REPUBLIC OF SLOVENIA
MINISTRY OF NATURAL RESOURCES AND SPATIAL PLANNING
SLOVENIAN NUCLEAR SAFETY ADMINISTRATION

Slovenian National Assessment Report on the Topical Peer Review 2023 Fire Protection

Final Report

October 2023

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Executive Summary

The European Union's Nuclear Safety Directive 2014/87/EURATOM (NSD) requires the member states to undertake Topical Peer Reviews (TPRs) at least every six years with the first starting in 2017 on topic ageing management. In November 2020, at its 41st Plenary Meeting, ENSREG decided that the topic of the second Topical Peer Review (TPR II) would be in the area of fire protection of the nuclear power plants as described in "Terms of References for the Topical Peer Review Process on Fire Protection". WENRA has developed a technical specification for the national assessment reports to ensure that they are all produced to a common standard. This report has been produced in accordance with that specification which includes a well-defined content and identifies report sections to be written by licensees and by regulators.

Based on given requirements, the Slovenian National Safety Authority (SNSA) – the national regulator, has issued the Decree 3571-5/2022/1 – "Strokovni pregled (TPR) na temo požarne varnosti in priprava Tehničnega poročila po Direktivi EU o jedrski varnosti" [177], as of September 5, 2022. In accordance with given SNSA Decree, the Krško NPP performed actions and prepared the required Technical Peer Review on the given topic Fire Protection Safety for NPP Krško. This report has been produced in accordance with WENRA specification [136] and SNSA requirement, and includes one operating nuclear power reactor Krško NPP, radwaste storage facilities and Dry Storage Facility (DSF), both located on Krško NPP site.

The scope of this report covers overall fire safety at the Krško NPP description, fire safety analyses, fire protection concept and its implementation (fire prevention, fire detection, active fire protection and passive fire protection), implementation of overall fire protection program requirements, overall assessment including main strengths and weakness identified during assessment.

Fire Protection Systems in Krško NPP are designed to provide adequate fire protection from all known fire hazards following a defense in depth approach. Prevention measures are incorporated into all activities and processes of the plant (operation, maintenance, or modification activities) to prevent the fire ignition and spreading. Part of fire prevention measures in the Krško NPP is achieved with the design of systems, structures and components. Apart from being included in the plant structural design, fire prevention is of a high concern in performing operation, maintenance and modification activities at the plant.

The fire hazard analyses for nuclear power plants are to be carried out, and kept updated to demonstrate that the fire safety objectives for the plant are met through the fire design principles satisfied, that the fire protection measures are appropriately designed, and that any necessary administrative provisions are properly identified and implemented in accordance with the Slovenian regulation "Rules on Radiation and Nuclear Safety Factors", Official Gazette of the Republic of Slovenia No. 74/2016 of 18.11.2016 [21], and also in accordance with the requirements of the WENRA Safety Reference Levels for Existing Reactors [132] - Issue E: Design Basis Envelope for Existing Reactors and Issue SV: Internal Hazards #SV6.1[132]. Krško NPP has two approaches to assure fire safety: a comprehensive deterministic fire hazard analysis (FHA) determines the adequacy of the fire protection measures, while a probabilistic risk assessment (Fire PSA) methodology is driven by and in support of the development of risk-informed performance-based fire safety engineering.

The initially prepared Krško NPP Fire Hazard Analysis (FHA) [3] was developed on deterministic basis, and it includes item-by-item assessment of Krško NPP in accordance with the positions set forth in BTP APCSB 9.5-1, Appendix A [127] and assesses capability to safely shutdown the plant from power operation in case of fire in any area as required (or in accordance) with 10CFR50, Appendix R [43]. Deterministic analyses have been upgraded and reflect the As-built (post Safety Upgrade Program) plant condition/configuration. It also covers fire in all operating modes, fire in Spent Fuel Pool area and systems dedicated to Spent Fuel Pool decay heat removal, Heating, Ventilation and Air Conditioning systems and the combination of fire and other events.

Krško NPP has established the NPP Fire Protection Program, which defines the organization of fire safety, fire safety measures and supervision over their implementation, provides instructions for handling in case of fire and specifies a training program to support a successful fire protection, strict rules and organization of the fire protection measures, controls and activities. It also defines the rules for the fire prevention and response to fire events.

In addition to the Fire Protection System itself, there are many design features of the plant that would contribute to confining and limiting a potential fire condition, as identified in this report. Krško NPP introduced various plant changes, purchased additional mobile equipment and performed modifications as a response to NEI 06-12 B.5.b "Phase 2&3 Submittal Guideline" [53] requirements. In the framework of the EU stress tests conducted by the European Commission following the Fukushima accident and as a precondition for long term plant operation, Krško NPP has performed continuous safety improvements in the scope of Safety Upgrade Program. Additionally, any change performed in Krško NPP were and will be continuously evaluated from the perspective of the impact on Fire Safety in accordance with applicable program and procedures.

Krško NPP conducted in 2022 the self-assessment regarding the fire protection and identified some gaps, which were resolved by complementing the existing FHA with four addendums as presented/ described in the report. It is also important to note that NPP Krško has in place a continuous improvement process which has also resulted in major improvements and modifications in the area of fire protection as presented in the report.

