SI-E-1618 - License and regulatory experience – NPP Krško

[generic/general]:

1. Screening criteria used in the fire analysis for those NPP that have not explicitly identified these.

   <u>**Krško NPP response:**</u>

   In the screening process, it was necessary to select those fire locations within the power plant having the greatest potential for producing risk dominant accident sequences. The objectives of location selection were somewhat competing and were balanced in a meaningful risk assessment study. The first objective was to maximize the possibility that all important locations were analysed, leading to the consideration of a potentially large number of candidate locations. The second objective was to minimize the effort spent in the evaluation of event trees for fire locations that turn out to be unimportant. A proper balance of these objectives resulted in an ideal allocation of resources and efficiency of assessment. The screening analysis was comprised of:

   a. **Identification of potentially important fire areas: Fire areas that had either safety-related equipment or power and control cables for that equipment were identified as requiring further analysis.**
   b. **Screen fire areas on unique fire-related failure modes: Fire areas where fires could only lead to a fire-induced initiating event were eliminated from further consideration. Quantification of this type of scenario essentially results in double counting of the internal events core damage frequency.**
   c. **Each fire area remaining was numerically evaluated and culled on frequency: The screening methodology describes how reduction of the initial group of fire areas to those fire areas remaining, with contributions to core damage frequency of greater than 1E-07 per reactor year, was accomplished.**

   Fire Probabilistic Safety Assessment Assumptions and Methodologies are described in NAR:2.1.2.7 and in some other chapters.

2. Defence in Depth (DiD): Regarding the level of fire DiD and the assumptions in the Fire Safety Analyses (FSA) the following questions arise:

   a) Has the failure of the fire protection means (features such as structures, systems and equipment, but also human failures in active fire protection) been taken into account in the fire analysis for the safety demonstration of the fire protection structures, systems and components (SSCs)?

      <u>**Krško NPP response:**</u>

      FHA is prepared with deterministic approach requires analyzing the consequences of a fire in a space that has vital equipment located, regardless of the equipment failure or human error. The Fire Protection system is designed in such a manner that system operation or failure does not create an unsafe condition. It means that routing of the fire protection water piping is in such a manner as to minimize exposure to Safety Class equipment; fire protection piping within the seismically qualified charcoal filters and near the reactor coolant pumps are supported to withstand a seismic event; each charcoal filter plenum and each main reactor coolant pump are protected by a separate manually operated water spray system and floor drains are provided in all areas of the plant which are protected by sprinkler systems and in all areas of the plant where fire protection piping is located. Safety evaluation of Fire Protection system is provided in USAR, Section 9.5.1.3

The operator recovery actions (modeling of human errors including manual firefighting) were considered in the PSA analysis. Each recovery action modeled was checked to see if the fire either precluded an action or produced elevated environmental stresses such as reduced visibility, impaired communications, and impaired accessibility, which would necessitate increasing the failure probability. Special attention was applied considering recovery actions which take place in the control room. Even though explicit procedures are in place for this situation, a high stress recovery probability was conservatively applied to operator actions model for failure of control cabling and unsuppressed control room cabinet fire.

In Fire PSA, failures of manual fire suppression have been analyzed. Delays in response have been assessed for each important fire area. Manual actions were also modelled but success is very limited (high failure probability actions). Fire brigade training and drills are held for both onsite and offsite personnel.

b) Both in the deterministic and probabilistic FSA, under which assumptions is this failure considered: full burnout in the fire area and failure of all SSC therein, functions of failure probability for the different SSCs, no damage due to the fire?

<u>**Krško NPP response:**</u>

The existing deterministic safe shutdown fire hazard analysis was performed very conservatively with a basic assumption that fire would damage systems and equipment located within a common fire area or cell, where the fire event occurred. Fire damage is assumed to occur regardless of the amount of combustibles in the area, the ignition temperatures, or the lack of an ignition source. The presence of automatic or manual fire suppression and detection capability is also not credited. To compensate for the disabled equipment, manual operator actions as well as use of alternate equipment is credited, for which the required procedures are established. The details are provided in NAR, section 2.1.3.1

In Fire PSA, COMPBURN tool was used to calculate the fire damage to the equipment.

Otherwise, the large transient fires were usually treated as limited to max. 50 % of equipment in fire area. For separation distances of more than 12 m failure of panels due to fire (12 m or more distant fire) was found not to be credible.

Two fire types were modeled, one of which was transient combustible located in proximity to the critical equipment; and second, fixed combustible fires on cables and equipment. The fires were placed on all relevant locations. Both small and large transient as well as fixed combustible fires were postulated in the fire modeling calculations for NPP Krško. A small fire was assumed to be 0.4 m in diameter and consist of 4.8 l of oil. A large fire was assumed to be 0.8 m in diameter and consist of 48.9 l of oil. It was shown that 48.9 l of oil bounds any large solvent or trash paper combustible source in terms of heat content and is, therefore, an appropriate upper bound on transient combustible fuel source size. Fixed combustible fire sources were modeled by consideration of the combustible content of the given component.

c) Under these considerations, do you consider your Fire PSA conservative or realistic?

