- Relevant WENRA Safety Reference Levels (SRLs);
- IAEA Safety Standards.

# 4- Fire Safety Analysis

*WENRAS3.1 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 S3.3 The fire hazard analysis shall demonstrate how the possible consequential effects of fire and extinguishing systems operation have been taken into account.*

## a. Principles

Control and mitigation of fire hazards in a nuclear facility 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 defence in depth principles (see also 5.a), the aim of the fire protection measures (FPM) implemented on the basis of this examination is to:

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

b) Mitigate the fire by
   - timely detection and extinguishing of fires;
   - preventing the spread of fires;

c) Mitigate secondary fire effects and maintain 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 hazard and limiting its consequences to achieve the safety objectives).

The fire hazard analysis (FHA) should provide justification of the adopted fire protection measures on the fulfilment of justified technical criteria. Based on the functional requirements associated with SSCs to be protected, the licensee should therefore justify that the technical performance of the fire protection measures ensures that the safety objectives will be met.

The scope of the deterministic FHA, the use of PSA, and the use of a combination of both shall be investigated. For both approaches, the following relevant information about principles applied is important:

### Safety Objectives and SSCs to be Protected

a) Describe the safety objectives to be met (e.g., no accident occurrence, damage of nuclear fuel, limitation of radiological consequences, no criticality, dynamic or static confinement) and the safety functions that have to be protected against fire.
b) Describe the methodology used to identify SSCs necessary to fulfil the required safety functions that have to be protected against fire.
c) For each safety function, provide a list of the main SSCs to be protected from fire.
d) Describe requirements for SSCs to ensure their required safety functions and the related fire damage criteria (temperature, pressure, heat flux, etc.).

### Fire Phenomena Taken into Account and Quantification

In the location where a fire starts, it can cause direct and indirect effects such as a temperature increase, a pressure rise, turbulent flows as well as the 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, on the one hand to assess the vulnerability of SSCs needed to be protected from fire and, on the other hand, for a suitable design and layout of fire protection means.

a) Describe the fire phenomena considered in fire safety analyses taken into account to analyse direct and indirect fire effects.
b) How are these fire effects considered in the safety demonstration?

The methods and tools applied to quantify fire effects have to be appropriated to the studied phenomena complexity. Fire simulation tools shall 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 shall be analysed to ensure they match the scenario.

In some specific cases (for example, if neither adapted calculation method nor experimental data are available), expert judgment can be considered while keeping a cautious approach.

a) Describe methodologies, tools and data used for the quantification of fire effects (temperature, pressure, soot...).
b) Describe the validation and verification (V&V) process applied to ensure qualification and adequacy of tools used to quantify effects from fire.

### Performance Criteria to be Met for Fire Protection Features and Uncertainties

Given the vulnerability of the targets to direct and indirect fire effects, provide precise performance criteria the fire protection features should meet.

a) Describe the process used to define such performance criteria according to the fire phenomena taken into account and the state-of-the art,
b) Provide performance criteria (such as thermal resistance, behaviour under pressure, etc.) used for fire protection features (fire doors, dampers, cable protections, etc.).

The risk analysis approach requires to evaluate 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.

Sensitivity analyses should also be provided.

a) Describe how uncertainties are taken into account when choosing fire protection measures to be implemented.
b) Describe how sensitivities of different parameters are provided within the analysis.

### Combinations of Fire Events

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:

- Consequent (subsequent) events: An initial event, e.g. an external or internal hazard, results in another event, e.g. an internal hazard (examples could be 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 (examples could include electromagnetic interference /seism as the common cause for station blackout and internal fire, or a storm/tsunami as the common cause for external flooding, internal flooding and internal fire as potential 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 facility at the same time interval[1].

a) Describe which combinations of events are taken into account in fire safety assessment.
b) Describe the rules/criteria applied to consider such event combinations.

### Single Failure for Deterministic Analyses

The robustness of the safety demonstration, and therefore the sufficiency of fire protection features and their design, is based on the study of complementary fire scenarios which effects could be more harmful than the reference scenarios considered at the design basis stage. The objective is then to verify that the consequences for safety, people and the environment remain acceptable.

a) Describe how the fire protection features´ worst single failure[2] is taken into account in the FHA (RL E8.2)

### Radiological Consequences

The assessment of radiological consequences of a fire associated with the radiological releases and their effect on population and environment is also necessary.