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Abbreviation List

AAC	Alternate AC
AAF	Alternative Auxiliary Feedwater System
AB	Auxiliary Building
AC/DC	Alternative Current/ Direct Current
ADB	Administrative Building
ADP	Administrative Procedure
AE	Severe Accident Management Equipment System
AESP	Alternative Equipment Support Procedure
AF	Auxiliary Feedwater System
AFI	Area for Improvement
AFW	Auxiliary Feedwater (System)
ALARA	As Low As Reasonably Achievable
AMP	Aging Management Program
AOP	Abnormal Operating Procedure
ARHR	Alternative Residual Heat Removal
ARP	Annunciator Response Procedure
ASF	Alternative Spent Fuel Cooling
ASI	Alternative Safety Injection
BB1	Bunkered Building 1
BB2	Bunkered Building 2
BDBA	Beyond Design Basis Accident
BTP	Branch Technical Position
BWR	Boiling Water Reactor
CAP	Corrective Actions Program
CB	Control Building
CC	Component Cooling
CCB	Component Cooling Building
CCW	Component Cooling Water (System)
CDF	Core Damage Frequency
CNT	Containment Closure
CRDM	Control Rod Drive Mechanism
CSNI	NEA Committee on the Safety of Nuclear Installations
DB	Decontamination Building
DBA	Design Basis Accident
DC	Direct Current
DEC	Design Extended Condition
DG	Diesel Generator
DGB	Diesel Generator Building

DHR	Decay Heat Removal
DSB	Dry Storage Building
DSF	Dry Storage Facility
ECR	Emergency Control Room
EDMG	Extensive Damage Mitigation Guideline
EEOP	Evacuation Emergency Operating Procedure
ELE	Electricity
ENSREG	European Nuclear Safety Regulators Group
EOP	Emergency Operating Procedure
EPRI	Electric Power Research Institute
ERO	Emergency Response Organization
ESD	Engineering Services Department
ESW	Essential Service Water (System)
FEDB	Fire Events Data Base
FHA	Fire Hazard Analysis
FHB	Fuel Handling Building
FM	Factory Mutual
FP	Fire Protection
FPAP	Fire Protection Action Plan
FPP	Fire Protection Plan
FPSA	Fire Probabilistic Safety (risk) Assessment
FRP	Fire Response Procedure
FSAR	Final Safety Analysis Report
GOP	General Operating Procedure
HEAF	High Energy Arcing Fault
HELB	High Energy Line Break
HEPA	High Efficiency Particulate Air
HERCA	Heads of European Radiological Protection Competent Authorities
HEX	Heat Exchanger
HOV	Hand Operating Valve
HPSI	High Pressure Safety Injection
HRA	Human Reliability Analysis
HRE	Higher Risk Evolution
HTS	High Temperature Seal
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
IB	Intermediate Building
IIE	Internal Initiator Event
INV	Inventory
IPE	Individual Plant Examination

IPEEE	Individual Plant Examination for External Events
IPERS	International Peer Review Service
ISFSI	Independent Spent Fuel Storage Installation
KSF	Key Safety Function
LE	Low effort
LERF	Large Early Release Frequency
LILW	Low and Intermediate Level Radwaste
LOOP	Loss of off - or/and – On-site Power
LTO	Long-Term Operation
MCC	Motor Control Center
MCR	Main Control Room
MHX	Mobile Heat Exchanger
MOV	Motor Operated Valve
MPC	Multi-Purpose Canister
NAR	National Assessment Report
NEA	Nuclear Energy Agency (OECD)
NEI	Nuclear Energy Institute
NEK	Nuklearna Elektrarna Krsko (Krsko NPP)
NFPA	National Fire Protection Association
NPO	Non-Power Operation
NPP	Nuclear Power Plant
NRC	U.S. Nuclear Regulatory Commission
NUREG	US Nuclear Regulatory Commission Regulation
OECD	Organization for Economic Co-operation and Development
OSC	Operations Support Center
PAR	Passive Autocatalytic Recombiners
PCV	Pressure Control Valve
PDM	Predictive Maintenance Procedure
PIS	Process Information Systems
PMF	Probable Maximum Flood
PMO	Mobile Equipment Storage Unit
PNV	Program Nadgradnje Varnosti (Safety Upgrade Program)
PORV	Power-Operated Relief Valve
POS	Plant Operating State
PRA	Probabilistic Risk Assessment
Pre-SALTO	Pre-Safety Aspects of Long-term operation
PSA	Probabilistic Safety Analysis
PSR	Periodic Safety Review
PWR	Pressurized Water Reactor
RB	Reactor Building

RCP	Regulatory Conformance Program
RCS	Reactor Coolant System
RCS CL	Reactor Coolant System Cold Leg
RCS HL	Reactor Coolant System Hot Leg
REC	Reactivity Control
RHR	Residual Heat Removal (System)
RHWG	Reactor Harmonization Working Group
RO	Reactor Operator
RWS	Radwaste Storage Building
RWSF	Radwaste Storage Facility
RWST	Reactor Makeup Water Storage Tank.
SALTO	Safety Aspects of Long-term Operation
SAME	Severe Accident Management Equipment
SAMG	Severe Accidents Management Guidelines
SAR	Safety Analysis Report
SBO	Station Blackout
SCADA	Supervisory Control and Data Acquisition
SCS	Support Cooling System
SD	Shutdown
SFP	Spent Fuel Pool
SG	Steam Generator
SI	Safety Injection (System)
SNSA	Slovenian Nuclear Safety Authority (URSJV)
SOP	System Operating Procedure
SR	Safety-related
SSA	Safe shutdown Separation Analysis
SRL	Safety Reference Level
SSC	Systems, Structures and Components
SSD	Safe Shutdown
SSE	Safe Shutdown Earthquake
SUP	Safety Upgrade Program
SW	Essential Service Water System
SWGR	Switchgear Room
TPR	Topical Peer Review
TR	Technical Report
TS	Technical Specifications
UL	Underwriters' Laboratories Inc
URSJV	Uprava Republike Slovenije za Jedrsko Varnost (SNSA)
USA	United States of America
USAR	Updated Safety Analysis Report