<u>**Krško NPP response:**</u>

According to assumptions presented in NAR, fire hazard analyses are regarded as conservative. Fire PSA analyses for full power and low power operation and are regarded as realistic and fire PSA for shutdown states (POS5 and POS6) is also conservative.

d) Is the single failure criterion considered in the fire analysis? If it is, on which regulatory basis and how is it considered?

<u>**Krško NPP response:**</u>

The Krško NPP Fire Hazard Analysis (FHA) fulfills the 10CFR50 Appendix R requirements where shutdown systems installed to ensure postfire shutdown capability need not be designed to meet seismic Category I criteria, single failure criteria, or other design basis accident criteria, except where required for other reasons, e.g., because of interface with or impact on existing safety systems, or because of adverse valve actions due to fire damage. Detailed description is provided in NAR, section 2.1.2.

NEK FHA follows APPENDIX A, to BRANCH, TECHICAL POSITION APCSB 9.5-1 "GUIDELINES FOR FIRE PROTECTION FOR NUCLEAR POWER PLANTS DOCKETED PRIOR TO JULY 1, 1976" (AUGUST 23, 1976) where a single failure in the fire suppression system should not impair both the primary and backup fire suppression capability. For example, redundant fire water pumps with independent power supplies and controls should be provided (in NEK, one electrical and one diesel fire protection pump).

Furthermore, on high safety level, plant level, single failure criterion is fulfilled. The basis for protection is DEC systems, that are dislocated and separated from the design systems, with dedicated power supply, therefore are not endangered by the fire on design systems and are capable to shut down the plant and provide long term cooling.

e) Are the spurious actuation of signals by a fire and the false operation of fire protection SCCs considered in the analyses? In what way?

<u>**Krško NPP response:**</u>

In original Fire PSA spurious actuations were not considered. This is one of the reasons that complete fire update/upgrade is in progress (IAEA review 2020). In latest partial upgrade of Fire PSA model with emergency control room, also spurious actuation was addressed from the fires in main control room.

False operation of fire protection system was addressed by design. All motor openings are facing down, therefore the water from sprinklers can not endanger the equipment operation. Additionally, drainage system is design to full capacity of fire protection system.

f) Provide information on which combinations of fires and other events have been included in the fire analysis with their justification. Please refer to Appendix I of the IAEA SSG-64 to address possible combinations of events.

<u>**Krško NPP response:**</u>

Combination of fire events with other events was addressed and documented in Fire Hazard Analysis and in Technical Report for the fire PSA combinations. Methodology applied is in compliance with later issued IAEA SSG-64. All relevant combinations were analyzed, concurrent, consequential, and random. Fire events were analyzed with internal initiating events, therefore bounding all external initiating events causing loss of external power, station blackout, loss of cooling, transients, and others. Additionally, fire events and internal flooding, high energy line breaks and seismic events were analyzed. Also, for the areas capable producing explosions, fire and explosion was analyzed (consequential or originating).

Additional information is presented in NAR Section 2.1.2.5, page 41 and Section 2.5.4, page 108.

g) With regard to these combinations of fires with other events in the analysis, is the failure of the fire protection features (for detection or suppression) caused by combined hazards – such as earthquake and consequential fire or a fire occurring coincidentally with a long-lasting external flooding – considered? What are the qualification requirements ensuring their required function during and after these events?

<u>**Krško NPP response:**</u>

Various combinations are considered. Due to very robust external flooding protection at NPP Krško, the frequencies with external flooding, causing problems at the plant were extremely low. The flooding protection is designed to withstand Probable Maximum Flood with return period several decades above the 10.000 – year flood. Additionally, plant is inherently safe by elevation to the 10.000 – year floods. Therefore, relevant combination frequency to flood the plant is extremely low (even without the fire event). Also, combinations with internal flooding were considered, that have much larger initiating frequencies.

Qualification requirement is that the equipment design criteria is not compromised.

Since the Fire Protection system is not seismically qualified, it could become inoperable in case of an earthquake or in case of combination of events including earthquakes. If the Fire Protection system is degraded, an alternate method of providing fire protection functions would be initiated (e.g., with mobile equipment which is in place at the site). In case of serious degradation and widespread fire, DEC equipment would be used to cool down the plant. Additional information is presented in NAR Section 2.5.4.

h) Consideration of the different Plant Operational States (POSs) and/or operating status and modes in the deterministic FSA.

<u>**Krško NPP response:**</u>

The deterministic FHA according to 10 CFR 50 Appendix R assumes that power plant is operating at power (MODE 1) when the single fire occurs in any plant area coincident with a complete 72-hour loss of offsite power. All equipment normally present in the plant is assumed to be functional at design capability and may be lost only as a result of fire damage. Analysis verifies and proves that existing power plant equipment, i.e., safe shutdown equipment, is capable to safely shutdown a plant and bring it through MODE 3 to MODE 4, or MODE 5 and maintained it in hot or cold shutdown.

Therefore, additionally analysis was performed, that includes lower operating and shutdown modes, specifically MODE 5 and 6, where each shutdown mode is further divided into shutdown states. The purpose of this analysis is to take in account all equipment needed for safe shutdown operation for each shutdown mode/state. This analysis is Appendix for existing FHA for covering shutdown modes where other systems are in the main focus and some equipment is not available due to equipment maintenance and existing outage management processes allowed by NEK Technical Specifications. Details related to power operation is provided in NAR, section 2.1.2.2 and related to shutdown modes in NAR, section 2.1.2.3.