The quantification of the fire consequences includes the quantities of radioactive material that could be involved. The airborne fractions of these materials are estimated while taking into account the nature of the radionuclides involved as well as their physicochemical form and volatile nature. The suspension rates considered, associated with each radionuclide or group of radionuclides, shall be justified. If experimental results are used the experimental conditions shall match closely the considered case.

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

a) Describe the approach and data used for quantification of radiological release due to fire.

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[1] Damages caused by the first event still affect the installation when the second event occurs.

[2] A failure and any consequential failure(s) shall be postulated to occur in any component of a safety function in connection with the initiating event or thereafter at the most unfavourable time and configuration.

## b. Deterministic Analyses

*WENRA S3.2 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 combinations of fire and other PIEs likely to occur independently of a fire.*

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 plant 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 analysis shall be based on the verification that the technical performance levels, justified through a hazard analysis, are fulfilled. The licensee shall 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,
- 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.

a) When and how often do you perform FHA and on what basis is it updated?
b) Provide the different steps of the FHA.
c) Describe the elements required to perform the FHA in addition to the description of the facility's characteristics (dimensions, organization of premises, layout, processes, etc.).
d) Do you have rules and justifications used to consider the absence of fire in specific situations?
e) Describe the scenarios studied in the FHA and the technical elements used to justify that they are the most relevant (bounding scenarios).
f) Describe the assumptions chosen regarding parameters used in fire scenarios (fire data: fuel type, combustion enthalpy, chemical reaction, mass loss rate, etc. – room data: geometry, ventilation rate, room leak rate, etc. – targets data: location, types and functional characteristic of target SSCs – mitigation data: types and characteristics of fire detection and extinguishing features including diagnosis and response times, manual firefighting capability, etc.).
g) Describe how experience feedback is used in the frame of the FHA and for performance requirements for fire protection features;
h) Describe if and how, as part of the final verification of the design, fire spreading/propagation from an initial fire compartment to adjacent ones is avoided to the extent practicable by suitable and reliable fire protection means in place, and, if it cannot be prevented, 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 venting systems shall be considered with specific attention given to leakages into the environment.

a) Describe the approach and data used for quantification of radiological releases due to the fire.

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 facility and within safety reassessments required by regulations.

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

## c. Probabilistic Safety Assessment

*WENRA O1.1 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.*

*WENRA S3.4 The fire hazard analysis shall be complemented by probabilistic fire analysis. In PSA Level 1, the fires shall be assessed in order to evaluate the fire protection arrangements and to identify risks caused by fires.*

Internal fires on a nuclear facility can damage plant components and initiate accident sequences that might lead to radioactive releases internally or in the environment. A probabilistic safety assessment (PSA) aims at calculating the frequency of fire accidents that might lead to serious consequences. For NPP, the practice is to assess safety on the basis of studies performed regarding core damage frequency (CDF) in level 1 PSA and radioactive releases (LRF/LERF) in level 2 PSA. This practice can be adapted to other facilities depending on the specific type of consequences in case of an accident.

The development of such PSA and its results provide an opportunity to verify that provisions (prevention and mitigation) against fire accident are sufficient to reduce the risks induced by fire in the facility. In general, learnings of such PSA conduct the utility to complete the existing protections against fire.

a) Do you develop and apply fire PSA?

b) If relevant, which global methodology is applied (short description for both actions of bullet a)) ?

c) If relevant, are the following items taken into consideration for the fire PSA development and how (short description):

- Collection of operating experience on internal fires,
- As built / as operated plant: identification of fire sources, walkdown,
- Identification of the zones in the facility that have to be considered in the fire PSA,
- Combination of fire with other events which can be induced by fire (flooding, explosion) or which can induce fires (seismic events…),
- Fire development, fire detection, fire brigade actions,
- Fire spreading to multiple fire zones,
- Fire impact on equipment and structures, on personal,
- Specific fire accident procedures.

d) If relevant, which criteria are applied to assess the acceptability of the fire PSA results?

e) If relevant, are the fire PSA results reviewed by the safety authority and when?

f) If relevant, can you provide examples of fire PSA results and insights and plant modifications based on fire PSA?

g) If no fire PSA has been developed yet, is it planned in near future?