VCT	Vertical Cask Transporter
WENRA	Western European Nuclear Regulators Association
WMB	Waste Manipulation Building
WSF	Waste Storage Facilities
YD	Krško NPP Yard
ZVISJV	Zakon o Varstvu pred Ionizirajočimi Sevanji in Jedrski Varnosti (Ionising Radiation Protection and Nuclear Safety Act)

1 General Information

Krško Nuclear Power Plant (NEK) is the only nuclear power plant in Slovenia. It is located on the left bank of the Sava River approximately 2 km southeast of the town of Krško in the east-southeast part of the Republic of Slovenia. The site is on the north-western brim of an alluvial valley surrounded by hills varying in relative elevation from 200 m to 700 m. The ground surface elevation of the site is 155.20 m above sea level.

The surrounding area of the site is sparsely populated. Except for a few small towns, Krško included, the area is mainly rural. The nearest of larger population centre is Zagreb, 38 km east-southeast from the site, with a population of approximately 900.000 inhabitants. The access to the plant is provided by means of the industrial road linked to the regional road Krško–Brežice which is, with the bridge over the Sava River, connected to the international road Ljubljana–Zagreb H-1. The plant also has an industrial railway line, which connects it with the Krško Railway Station.

Krško NPP owns the land within the site boundary in a rhomboid shape with sides approximately 400 m in length. The site boundary is marked by a fence.

The Krško NPP was built jointly by the Republic of Slovenia and by the Republic of Croatia. Net electrical output of the plant is 700 MWe. The plant is equipped with the Westinghouse pressurized-water reactor with thermal power of 1994 MWt. The plant is connected to the 400 kV transmission system to cover the needs of major consumers of Slovenia and Croatia. Planned annual electric power production amounts to over 5 TWh. For start-up and emergency, Krško NPP is also connected to the 110 kV grid by the power line Krško NPP – gas-powered Brestanica Plant.

Krško NPP's operating license has no time limitation, but it dependent on the regulatory approval of every subsequent Periodic Safety Review (PSR). PSR is required by law every 10 years to confirm that the plant is safe as originally intended, determine if there are any structures, systems or components that could limit the life of the plant in the foreseeable future, and compare the plant against modern safety standards and to identify where improvements would be beneficial at justifiable costs. Operating limits are stated in the Krško NPP Technical Specifications and Radiological Effluent Technical Specifications, Design Extension Technical Specifications, Dry Storage Technical specifications and the Updated Safety Analysis Report.

Periodic review of the emergency preparedness is required after each new risk assessment, after each change in emergency resources or at least every three years.

Plant History and Important Events

1983 Start of commercial operation

1983 First outage, refuelling

1984 Operating license issued by Slovenian regulatory body

2000 Replacement and uprate of steam generators

2012 SNSA approved Ageing Management Program on which life-extension is based

2022 Safety Upgrade Program completed

After the Krško Basin had been selected as a candidate site for Nuclear Power Plant, the Working Group of the Republic of Slovenia Business Association for Electric Power Resources in Collaboration with Slovenian electric Power Utilities and research institutes carried out first researches during the period from 1964 to 1969.

Following the proposal given by the Slovene and Croatian electric power utilities, the Governments of Slovenia and Croatia signed an agreement on joint construction of two nuclear power plants to cover the increasing needs for electric power in both Republics. The decision to construct nuclear power plants was expedited by the fact that both Republics lacked conventional power resources.

The investors of the plant were Savske elektrarne, Ljubljana and Elektroprivreda, Zagreb. Their Investment Team carried out preparatory works, officially invited tenders and selected the most auspicious one.

In August 1974, the two investors entered into a turn-key contract with the U.S. Westinghouse Electric Corporation for the supply of equipment and the construction of the 635 MW nuclear power plant. According to the main contractor Westinghouse, the designer was the American company Gilbert Associates Inc., while work performers were delegated from Slovene and Croatian companies. Civil works were carried out by Gradis and Hidroelektra and erection works by Hidromontaža and Đuro Đaković. The plant uprate for Krško NPP was performed in year 2000 where both of the original steam generators were replaced with new ones from Siemens. Additionally other modifications were performed to increase the MWe output of the plant. The project resolved issues with the original steam generators and increased the power output by approx. 6%, to 700 MW.

The Republic of Slovenia and the Republic of Croatia participated equally in providing financial resources.

On 1 February 1975, civil works began. The plant became the nuclear facility in May 1981, when the initial core was loaded. The first criticality was achieved in September 1981. On 2 October 1981, the generator was synchronized to the grid for the first time. In August 1982, the plant started to operate continuously at 100% power. On 1 January 1983 commercial operation of the plant began.