3. Fire resistance/fire hazard rating: The fire resistance rating of fire compartments, or fire hazard level, is often determined based on the fire load density (MJ/m^2) in every fire area or compartment accounting for both permanent and transient fire loads and potential ignition sources.

   a) Provide details on the rationale followed.

      <u>Krško NPP response:</u>

      As states in existing FHA; fire barriers are evaluated using combustible loading methodology to verify that such structures are capable of containing a fire that consumes all combustibles within a given fire area. Additionally, the transient and intervening combustible loads are controlled through Krško NPP administrative procedures and they are documented. The details related to the fire barriers are provided in TPR, Section 3.1.2.

   b) Fire load criteria values may differ amongst facilities and countries depending on the regulatory framework. How are these respective criteria justified?

      <u>Krško NPP response:</u>

      The values of combustible content and equivalent fire severity were developed, and specific methodology used in calculating fire severity in minutes is based on the NFPA Fire Protection Handbook, 16th and 19th Edition. The total heat content in MJ of each quantity of material was divided by the floor area in square meters of the fire area under consideration, resulting in the fire loading in MJ/m2. The equivalent fire severity (EFS) in hours/minutes was then determined using the combustible loading - duration relationship from the NFPA Fire Protection Handbook, 16 Edition. While it is recognized that this methodology is not specifically intended for nuclear power plant applications, this technique is endorsed by the USNRC NRR Staff as an appropriate means of quantifying fire hazards to determine the relative degree of hazard in each plant fire area. Accordingly, this technique is consistently utilized in Fire Hazards Analyses performed for US and other nuclear power facilities.

   c) Are they justified knowing that fires in nuclear facilities are generally under-ventilated?

      <u>Krško NPP response:</u>

      No, under-ventilated fire progress was not considered in FHA, since the FHA is performed in accordance with a basic assumption, that all systems and equipment located within a fire compartment affected with fire will be damaged, regardless of the amount of fresh air.

4. Qualification of cables: As far as qualified cables (typically FRNC) are available, in how far are they taken into account as fire load and fire source? How is the qualification of those cables been considered in the fire analysis and for what objective? In how far are protected cables (e.g., protected by protective coatings) considered as contributors to fire propagation in the fire analysis?

   <u>Krško NPP response:</u>

   The flame-retardant qualified cables in accordance with IEEE383 standard are used at Krško NPP, i.e. electrical cables installed at Krško NPP have self-extinguishing, flame-retardant characteristics, in accordance with design specifications (IEE383). Some of them have Slow Burning characteristics (accordance to IEE383). Cables do not give off corrosive gases while burning and cable trays are used only for the routing of electrical cables. No miscellaneous storage in cable trays or raceways is permitted.

   In addition, a list of the inventory and associated equipment and cables that are physically located inside the fire area was prepared for each fire area. Based on inventory in each fire area, the total volume of combustible load and corresponding time severity were calculated, and the

cables are considered as fixed combustible loads in all fire areas in Krško NPP. The volume of cables for each fire area assumes that cable trays are filled to the maximum allowable loading as described in the Krško NPP USAR. For conservatism, this value is assumed, regardless of the actual tray fill percentage. The maximum percent fill (50%) is conservatively assumed to be composed of 100% cable insulation, with no allowance for the noncombustible cable core. Cables routed in conduits were not considered as combustible material.

In fire PSA, temperature effect was considered for insulation ignition temperature along with a damage temperature, which are based on fire testing experience. Analyses in COMPBRN used an area model that breaks the fire environment into three areas: flame/plume, hot gas layer, and ambient. Fire and heat transfer models and correlations are employed to predict the thermal environment as a function of time. Cables that are IEEE-383 qualified are not considered as a self-ignited fire source. Cabling in all the areas of interest (important areas for shut down and safety areas) at NPP Krško is IEEE-383 qualified. Critical temperatures assumed in fire PSA for IEEE-383 cabling: spontaneous ignition 773K, damage 623K.

5. Transient combustibles and ignition sources: In how far and how have transient combustibles and ignition sources (by e.g. hot works) been included in the fire analysis and what are the hypotheses related to their inclusion?

<u>**Krško NPP response:**</u>

Original Krško NPP Fire Hazard Analysis (FHA) was developed on deterministic basis, covering on-line plant operation, a single fire and consequential spread, any plant location where fixed or transient combustible material is present and credible. Control of fire loads and ignition sources is described in NAR, Section 3.1.2. The transient combustibles (e.g., lubricating oils, cleaning solvents, paints, wood, plastics) and ignition sources (e.g., welding, cutting, and grinding operations, and electrical hazards associated with temporary power) are recognized as additional fire risks in existing FHA and TD-6 "Fire Protection program". Krško NPP procedure FPP-3.7.004 "Kontrola vnosa gorljivih snovi" (Control of Transient Combustible) and establishes the control of transient combustibles associated with plant maintenance and modification activities. For transient loads there is separate process, which is supported with digitalized application. Fire risk is calculated based on calorimetric value of each fire load. Current amount of burnable material is taken into account when approving additional fire loads. Total limit, which is defined by design for each fire area, must not be exceeded. Insertion of transient fire loads must be approved by initiators leader and by designated person and is periodically controlled once per refueling cycle.