## 5- Implementation of Fire Protection Measures

### a. Defence in Depth Principle

*WENRA S1.1 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.*

Fires could, because of their nature, 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 accordance with the concept of defence in depth (the first level of defence in depth), protection against fire is provided in general by ensuring the high quality and reliability of SSCs, by environmental qualification of these SSCs, by application of the principles of redundancy, 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 surveillance and in-service inspections of SSCs need to be implemented for timely detection of the occurrence of a fire (or of signs that can lead to 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 eliminate them.

WENRA RHWG Safety Reference Levels for Existing Reactors (24th September 2014) presents Defence-in-Depth (DiD) approach for nuclear power plants. With respect to the principles corresponding to this approach, DiD concept shall also be implemented within the specific field of fire protection and different levels shall be then identified as follows:

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

Design and layout of fire protection means in place shall meet the objectives related to the aforementioned DiD levels as far as reasonably practical.

The principle of DiD as mentioned could be applied to any kind of nuclear facility concerned by the proposed TPR, not limited to NPPs. Indeed, these DiD levels are focuses on general fire safety objectives, not specific to NPPs.

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.

**Fire Prevention**

Several measures should be taken in the design to minimize the likelihood of internal fires. Usually, these provisions concern fire loads (Removal, minimization and segregation of fixed and transient fire loads, as far as practicable, quantity, place and reaction to fire), ignition sources (elimination of potential ignition sources to the extent practicable; otherwise, the strict control of any such sources, segregation of ignition sources from fuel sources, management of hot work, prevention of electrical faults, etc,) and oxygen (reduce oxygen concentration, inert gas atmosphere, etc.).

*WENRA S2.1 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 plant state during and after a fire event.*

a) Describe the process to design a facility in order to minimize the frequency and the effects of fire on SSCs.
b) Describe the fire prevention measures including specific needs due to the facility processes (pyrophoric materials, flammable liquids, etc.).

*WENRA S5.1a 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.*

a) Describe procedures to verify that fire loads are consistent with those of the safety demonstration and the control frequencies.
b) How are these procedures adapted to rooms where SSCs or radioactive materials are located?

### Fire Detection and Extinguishing

It should be described:

- that suitable and reliable fire detection and alarm features are in place for detecting any incipient fire and providing a detailed annunciation of and fire location to occupants and fire emergency organizations, including for reactors the control room personnel,
- 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.

Following detection, the fire has to be extinguished and the facility has to be put in a safe condition.

### Fire Detection

*WENRA S4.1 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.*

a) Describe guidelines for the arrangement of fire detectors in the nuclear facility and to determine the type(s) of detectors being implemented;
b) Describe the process for ensuring that the fire detectors are capable to withstand the ambient conditions of the locations where they are installed (especially humidity, and radiation);
c) Different detector types and a huge number of detectors are installed in a facility such as for example “Intelligent” multi-criteria / multi-sensor detectors. Explain if and how control room operators and fire brigade(s) manage these systems;
d) Describe the approach for ensuring fire detection in locations where ambient conditions, or operations (hot works, dysfunctions) make it impossible to operate fire detectors;
e) The fire detection system can manage many automations (alarms, actuation of extinguishing systems, closure of fire doors and fire dampers, etc.). Describe how operators are trained to perform, if needed, manual actions to perform these measures that are usually automatic (choice of equipment to activate, appropriated timing, etc.).

### Fire Extinguishing

*WENRA S6.2 Written emergency procedures that clearly define the responsibility and actions of staff in responding to any fire in the plant shall be established and kept up to date. A firefighting 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.*

It should be described:

- that suitable and reliable fire extinguishing features are in place, including justification that they are designed and located such that their rupture, spurious or inadvertent operation does not inadmissibly impair SSCs important to safety;
- that 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 the fire water distribution network for fire hydrants outside buildings and the internal standpipes provides adequate coverage of all plant areas;
- that fire extinguishing systems and support systems (e.g. ventilation and drainage 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;
- that the control of fire is achieved through a combination of fixed fire suppression and extinguishing systems and equipment and manual firefighting capabilities.