1.1 Nuclear Installations Identification

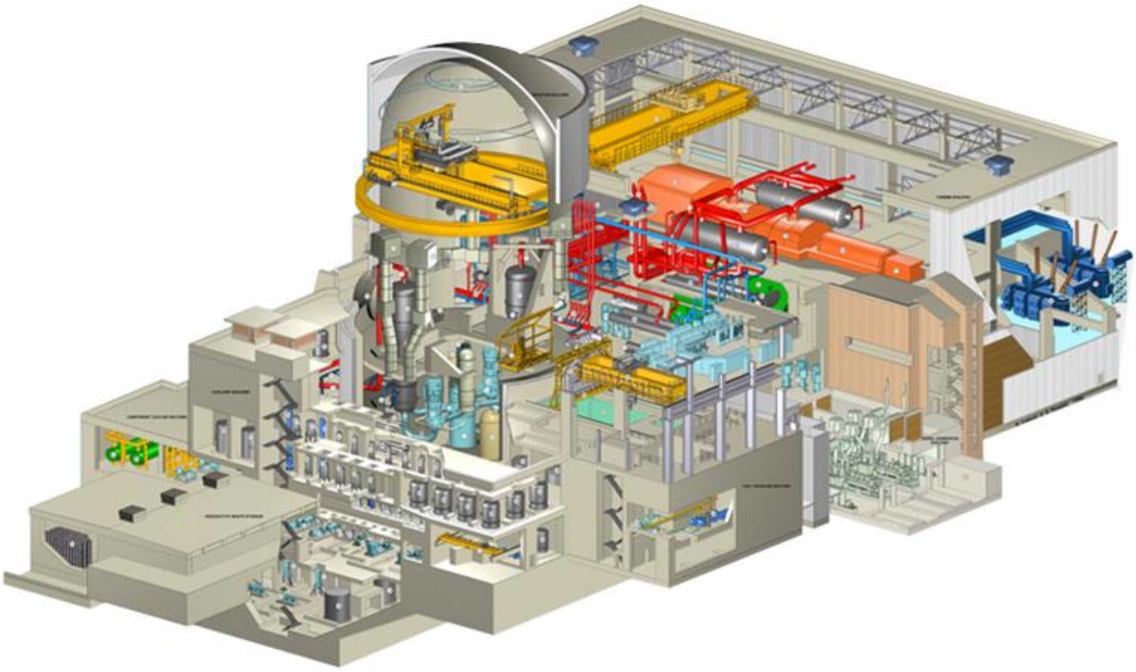
All the principal structures of the Nuclear Power Plant are located on a solid reinforced concrete platform, which is situated upon the Pliocene sandy-clay sediments of the Krško basin.

The principal plant structures are the Reactor Containment Building, the Turbine Building, the Auxiliary Building, the Intake Structure, the Fuel Handling Building, the Solid Waste Storage, the Decontamination Building, the Bunkered Building 1, the Bunkered Building 2, the Waste Manipulation Building 1, the Operation Support Center and the Dry Storage Building.

The Containment consists of a free-standing cylindrical steel shell enclosed by a separate reinforced concrete Reactor Building and was designed by Gilbert Associates, Inc. It is designed to accommodate normal operating loads, functional loads resulting from a loss-of-coolant accident, and the most severe loading predicted for seismic activity. In addition to a Containment Spray System, a Containment Recirculation and Cooling Ventilation System is provided to remove post-accident heat.

The Turbine Building contains the turbine generator and all the power conversion related accessories. The building does not contain any safety-related equipment and is designed in accordance with the local and national building codes.

Figure 1: Krško NPP Major Structures



The Auxiliary Building structures are of reinforced concrete design with shear walls and beam and slab floor systems, suitably protected to prevent the intrusion of groundwater and to preclude simultaneous flooding due to a fluid-system rupture.

The Intake Structure consists of two separate substructures: a non-safety category structure containing the main condenser Circulating Water pumps and related equipment and a safety category structure containing the Service Water pumps and the related equipment. A dam has been built across the Sava River with a pumping station and water intake, and discharge structures for cooling water intake. Three batteries of cooling cells and two pumps are included for combined cooling in the event of low river flow rates.

The Fuel Handling Building is an integral part of the Auxiliary Building and is a reinforced concrete structure designed to withstand missiles as required to protect new and spent fuel and nuclear Safety Class equipment and components.

Solid Waste Storage is located on the south-western border of the plant and can temporarily hold approximately 11.000 standard drums. Waste Manipulating Building (WMB) located near the Solid Waste Storage Facility, provides capabilities for the collection, treatment and conditioning of low and intermediate-level waste (LILW), preparation for transport, and radiological control of materials.

Decontamination Building is a reinforced concrete building with the primary function of housing two old steam generators and storing low and intermediate level waste produced during the replacement of the steam generators.

Bunkered Building 1 (BB1) is a reinforced concrete building, which houses emergency diesel generator DG3, 6.3 kV switchgear, 125 VDC batteries, 400 V MCC, and other equipment necessary to supply emergency standby electric power to operate safety systems replacing any emergency diesel generator or as a standby AAC source. Also, BB1 houses the Emergency Control Room (ECR) and Technical Support Center (TSC). The ECR ensures the plant capability for remote shutdown and to cooldown and maintain the cold shutdown plant status in the case of the MCR evacuation or Design Extended Conditions (DEC).