When hot work is to be performed, the initiator of work order issues a "fire permit" (in accordance with procedure FPP-3.7.006 "Požarna dovolilnica" (Fire Permits)), which is processed and approved by fire protection department. The process is performed by digital aplication, which enables on-line control of all hot works (and other fire related issues) at the plant.

In Fire PSA they are recognized as transient fires and are taken into account as per case by case as capable fire sources. Transient fires were considered from three sources:

(a) cable fires due to welding,

(b) transient fires due to welding, and

(c) "other" sources (such as extension cords and heaters).

Transient fires due to cigarette smoking and candles were specifically excluded as not being applicable due to prohibitions on smoking and open flames in all areas of the plant. In the calculation of transient fires and cable fires due to welding; switchgear, cabling, battery, and control room areas were specifically excluded since welding is prohibited in these areas while at

power. Each of the other remaining plant areas was assumed to have an equal likelihood of welding fires.

6. Direct fire effects: Are direct fire effects (either by smoke, pressure, temperature, soot, etc) onto SSCs important to safety considered in the fire analysis (including reliability of human actions, fire pressure effects on fire doors, fire overpressure effects on cascade flow and pressure gradients of the dynamic confinement system, …)? Some detailed information about the regulatory requirements applicable and the way such effects are taken into account regarding design/conception/construction/modifications would be appreciated.

   Krško NPP response:

   A basic assumption for deterministic FHA, in accordance with 10CFR50 Appendix R, is that all systems and equipment located within a fire compartment affected with fire will be damaged. Fire damage is assumed to occur regardless of the amount of combustibles in the area, the ignition temperatures, or the lack of an ignition source. Therefore, the direct fire effects were not separately analyzed in FHA for safety shutdown equipment, since there is a redundant train, unaffected with that fire event, which can achieve its safety function.

   The SSCs are certainly designed and installed considering fire event and effect of fire. As already mentioned above, the cables must be flame-retardant (in accordance with IEEE383 standard) and some of them have Slow Burning characteristics (accordance to IEE383), cables do not give off corrosive gases while burning. Thermal isolation applied in Krško NPP have to be noncombustible, or with flame-spread ratings in accordance with ASTME 84 Standard Test Method for Surface Burning Characteristics of Building Materials, oz. ANSI/UL 723 Tests for Surface Burning Characteristics of Building Materials.

   Ventilation systems are designed and installed in accordance with applicable NFPA standard and considering the indirect effects of fire, 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, as well as radioactive releases to the environment. The fire dampers must have the same fire resistance as penetration where they are installed, in accordance with NFPA 90A and UL 555. Smoke removal provisions are provided for various plant areas; HEPA filters and radioactive monitoring capability are provided in the ventilation systems for areas containing radioactive material. Ventilation systems designed to exhaust smoke or corrosive gases are provided with redundant isolation dampers, such that a single component failure cannot preclude the ability to isolate the exhaust path. In addition, the ultimate discharge path (the plant vent) is provided with radiation monitoring equipment. Therefore, smoke will not affect the equipment in those areas to achieve its safety function.

   The structures in Krško NPP, have a fire-resistance walls with fire resistance of 180 minutes or less, in accordance with NFPA standards. The same fire resistance is required for fire-resistant doors, built into walls against adjacent buildings.

   Analyses in COMPBRN used an area model that breaks the fire environment into three areas: flame/plume, hot gas layer, and ambient. Fire and heat transfer models and correlations are employed to predict the thermal environment as a function of time.

   For each fire area, in which the fire could affect the equipment for the safe shutdown of the power plant, a solution is defined how to perform safe shutdown, cooldown and how to maintain plant in the cold shutdown mode. There are also fire areas where safe shutdown function is available using alternative equipment, installed in scope of Safety Upgrade Program (SUP), as listed in NAR, section 2.1.4.2 (Alternative Auxiliary Feedwater system, Alternative Residual Heat Removal system, Diesel Generator 3, ECR and mobile equipment). The Emergency Control Room (ECR) is constructed as a centralized location for the Remote Shutdown and Cooldown location

for remote control, administration, and communication center in the event of a MCR evacuation due to fire or any other events. The ECR was designed to adequately meet the requirements of 10 CFR Part 50, Appendix A, General Design Criterion 19, to permit access and occupancy of the control room under the postulated accident conditions including shielding requirements.

The third diesel generator provides power supply if both safety trains are lost due to fire event, in "ISLAND" mode of operation and provide power supplies for all the DEC equipment (ASI, ARH and AAF) together with the ECR instrumentation and controls. In that case the set of emergency procedures (EEOP) can be used to control that kind of event. DG3 is located in a separate building, therefore the fire event cannot disable both power sources simultaneously.

7. Electrical fires: Have electrically induced fires (including fires by high-energy arcing faults, HEAF) been considered in the fire analyses?

   Krško NPP response:

   In fire PSA, temperature effect was considered for insulation ignition temperature along with a damage temperature, which are based on fire testing experience. Two fire types were modeled, one of which was transient combustible located in proximity to the critical equipment; and second, fixed combustible fires on cables and equipment. The fires were placed on all relevant locations. High-energy arcing faults, HEAF, was not considered and this is one of the reasons for the fire PSA upgrade that is in progress (IAEA review 2020).