*WENRA S6.3 When reliance for manual firefighting capability is placed on an off-site resource, there shall be proper coordination between the plant personnel and the off-site response group, in order to ensure that the latter is familiar with the hazards of the plant.*

*WENRA S6.4 If plant personnel are required to be involved in firefighting, their organization, minimum staffing level, equipment, fitness requirements, and training shall be documented, and their adequacy shall be confirmed by a competent person.*

### Administrative and Organisational Fire Protection

It should be demonstrated:

- that suitable written procedures clearly defining responsibility and actions of staff in responding to any fire in the facility 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 plant internal firefighting capability is supported by offsite resources, proper coordination between the plant personnel and the offsite response group is ensured, in order to ensure that the latter is familiar with the hazards of the plant, including conducting emergency training, drills and exercises;
- that and how the following is ensured for plant personnel required for firefighting and documented by a competent person of the operating organisation:
    - firefighting capability and organization,

- minimum staffing level for firefighting,
- availability of suitable firefighting equipment,
- fitness requirements, skills and training for fire fighters.

a) Describe if there is a professional plant internal fire brigade present on the site or if there are only non-professional plant fire fighters.
b) In the first case, is there a need to involve an external fire brigade in addition ? If so, how is the fire response organised between on-site and off-site brigade?
c) In case of non-professional on-site fire fighters, how are the responsibilities distributed for firefighting (off-site professional/on-site non-professional)?
d) Describe the different responsibilities of on-site firefighting resources, prioritisation of their work (s firefighting vs. other shift work).
e) Explain if the internal non-professional resources are able to fight a fully developed fire in the installation .
f) Explain if there are specific measures for management of a fully developed fire in situations with total loss of facility access (such as in the event of earthquake, snow, flooding, …);
g) Explain if and how often there are periodic drills with off-site firefighting resources.

*WENRA S4.2 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.*

a) Describe guidelines for the arrangement (location) and types of extinguishing systems and equipment implemented in the facility (fixed or mobile, automatically or manually actuated).
b) Describe the process to determine the type of extinguishing agent compliant with safety (nuclear containment, criticality hazard, etc.).
c) Fire protection features can cause secondary effects after actuation, e.g. flooding. Describe how are these possible induced effects are considered in the safety demonstration.
d) Describe specific provisions implemented to deal with the effluents produced by extinguishers, which could generate contamination (transportation of radioactive material) or criticality risks.
e) Describe the specific fire protection measures taken in the event that there are access difficulties to the fire area.

*WENRA S4.3 The distribution loop for fire hydrants outside building and the internal standpipes shall provide adequate coverage of areas of the plant relevant to safety. The coverage shall be justified by the fire hazard analysis.*

a) Describe the fire water network design and analysis (pressure, flow, volume of water reserves, seismic resistance, frost resistance, etc.).

### Preventing the Spread of Fires

The third level of the DiD 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 not extinguished, thus minimizing effects and consequences, especially to avoid common cause failures and to limit the quantity of radioactive material involved in the fire.

*WENRA S2.3 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. (A fire compartment is a building or part of building that is completely surrounded by fire resistant barriers of sufficient rating so that a total combustion of the fire load can occur without breaching the barriers (barriers comprise doors, walls, floors and ceilings). The fire resistance rating of the barriers must be sufficiently high so that the total combustion of the fire load in the compartment can occur without breaching the barriers.)*
*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.*[3]

Describe the process to determine the fire barriers forming fire compartment or fire cell boundaries, according to the safety goals, and to ensure the thermal and mechanical integrity of structures;

a) Describe the compensatory measures taken to prevent against the propagation of fire and smoke beyond the fire cells boundaries (HVAC systems, “fire-load-free zones”, etc.).

b) Describe the process to justify that the fire barriers remain efficient under transient operations that increase the fire load (maintenance, modifications, etc.).