Bunkered Building 2 (BB2) is reinforced concrete building with primary function of housing pumps, piping, an electrical distribution system and water source tanks of Alternative Safety Injection (ASI) system and Alternative Auxiliary Feedwater (AAF) system.

Operations Support Center (OSC) is comprised of two structures; an old OSC shelter located in the basement of the Administrative Building and a new reinforced concrete structure, located in the non-technological area. The new OSC structure provides a safe shelter and working environment for up to 200 persons for 30 days period for managing and mitigating effects immediately after a severe accident or design extension conditions (DEC) event.

The Dry Storage Building (DSB) is a reinforced concrete and steel building used for storage of the HI-STORM FW casks.

Mobile Equipment Storage Unit 1 (PMO1) and Mobile Equipment Storage Unit 2 (PMO2) are housing mobile SAME equipment used for prevention and mitigation of the plant beyond design basis accidents.

1.1.1 Qualifying Nuclear Installations

As per WENRA TPR2 Technical Specifications [136] description, NPP Krško is comprised of 3 nuclear installations: Nuclear Power Plant, Spent Fuel Storage Facility (Spent Fuel Dry Storage Building) and on-site storage facilities for radioactive waste. Howevere, all od them are part of Krško NPP.

The Dry Storage Building and Waste Storage Facilities are on-site facilities, both located inside Krško NPP fence, they operate with the operating license of Krško NPP and they have a common fire protection program, as well as fire protection and detection system and all other systems (including electrical supply). These installations housed radioactive materials produced within NPP Krško.

1.1.1.1 Brief Summary of Krško NPP

The Krško Nuclear Power Plant is equipped with the Westinghouse Pressurized Water Reactor (PWR) with two cooling loops and it consists of the reactor vessel with its internals and head, two steam generators, two reactor coolant pumps, pressurizer, piping, valves, and of reactor auxiliary systems. Demineralized water serves as reactor coolant, neutron moderator and for dilution of boric acid solution. In the steam generator, the heat from the reactor coolant is transferred to the feedwater on the secondary side of the steam generator to generate steam.

Reactor coolant pressure is maintained by the pressurizer, which is supported by electrical heaters and water sprays supplied with water from the cold legs of the reactor coolant system. Data necessary for reactor control and protection system is provided by measuring the neutron flux, reactor coolant temperature, flow rate, pressurizer water level and pressure detectors. Control rods regulate reactor power. Control Rods Drive Mechanism (CRDM) is fixed on the reactor head, while the absorber rods extend into the reactor core. Long-term core reactivity changes and core poisoning with fission products are compensated by means of boric acid concentration change in the reactor coolant.

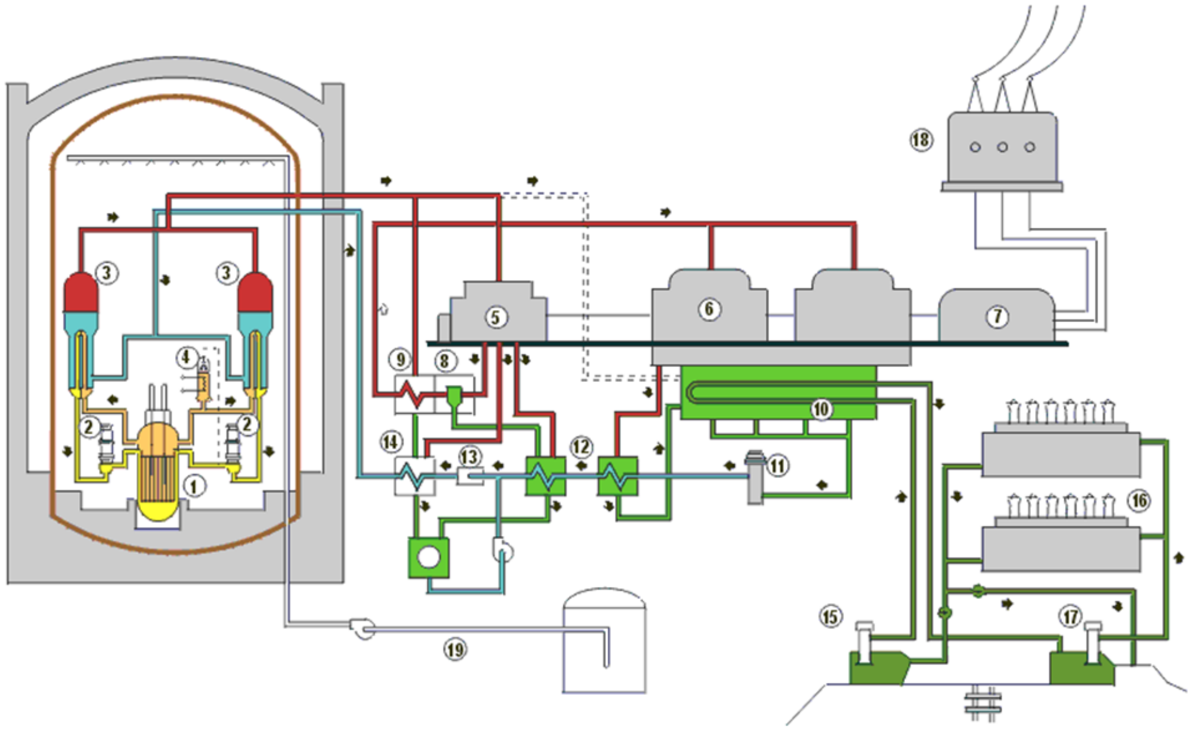
The reactor core is composed of 121 fuel assemblies. Each fuel element consists of fuel rods, top and bottom nozzle, grid assemblies, control rod guide thimbles and instrumentation guide thimbles. Fuel rods contain ceramic uranium dioxide pellets welded into Zirlo tubes. Uranium oxide fuel is shaped into sintered pellets and is enriched with uranium 235. At the end of each fuel cycle, a number of the fuel assemblies is removed, and fresh fuel is loaded. Fresh fuel assemblies are kept in the Spent Fuel Pool. The spent fuel from the Spent Fuel Pool is transferred to the Spent Fuel Dry Storage (SFDS) building, which is designed to provide additional spent fuel assembly storage, outside of the currently used spent fuel wet storage racks and which further improves the nuclear and radiation safety of the plant.