   The combination of high energy arc failure (HEAF) and fire is evaluated in a separate FHA analysis DCM-TD-040. All fire areas that contain safe shutdown equipment is screened for possibility of High Energy Arc Fault (HEAF).

8. Fire Brigade: How have the response times of the fire brigade (onsite, offsite brigades) been taken into account in the fire analysis? This question is more relevant in those installations that do not have a dedicated onsite fire brigade.

   Krško NPP response:

   Response times were measured during fire drills for different areas of the plant. This data was used in Fire PSA.

   In Fire PSA, failures of manual fire suppression have been analyzed. Delays in response have been assessed for each important fire area. Manual actions were also modelled but success is very limited (high failure probability actions). Fire brigade training and drills are held for both onsite and offsite personnel.

   Krško NPP has a dedicated onsite fire brigade and details are provided in NAR, Section 3.2.2.1, 3.2.3.2 and 3.2.3.3.

9. Radiological consequences of fires: Please provide more details about the methods of addressing the radiological consequences of the fires in the fire analysis and the radiological criteria of acceptance and the corresponding threshold values applicable.

   Krško NPP response:

   Radiological consequences of fires are addressed by the Level 1 and Level 2 PSA analyses. The basis for the analysis is according to ANS PSA standards: ASME/ANS RA-S-1.2-2014, "Severe Accident Progression and Radiological Release (Level 2) PRA Standard for Nuclear Power Plant Applications for Light Water Reactors (LWRs), American Society of Mechanical Engineers - American Nuclear Society. Criteria for determination of exclusion area, low population zone, and population center distance is according to 10 CFR 100.

The radiological consequences are assessed in FHA for all area with potential for release of radioactivity into the environment. Emissions from the building's ventilation system are directed into the existing central exhaust of the Krško NPP ventilation system (Plant Vent System), which is radiologically controlled, therefore the discharges into the environment, except for controlled discharges through the existing Plant Vent system are not possible. Additionally, the ventilation systems, installed in radwaste storage facilities confines the radioactive material, if any, and in case of fire, fire detectors will alarm the main control room and workstations, the ventilation system will be shutdown without time delay and all dampers will close to prevent supply of fresh air in the zone of fire and to prevent exhaust the potentially radioactive material to the environment.

The Dry Storage Facility is not connected to Plant Vent system, but it does not present an unacceptable risk to the public and the environment. Radiological impact following a fire event, as postulated in the safety analysis of the Dry Storage Building (DSB) installation, in relation to the safety and radiological objectives cannot cause significant or important radioactive release, even if considering the combination of fire and other credible events.

10. Analytical methods:

a) For the installations that do not provide enough detail on the tools and models used in the fire analysis, please provide a more detailed description.

Krško NPP response:

The current NEK Fire Hazard Analysis (FHA) is performed in accordance with US regulation - 10CFR50 Appendix R, and analysis is developed on a deterministic basis, covering the all normal operating and shutdown states, for the single initiator event - fire, and the consequential spread, anywhere there is fixed or transient combustible material in fire area. The details are provided in TPR, Section 2.1.1.

Analyses in COMPBRN used an area model that breaks the fire environment into three areas: flame/plume, hot gas layer, and ambient.

b) In cases where computational tools have been used within fire safety analyses, provide information on the sensitivity and uncertainty analyses carried out.

Krško NPP response:

Fire Hazard Analysis for Nuclear Power Plan Krško was made on Prescription approach. FHA consider International Guidelines for the Fire Protection of Nuclear Power Plants, published by American Nuclear Insurers West Hartford, Connecticut – U.S.A. on behalf of the Nuclear Pools` Forum (revised edition 1997) as well. These Guidelines have been developed by a Steering Committee representing nuclear insurers in consultation with fire protection specialists and other technical experts. Due to the importance of achieving the highest possible level of fire protection and prevention at Nuclear Power Stations, has been approved by the members of the Nuclear Pools` Forum (for use by electric utilities).

Some fire areas have not followed the Appendix R requirements and fire simulation has been performed and analyzed to achieve regular requirements – one train of safe shutdown free from fire – for those fire areas, marked as critical compartments. The CFAST software has been used. The results of that analysis have been introduced and shown in previous revision of FHA.

The CFAST software calculates the temperature and evolving distribution of smoke and fire gases throughout a building during a user-prescribed fire. The model was developed, and is maintained, by the Fire Research Division of the National Institute of Standards and Technology (NIST).

In fire PSA, lack of fire sensitivity and uncertainty analyses, is one of the reasons for the fire PSA upgrade that is in progress (IAEA review 2020).

c) The use of calculation tools is growing. What are your review processes to identify the needs and advantages/disadvantages of adopting such tools? What are the outcomes of these prospects?

Krško NPP response:

In fire PSA this is one of the reasons for the fire PSA upgrade that is in progress (IAEA review 2020).

d) How are you facing to this (understanding of the corresponding studies by the stakeholders)?

Krško NPP response:

In fire PSA this is one of the reasons for the fire PSA upgrade that is in progress (IAEA review 2020).