*WENRA S2.2 Buildings that contain SSCs important to safety shall be suitably fire resistant in accordance with the results of the fire hazard analysis.*

a) The building structures fire resistance especially depends on temperatures and duration of fire. Describe the process to determine the building fire resistance rates.
b) Describe worst case (bounding) fire scenarios used to justify fire resistance rating of buildings. Explain if and how these scenarios take into account:
    - the maximum fire duration,
    - extinguishing failing that may increase the fire severity and duration,
    - full burnout of the fire compartment depending on the oxygen concentration,
    - credible combinations with other event that could damage the integrity of fire barriers (e.g. seismic, explosion, etc.).
c) Explain how adverse effects from fire extinguishing (quick cooling, hose stream damages, gas pressure, etc.) on the structures exposed to the fire are considered.

### Failures of Electrical Equipment

The failure of electrical cables exposed to fire conditions should be a safety concern for operating nuclear facility. To permit continued operation or to ensure a controlled shutdown of critical equipment during fire conditions, electrical circuit integrity has to be ensured during exposure to an external fire.

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[3] *(In the fire cell approach the spread of fire is avoided by substituting the fire resistant barriers primarily with other passive provisions (e.g. distance, thermal insulation, etc.), that take into account all physical and chemical phenomena that can lead to propagation. Provision of active measures (e.g. fire extinguishing systems) may also be needed in order to achieve a satisfactory level of protection. The achievement of a satisfactory level of protection is demonstrated by the results of the fire hazard analysis.)*

a) Describe methods and criteria used for selecting electrical cables that should be protected against fire.
b) Describe how the identified fire-induced common cause failure are handled (implementation of FPM, equipment reorganization, implementation of additional SSCs, etc.).

**Ventilation Systems**

*WENRA S4.4 Ventilation systems shall be arranged such that each fire compartment fully fulfils its segregation purpose in case of fire.*

*WENRA S4.5 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.*

It should be described:

- that suitable ventilation systems are in place which compromise neither building compartmentation nor the availability of redundant trains of safety systems;

- that each fire compartment containing a redundant train of a safety system should has a ventilation system designed such that a fire in one safety fire compartment will not propagate fire effects that induce a loss of ventilation of another safety 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;

- that for those ventilation systems serving more than one fire compartment, provision are in place to maintain the segregation between fire compartments and which means are in place to prevent the spread of fire and dangerous, mainly gaseous (e.g. toxic, corrosive, radioactive, etc.) fire by-products to other fire compartments.

For specific facilities, in addition to static containment of radioactive material, nuclear installations are equipped with ventilation systems that circulate air from areas with low risk of radioactive material dissemination to areas with higher risk; these ventilation systems also allow the extracted air to be filtered (dynamic confinement).

In case of fire, variations of 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 cause damage to filters and ventilation ducts and facilitate the transfer of radioactive aerosols within the installation and into the environment.

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

Fire can significantly damage safety equipment, even far from the fire and in different ways, corrosive material and soot within the smoke can cause equipment malfunctions that are different from those caused by the thermal fire effects. Furthermore, smoke release can generate toxicity risks for employees, reduce visibility and thereby hinder operating and intervention actions as well as actions necessary to bring the installation into a safe state. Fire resistant barriers are usually based on equipment designed to avoid the spread fire and fire by-products through them (fire doors, fire dampers, etc.) but not to avoid these "side" effects of a fire.

*WENRA S2.4 Buildings that contain radioactive materials that could cause radioactive releases in case of fire shall be designed to minimize such releases.*

Fire could cause important radioactive suspension and damage to containment provisions, especially ventilation and filtrations systems.

a) Describe how the buildings or rooms where such releases have to be minimized (criteria) are screened;
b) Describe the confinement provisions used in case of fire (static or/and dynamic containment);
c) Describe how they are designed to withstand fire effects;
d) Describe how it is justified that the confinement performance is sufficient ;
e) Explain the objectives of and procedures for ventilation management in the event of fire;
f) Describe, the strategy regarding the maintenance of dynamic confinement considering the risk of fire propagation through ventilation systems.

*WENRA S2.5 Access and escape routes for fire fighting and operating personnel shall be available*

a) Describe the process to determine adequate access and escape routes;
b) Describe the process to determine adequate access routes to the site for external fire brigades and plant shift personnel;
c) Explain provisions provided to justify these routes remain accessible, suitably and reliably protected during a fire.