During the refuelling, fuel assemblies are removed from the reactor through a flooded transfer canal penetrating the containment vessel into the spent fuel pool. During the refuelling the reactor is open and the reactor cavity is flooded. The refuelling machine removes the spent fuel assemblies from the reactor core and replaces them with the fresh ones. Fuel assemblies remain in the reactor core for several cycles. Spent fuel assemblies are kept under water in the spent fuel pool, where they are cooled.

The steam generators generate saturated steam, which drives the turbine. Expanded steam from the turbine enters the main condenser where the condensation process takes place. Condensate is then returned to the steam generators via the condensate and feedwater system.

The nameplate rating of the three-phase generator is 850 MVA, voltage 21 kV.

Figure 2: Krško NPP Function Diagram



Plant Function Diagram:

1. Reactor
2. Reactor Coolant Pumps
3. Steam Generators
4. Pressurizer
5. High Pressure Turbine
6. Low Pressure Turbine
7. Generator
8. Moisture Separator
9. Reheater
10. Condensers
11. Condensate Pumps
12. Low Pressure Heater
13. Feedwater Pumps
14. High Pressure Feedwater Heater
15. Circulating Water Pumps
16. Cooling Towers
17. Cooling Tower Circulating Pump
18. Transformer
19. Refuelling Water Storage Tank

The Krško Nuclear Power Plant is connected to the 400 kV transmission system through the 400 kV switchyard. The generator transmits the generated power via two 21/400 kV transformers to the plant switchyard.

In a case of the 400 kV system failure, the electric power is supplied to the plant from the 110 kV system or through 110 kV transmission line from the Brestanica Gas Power Plant, which is 7 km away from Krško NPP. The Brestanica Power Plant can cut-off all other consumers, separate from the 110 kV system and supply the power only to the Krško Nuclear Power Plant.

In addition, the plant is provided with two originally installed emergency diesel generators, each with rated power of 3500 kW, which serve as an independent emergency power source for essential and safety-related plant systems.

The third emergency diesel generator (DG3) with rated power of 4000 kW serves either as an Alternative AC (AAC) source to the plant in case of a total loss of onsite and offsite power, or as a substitute to either of the existing plant Emergency Diesel Generators (DG1 or DG2) in case one of them is out of service due to extended maintenance.

DG3 provides an AC source (6,3 kV, 400 V and 118 V), and dedicated batteries provide DC source (125 V) for all DEC loads and control (Emergency Control Room) in the BB1 building.

Krško NPP introduced various plant changes, purchased additional mobile equipment (mobile diesel generators, pumps, etc.), and performed modifications as a response to NEI 06-12 B.5.b "Phase 2&3 Submittal Guideline" [53] requirements, enabling additional equipment to be connected to the existing Krško NPP's systems (fast connections) and introduced different strategy for accidents mitigation.

Provisions to use mobile devices (availability of such devices, time to bring them on-site and put them in operation) is estimated that Krško NPP has man forces, mobile equipment and resources to manage initial emergency response in case of a severe accident for an extended time - up to 24 hours without any off-site support and up to 1 week with no needs for additional heavy mobile equipment from off-site. The mobile equipment essential for managing severe accidents (SAME) according to the EOP and SAMG strategies are stored at different locations on-site. SAME is placed on safe locations with respect to preventing their impairment in accident conditions (earthquake, floods, fire etc.). Mechanical connections, power supplies, connection tools and other arrangements are prepared in advance at locations and on components of systems where SAME should be connected to or applied to implement the required severe accident management strategies. This enables preparation and implementation of severe accident management strategies only with shift crews effectively trained for accident conditions.

SAME is included in Krško NPP equipment data base as an AE (Accident Equipment) system and is regularly tested and maintained in accordance with plant maintenance procedures. Regular training and drills for shift personnel and other personnel in Emergency Response Organization (ERO) responsible for the implementation of severe accident strategies and handling with SAME are conducted on an annual basis.

Safety Upgrade Program

The Safety Upgrade Program (SUP) is important for the plant's long-term operation and has been supplemented on the basis of experience following the nuclear accident in Fukushima, Japan.

It 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).