11. Operating Experience: Provide a detailed description on if and how the operating experience from both (i) fires and (ii) other events (whether reportable or not) with degradation or failure of fire protection features in the installation analysed –and, as far as available, also from other nuclear installations– is considered in the fire analysis.

Krško NPP response:

The Krško NPP operating experience program is based on Krško NPP Corrective Action Program MD-20, which outlines the responsibilities and requirements for Krško NPP operating experience (OE) feedback program. It includes use of lessons learned from events that have occurred, both within and outside Krško NPP. The applicable program (Operating Experience Assessment Program) and procedure (Use of Corrective Action Program) define requirements, roles, and responsibilities for effective of Operating Experience program.

Krško NPP operating experience program includes all required steps such as: collection of external operating experience; screening; analysis and trending; management of corrective actions; use, dissemination, and exchange of operating experience; review of the effectiveness as well as data documentation. All internal events are noted, processed, and analysed per this program and corrective actions are prescribed and tracked. External events that are delivered to Krško NPP via international organizations are also processed in the scope of the Corrective Action Program. Each related event is analysed and actions for preventing a similar event is defined, if applicable for Krško NPP. The SNSA performs regular thematic inspections in order to access the status of fire safety analysis, which also include fire foreign operating experiences (NRC IN 2013-06, IAEA IRS 8343, IAEA IRS 8426, NRC IN 2014-10 "Potential Circuit Failure-Induced Secondary Fires or Equipment Damage"). All findings from SNSA inspections were solved or properly addressed by Krško NPP.

NPP Krško Deterministic Analysis of Combination of Fire and Other Events, DCM-TD-040 was carried out in response to the request of the Slovenian regulation »Regulation on radiation and nuclear safety factors, Official Gazette of the Republic of Slovenia no. 74/2016 of 18.11. 2016, regarding the deterministic analysis of credible combinations of fires and other events. Credible combinations of events are determined based on document NEA/CSNI/R (2016)7, "Event Combinations of Fire and Other Events, The Fire Incidents Records Exchange Project Topical Report No. 3", 2016. That report presents the results of analysing event combinations of fires and other events in the FIRE Database (OECD), which at present contains 448 fire events from nuclear power plants (NPP) in twelve countries.

In accordance with observations and findings of various events, the improvements were performed in Krško NPP, as listed in NAR, section 3.1.3.2.

12. Additional analyses: Following the accident at the Fukushima NPP, stress tests were defined for European NPP. Has there been followed a similar approach regarding beyond-design-basis fire events for nuclear power plants in your country?

    Krško NPP response:

    Krško NPP performed modifications as a response to Fukushima accident, in line with NEI 12-06 requirements, and response to B.5.b (NEI 06-12) actions enabling additional equipment to be connected to the existing Krško NPP's systems (fast connections) to improve the management of beyond design basis accidents. and introduced different strategy for accidents mitigation including fire. As part of the action plan per B.5.b order issues by US NRC, generic analyses have been performed for large commercial aircraft crash into containment and surrounding building. Results indicated that for large dry double containment, as the one at NPP Krško, no direct primary pressure boundary damage can be expected. Krško NPP also expanded its capability to cope with the large fires, as response to NEI06-12 B.5.b requirement, by getting new fire protection equipment, as detailed listed in NAR, section 2.1.4.5.

    Additionally, the fire safety was increased due to construction of additional primary and secondary cooling capacities, DEC systems and dedicated water supply , located in separate, bunkered building 2, with DEC power supply, located in bunkered building 1. This DEC systems are capable to cool the plant and provide long term cooling in case of large fire on design systems. They represent additional, independent, separated, dislocated train for primary and secondary cooling.

    Installation of the Emergency Control Room (ECR) significantly improved the Shutdown Capabilities of the Krško NPP and expanded possibilities to cope with a postulated fire in the MCR or cable spreading rooms and as such increased the margin of safety considerably. Refer also to NAR, 2.1.5.2.2 Safety Upgrade Program (SUP).

    Set of modifications in general, but also with regards to fire safety, was introduced within the Krško NPP's Safety Upgrade Program (SUP), which is detailed described in NAR, section 1.1.2.

13. Results of the Fire Safety Analyses, revisions and actions: Please provide details about:

    a) A more elaborated description of the results of the analysis since for some plants the description is not very detailed.

       Krško NPP response:

       As result of fire safety analysis, set of the procedures are developed and the validation of those procedures on the simulator prove the existing systems with the combination of additional installed system (in scope of SUP project) ensure that fire will not jeopardize the safe operation of the plant and that radioactive release in the environment will be prevented. Krško NPP has developed several operating procedures in connection with the Fire Protection (FP) system, from System Operating Procedures (SOP) to Alarm Response Procedures (ARP), which give the operator instructions for taking actions when an individual alarm occurs on the alarm system. The Fire Response Procedure (FRP) are developed based on the FHA analyses and cover actions of operators in the fire event in the technological part of the power plant.