## b. Administrative Controls and Maintenance

*WENRA S6.1 The licensee shall implement adequate arrangements for controlling and ensuring fire safety, as identified by the fire hazard analysis [4].*

Compliance with the requirements of any element involved in fire protection have to be guaranteed over time. In particular, to maintain the performance of the fire protection features implemented (availability, integrity, etc.), an equipment maintenance programme (preventive and corrective maintenance) should be implemented. An appropriate staff training, development and qualification programme (including provisions such as tutoring, drills, etc....) should also be in place at the facility and kept under constant review for establishing and maintaining a high level of competence. The frequency and the contents of periodic tests, maintenance and training particularly depend on the importance of the requirements for fire protection features being implemented resulting from the safety demonstration, the resistance to stress and the vulnerability to ageing.

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.

[4] *Such arrangements must include nominating persons to be responsible for or have duties with respect to fire protection. The arrangements must set out the requirements for control of all activities that can have impact on fire safety, e.g. maintenance; control of materials; training; tests and drills; modifications to layouts and systems - such as fire detection, fire extinguishing, ventilation, electrical and control systems*

*WENRA S5.1b 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.*

a) Describe controls, inspection and maintenance carried out for the fire protection features ;
b) Describe the process/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 facility;
c) How is ageing of fire protection features taken into account?
d) How is it demonstrated that the unavailability of fire protection features in place is sufficiently compensated by other measures?

## 6- Feedback and Research Activities to Support Fire Safety Assessment

In order to assess accuracy of fire protection measures, a FHA needs to determine 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:

- fire source characteristics (heat release rate, fire growth, combustion products, etc.) based on open and confined fire tests representative of fire scenarios in nuclear installation. For example, international fire research activities are ongoing to investigate the fire growth and flame spread on electrical cable trays.
- the failure criteria of SSCs. For example, experimental research shows that electronic device malfunctions due to combined effects such as smoke and thermal effects may lead to failure thresholds lower than those due to thermal effects only.
- the performance criteria of FPM. For example, tests should be conducted on fire doors or dampers under thermal and mechanical stress (pressure) to assess their behaviour. The main outcomes of these tests are the aeraulic behaviour and the pressure rupture threshold of these fire barrier elements.

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

Finally, in order to define fire scenarios and corresponding fire protection features´ reliability data for Fire PSA, experience feedback from nuclear and, if this database is not sufficient, also from non-nuclear installations must be analysed. The following data can be established:

- Data on the facility being investigated including site aspects (installation's plant operational states (POS) durations, unavailability periods of SSCs during these different states (e.g., for corrective maintenance, preventive maintenance, or periodic test), etc.);
- Equipment (SSCs´ and fire protection features´) reliability data (e.g. based on installation feedback);
- Data on common cause failures (e.g. based on installation feedback);
- Data specific to human factors.

a) Describe how feedback is used to define fire scenarios and calculate reliability data.
b) Describe how research and development needs are identified and built up to determine fire properties, SSC failure criteria, or fire protection features performance criteria. Provide the current list of needs.

c) Describe which fire research and development results have been used in support of fire safety analyses.
d) If a fire computational tool (e.g. a fire simulation code) is used in support studies, describe how the reliability of the results, the related uncertainties and the model's limitations are considered.

## Acronyms:

| | |
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| **TS** | Technical Specification |
| **TPR** | Topical Peer Review |
| **NPP** | Nuclear Power Plant |
| **SFP** | Spent Fuel Pool |
| **FHA** | Fire Hazard Analysis |
| **WENRA** | Western European Nuclear Regulators Association |
| **RHWG** | (WENRA) Reactor Harmonisation Working Group |
| **SRLs** | (WENRA) Safety Reference Levels |
| **IAEA** | International Atomic Energy Agency … |
| **SSCs** | Structures, Systems and Components |
| **PSA** | Probabilistic Safety Analyses/ Assessment |
| **V&V** | Validation and Verification |
| **PIE** | Postulated Initiating Event |
| **PSR** | Periodic Safety Review |
| **CDF** | Core Damage Frequency |
| **LRF/LERF** | Large / Large or Early Release Frequency |
| **DiD** | Defence-in-Depth |
| **HVAC** | Heating, Ventilation and Air Conditioning |
| **FPM** | Fire Protection Measures |
| **POS** | Plant Operational States |