The Program consists of three phases and comprises projects of upgrading certain safety systems, safety power supply, radioactive release surveillance, flood safety and spent nuclear fuel store.

During the 2013 outage, the first phase of the safety upgrade was finished, and it included the installation of the passive containment filtered pressure relief ventilation system and the installation of passive autocatalytic hydrogen recombiners in the containment.

After 2013, intensive work of phases 2 and 3 has been on-going and it includes the following projects:

- upgrading anti-flood protection of NPP buildings;
- constructing the new Operations Support Centre;
- constructing an Emergency Control Room and a Technical Support Centre;
- installing additional pressure relief valves in the reactor coolant system;
- installing additional sprays for cooling the spent fuel pool and a connection for a mobile heat exchanger;
- installing an additional pump and a heat exchanger for alternative long-term cooling and residual heat removal;
- construction of the spent fuel dry storage;
- construction of a bunkered safety building (project BB2) with accompanying systems for:

- alternative reactor cooling through water injection into the primary system and the containment (ASI),
- and for adding reactor cooling water to steam generators (AAF) with two tanks, one with demineralized water and the other with borated water.

The implementation of the Safety Upgrade Program (SUP) has been finalized in 2022.

1.1.1.2 Dedicated Spent Fuel Dry Storage Facility

The Spent Fuel Dry Storage (SFDS) is constructed for long-term dry storage of the spent fuel which consequently improves nuclear safety due to its passive spent fuel assemblies cooling nature, reducing the overall number of spent fuel assemblies in the spent fuel pool. The SFDS with the belonging systems and components, fulfil DEC A conditions in accordance with DEC requirements given in Slovenian regulation ([21] and [80]), and was performed in the scope of the Krško NPP's Safety Upgrade Program [55].

SFDS technology represents a safer way of storing spent fuel as the cooling system is passive, so no device, system or energy source is needed for cooling and operation. The dry storage system technology allows spent fuel to be transferred into special canisters and storage casks that provide passive cooling and shielding against ionizing radiation.

The SFDS is designed to provide additional spent fuel assembly storage of spent fuel assemblies into the special HI-STORM FW XL system storage casks outside of the currently used spent fuel wet storage racks, until the moment when the spent fuel will be transported off site for recycling or disposal. The SFDS is comprised of the Dry Storage Building (DSB), which is designed and constructed (on the Krško NPP site) for interim storage of spent nuclear fuel using HI-STORM FW XL casks at Krško NPP site. It represents Independent Spent Fuel Storage Installation (ISFSI) in a sense as defined in USA NRC code 10 CFR 72.3, and fulfills similar given requirements.

The HI-STORM FW XL system consists of interchangeable Multi-Purpose Container (MPC) package, which maintains the configuration of the spent nuclear fuel assemblies, and is the confinement boundary between the stored spent nuclear fuel and the environment, and a HI-STORM FW XL concrete storage overpack that provides structural protection and radiation shielding during long-term storage of the MPC in DSB. The system as a whole provides containment, criticality control, structural protection, cooling, and radiological shielding of the spent nuclear fuel during all operations. The HI-STORM FW FSAR includes all the systems design codes, component classifications, and compliance to 10 CFR 72 provisions. Short-term operations with MPCs are handled in the HI-TRAC VW transfer cask until MPC is placed in the HI-STORM FW XL storage overpack. The HI-TRAC VW is engineered to provide maximum shielding to personnel, providing physical protection to MPC, serve as a container to lift and handle MPC, and facilitate transfer of MPC into transfer to the HI-STORM FW XL overpack.

The cooling of Spent Fuel in DSB is provided by the natural convection ventilation system where it is passively cooled. The ISFSI system does not have Spent Fuel Cooldown function/system, and therefore cannot be jeopardized with potential fire in this area in whole. The Dry Storage Building and casks are cooled passively by natural convection and thermal radiation. The decay heat generated by the spent fuel assemblies stored in MPC heats the surrounding air and induces a buoyancy-driven air flow inside the building. Ambient air is drawn into the building through the air inlet louvers above the concrete wall in the lower portion of DSB, and warm air escapes through the air outlet louvers around the top of DSB. The building vents are sized to allow sufficient passive air flow for heat removal from the loaded casks, as analysed in USAR, Chapter 21 [1].

1.1.1.3 Radwaste Storage Facilities

The Krško NPP includes the following buildings for radioactive waste storage:

- The Radwaste Storage Facility (RWSF), built as an interim storage for solid Low and Intermediate Level Waste (LILW) waste. The inner area is divided into six areas by thick interior concrete walls; the exterior walls and the ceiling are also thick concrete structures, providing appropriate insulation and radiological shielding. The facility has provisions for storing different types of solid radioactive waste separately and retrieving them for further processing (supercompaction, incineration, melting and clearance after the decay of the radionuclides) or disposal at a later time.

- The Decontamination Building (DB), an interim storage, built for decay storage of two old steam generators and radioactive waste produced through the replacement of steam generators and other larger components. The outer wall and the roof slab design were governed by radiological shielding requirements.
- The Waste Manipulation Building 1 (WMB) is a reinforced concrete shielded structure, located adjacent to the Auxiliary Building and the Radioactive Waste Storage Facility, providing a functional connection between the two buildings. Systems and equipment in WMB provide capabilities for the collection, treatment, conditioning of low and intermediate level waste (LILW), waste reduction for compressible waste (2 hydraulic balers and supercompactor) as well as waste assay measurements, preparation for transport, radiological control of materials and for handover to the national disposal facilities.