       Original design of the Krško NPP provided remote shutdown panels, with which the plant could be safely shut down and remove decay heat in case of the MCR evacuation, but was not equipped with controls to cope with combined events, such as MCR evacuation and a LOCA. After implementation of the Krško NPP's SUP, the new ECR functions were expanded, thus enabling the operators to shut down and cool the reactor in case of loss of the MCR, combined with DBAs or DEC events in accordance with the EEOP "Evacuation Emergency Operating Procedures

More information about revisions and actions is provided in NAR, chapter: 2.1.5 Periodic review and management of changes and 4.2.1 Krško NPP's Deterministic Fire Hazard Analysis, 4.2.2 Fire Probabilistic Safety Assessment,

Slovenian regulations require to perform the revision of FHA at least every two years and revision of FHA includes all changes (modifications and other changes on SSCs or mode of operation, which can be performed through modification process, wok order or Corrective Action Program) performed in previous period. The details are also provided in NAR:

2.1.4.7 FHA Results Procedures Integration,
2.1.4.8 Fire Probabilistic Safety Assessment Results,
2.1.4.9 The Most Important Accident Sequencies from Fire PSA,
2.1.4.10 The Most Important Accident Sequencies from Spent Fuel Pool,
2.1.4.11 Combinations of Events with Fire Events,
2.1.4.12 The Most Important Accident Sequencies from Dry Storage,
2.1.4.13 Contribution of Fire Events to Overall PSA Results.

b) Please provide results for the fire contribution to CDF / LRF / LERF.

Krško NPP response:

The contribution of the fire events to the overall PSA results for different plant states is presented in the table below. Plant states descriptions are provided in NAR, section 2.1.4.13 (POS1C presents startup, POS2A and POS3A presents hot standby and hot shutdown, respectively; while POS5 and POS6 presents shutdown states).

Contribution of Fire Events to Overall PSA Results

Plant State	Fire CDF [/ry]	Fire LERF [/ry]	Total CDF [/ry]	Fire CDF [%]
Full Power	3.53E-07	5.11E-10	1.35E-05	2.61%
POS1C	2.54E-09	3.7E-12	9.59E-08	2.64%
POS2A	4.88E-09	7.12E-12	1.49E-07	3.27%
POS3A	3.39E-09	4.95E-12	9.89E-08	3.43%
POS5A	7.18E-08	≈0	7.04E-07	10.21%
POS5B	1.7E-08	≈0	7.42E-08	22.92%
POS5C	3.87E-08	≈0	2.43E-07	15.92%
POS6A	1E-08	≈0	3.55E-08	28.21%
POS6B	1.34E-07	≈0	4.73E-07	28.23%
POS6C	9.3E-08	≈0	2.11E-07	44.08%

Contribution of Fire Events to Overall PSA Results for Spent Fuel Pool

Plant Area	Fire Frequency of SFU* [/y]	Fire LERF [/y]	Total Frequency of SFU [/y]	Fire SFU [%]
SFP	**7.5E-09**	**≈0**	**1.19E-06**	**0.6%**

** SFU: Spent Fuel Uncovery*

Contribution of Fire Events to Overall PSA Results for Dry Storage

Plant Area	Fire Risk [annual probability]	Total Risk [annual probability]	Fire Risk [%]
Dry Storage	≈0	8.88E-15	0.00%

Details are also provided in NAR:
2.1.4.9 The Most Important Accident Sequencies from Fire PSA,
2.1.4.10 The Most Important Accident Sequencies from Spent Fuel Pool,
2.1.4.12 The Most Important Accident Sequencies from Dry Storage

c) The process carried out to update the fire analysis and the reasons for that.

Krško NPP response:

Slovenian regulations require to perform the revision of deterministic FHA at least every two years and revision of FHA includes all changes (modifications and other changes on SSCs or mode of operation, which can be performed through modification process, wok order or Corrective Action Program) performed in previous period. The details are also provided in NAR, section 2.1.5 Periodic review and management of changes.

d) The procedure and responsibilities to design and establish compensatory measures when non-conformities or weaknesses have been identified.

Krško NPP response:

The original Krško NPP FHA was limited to provide the reactor shutdown and cool down function, as required by 10 CFR 50 Appendix R. Within the preparation of the report for the 2nd TPR, the Krško NPP's FHA were expanded to include fire hazard analyses for the SFP Decay Heat Removal, for HVAC systems, for shutdown modes of operation, as well as for the combination of fires with other events. This way the Krško NPP's FHA is in line with the latest WENRA RLSs and best industry practice. Where consequences of analysed events could jeopardize safe shutdown of the plant, jeopardize the SFP decay heat removal function or cause potential release of radioactive material, compensatory actions were prescribed to enable safe state of the plant, to extinguish fire by using installed or mobile fire protection equipment and to minimize effects of radioactive release to environment. Appropriate procedures for compensatory measure are in place.

Fire protection equipment, including fire detection and suppression systems, fire barriers, and penetration seals is controlled through the administrative program, and appropriate remedial actions are taken as needed. As conditions warrant, remedial actions include compensatory measures to ensure that an equivalent level of fire protection is maintained, while ensuring that equipment repairs and restoration to service is performed in a timely manner.

PSA analyses need update due to:

- Living fire PSA update due to the plant's Safety Upgrade Program; and
- Development of standards and practice after the Krško NPP fire PSA implementation.

PSA update is currently in progress.

Details are provided in NAR, section 2.1.6 Licensee's Experience of Fire Safety Analyses

e) The use of the fire analyses by the regulator.

Regulator (SNSA) response:

The safety analyses are important for the Slovenian Nuclear Safety Administration's (SNSA) regulatory activities. The fire analyses serve as the bases for various regulatory actions, including:

- **Review and assessment: for important modifications, the regulator reviews if the fire hazard analyses are correctly modified or updated. SNSA utilizes fire safety analyses to**

review and assess the licensee's nuclear safety, focusing on areas such as fire protection.

- **Independent analyses: SNSA conducts its own analyses, separate from the licensee, to assess fire events at the Krško NPP.**
- **Emergency preparedness: fire hazard analyses are used to support the SNSA in its emergency preparedness.**
- **Inspections/thematic fire inspections: safety analyses inform the scope and focus of inspections conducted by SNSA at the Krško NPP. This includes reviewing the adequacy of the licensee's fire protection measures. Twice a year, SNSA performs in-depth fire safety inspections at the Krško NPP site. These inspections include a thorough review of the various fire analyses prepared by the licensee, such as fire event analyses, fire hazard analyses, and fire probabilistic safety assessments (PSA).**

f) The influence of international reviews on the Fire Safety Analysis.

Krško NPP response:

Krško NPP introduced various plant changes, purchased additional mobile equipment (mobile diesel generators, pumps, heat exchangers, compressors, strainers, etc.), and performed modifications as a response to NEI 06-12 B.5.b ”Phase 2&3 Submittal Guideline” requirements, enabling additional equipment to be connected to the existing Krško NPP’s systems (fast connections) and introduced different strategy for accidents mitigation through Extensive Damage Management Guidelines (EDMG's).

In the framework of the EU stress tests following the Fukushima accident, Krško NPP has performed continuous safety improvements in the scope of Safety Upgrade Program (SUP). The SUP comprises the construction of additional safety systems to provide reactor core and spent fuel cooling and represents an even higher level of resistance of the plant in case of extraordinary natural and other unlikely events such as extreme earthquake, flood, and aircraft crash. Additional safety systems increase protection of defence-in-depth and further minimize plant’s core damage frequency (CDF).

Several international reviews were performed as described in NAR, Section 2.1.6.2 and results were upgrades of plant design and upgrade of fire safety analyses (fire hazard analyses and fire PSA analyses). Large quantity of combustible materials was substantially decreased at Krško NPP as response to OSART mission undertaken 2003. The response to Independent review mission 2007 finding, Fire Detection system was installed in all areas of the technological part of the plant and all fire barrier plates between safety and non-safety related cable trays are repaired. Independent review missions, undertaken 2011 and 2014 resulted in improvements in the field of fire protection - the modification was performed to provide actuation of the suppression system for reactor coolant pumps from MCR and procedure for fire drills (FPP-3.7.018 “Performance of fire drills”) was revised to clearly define the purpose, goals and acceptance criteria of fire drills. OSART mission undertaken 2017 is identified that Krško NPP did not have Fire Preplans for managing big fires (airplane crash); that there is no control of transient combustibles in temporary modification process; and that mobile diesel generators do not have installed Fire Detection System. As response Krško NPP Krško NPP developed new Fire Preplans for big fires DCM-TD-037 “Fire Plan in Krško NPP – Large Fires in Plant Area”; temporary modification process was upgraded with control of transient combustibles and mobile diesel generators were equipped with the Fire Detection System. Additional details related to international reviews and Krško NPP responses are provided in NAR, section 2.1.6.2 Lessons Learned from Events, Reviews, Fire Safety Related Missions, etc.

14. Strengths/weaknesses: In cases that no strengths and weaknesses have been explicitly mentioned in the NAR, please confirm that neither strengths nor weaknesses have been identified.

Krško NPP response:

Strengths of plant design and analyses is in regular plant design improvements (FPAP, SUP), fire response procedures and regular updates of fire hazard and PSA analyses, that were able to support the identification of plant weaknesses and to support plant upgrade modifications prioritization. Additionally on the highest level of plant safety, plant follows single failure criterion even in case of fire event by use of independent DEC systems (what is well beyond the 10 CFR 50 Appendix R requirements). In addition to that, analyses of combination of all events with fires were also carried out, which show that the Krško NPP is safe even for cases of combinations of events.

The weaknesses in the field of plant design (already identified in NAR, section 2.1.6.1) with the highest risk impact, was mitigated with the implementation of the fire protection action plan modifications, while other weaknesses were compensated with appropriate administrative procedures (control of combustible material, firefighting readiness, etc.). After the implementation of the Krško NPP's SUP, which included installation of an independent safety train (separated physically and electrically) in a dislocated bunkered buildings, as well as installation of the ECR, from where operators can control (shut down and cooldown the reactor as well as SFP), the fire safety of the Krško NPP was further enhanced, as these systems provide an alternative / dedicated shutdown capability and ensure the safety of the plant even in case of worst case fire scenarios. This capability compensates for the rest of the weaknesses identified by the comparison with the Appendix R requirements.

Fire PSA weakness is that the analyses have to be upgraded to follow the current standards and practices and to reflect the upgrade of plant and fire hazard analyses according to the IAEA review findings. Fire PSA update/upgrade is currently in progress.