The radioactive waste management in Krško NPP is performed according to the requirements of ZVISJV-1 [79], in particular according to the provisions set in article 121, the generation of radioactive waste is kept to the minimum, and available storage capacity is analysed at least every two years with the revision of Radioactive Waste Management Program TD-0C [74] and technical report NEK ESD-TR-03/97 [78]. The stored waste meets special storage criteria that comply with the Rules on Radioactive Waste and Spent Fuel Management [80]. These Rules regulate the classification of radioactive waste according to radioactivity level and type, radioactive waste and spent fuel management, the scope of reporting on radioactive waste and spent fuel generation, and the manner and scope of keeping central records on radioactive waste and spent fuel generation, and keeping records on stored and disposed radioactive waste and spent fuel. Information about radioactive waste is updated every year in USAR, Chapter 11 [1].

1.1.2 National selection of installations for TPR II and justification

Slovenian selection of installations for TPR II followed the criteria set forth in the WENRA Topical Peer Review 2023, Fire Protection, Technical Specification for the National Assessment Reports [136]. According to the mentioned specification, the selected installations that are covered by the Nuclear Safety Directive (NSD) are:

- Nuclear power plant: Krško NPP is currently the only NPP in Slovenia.
- Spent fuel storage facility: Spent Fuel Dry Storage Building (belongs to the Krško NPP).
- Storage facilities for radioactive waste that are on the same site and are directly related to the types of nuclear installations listed above: Radwaste Storage Facility, Decontamination Building, Waste Manipulation Building 1 (all belong to the Krško NPP).

The Dry Storage Building and Waste Storage Facilities are on-site facilities located inside Krško NPP fence, they operate with the operating license of Krško NPP and they have a common fire protection program, as well as fire protection and detection system and all other systems (including electrical supply). These installations house radioactive materials produced within the Krško NPP.

Excluded from the national selection is the TRIGA Mark II research reactor (RR) operated by the Jožef Stefan Institute in Ljubljana. The reason for such an exclusion is that the Ljubljana TRIGA RR does not pose significant radiological risk to the environment and the population in case of a fire event. Therefore, the RR fulfils the criterion for omission from the TPR II reporting installations. For the facility, a fire hazard analysis was prepared, and it provided a basis for improvements of fire safety that were implemented. Material posing fire hazard was eliminated. As the result, the consequences of a fire would not result in significant radiological release or contamination of the environment. The Ljubljana TRIGA Mark II RR cannot be directly compared to other TRIGA RR in EU. Following the fire event in 2010 the RR operator invested in many equipment improvements and procedural/emergency response actions that significantly improved the fire safety of the facility. Such fire safety improvement campaign may not have been the practice in some other countries with ageing RR. The fire safety of the facility was reviewed independently by the IAEA INSARR mission and some recommendations for safety improvements were identified that were all implemented, as was confirmed among other also by the IAEA INSARR follow-up mission. The fire safety of the facility was also reviewed within the Periodic safety review.

Other installations listed under the NSD (enrichment plants, nuclear fuel fabrication plants, reprocessing plants) are not present in Slovenia and are therefore not dealt with in this NAR.

1.1.3 Key Parameters per Installation

1.1.3.1 Krško Nuclear Power Plant – Krško NPP

Name	Krško Nuclear Power Plant
License	Nuklearna elektrarna Krško, d.o.o.
Type of reactor	Pressurized Water Reactor (PWR)
Thermal and electrical net power	1994 MWt and 735 Mwe (gross)/700 Mwe (net)
Year of first operation	1983
Year of operating license	1984
Scheduled end of operation date (if any)	2043

NUCLEAR POWER PLANT		
Reactor Thermal Power	MWt	1994
Gross Electrical Output	MW	735
Net Electrical Output	MW	700
Heat Consumption	kcal/kWh	2560
Thermal Efficiency Factor	%	36
CONTAINMENT		
Height	m	71
Inside Diameter	m	32
Outside Diameter	m	38
Steel Shell Test Pressure	MPa	0.357
REACTOR VESSEL		
Outside Diameter	m	3.69
Height	m	11.9
Wall Thickness	m	0.168
Empty Vessel Weight	t	327
Vessel Weight with Internals	t	436
REACTOR COOLANT		
Chemical Composition		H_2O
Additives		H_3BO_3
Number of Cooling Loops		2
Total Mass Flow	kg/s	9220
Pressure	MPa	15.41
Total Volume	m^3	197
Temperature at Reactor (Vessel) Inlet	ºC	287
Temperature at Reactor (Vessel) Outlet	ºC	324
Number of Pumps		2

Pump Capacity	m^3/s	6.3
Pump Driving Power	MW	5.22

STEAM GENERATORS

Material		INCONEL 690 TT
Number of Steam Generators		2
Steam Pressure	MPa	6.5
Steam Temperature	^oC	282
Feedwater Temperature	^oC	223
Total Steam Mass Flow	kg/s	1088
Steam Generator Height	m	20.6
Steam Generator Weight	t	345
Number of U-tubes		5428
Total Heating Surface	m^2	7177
U-tube Outside Diameter	mm	19.05
U-tube Thickness	mm	1.09

REACTOR CORE

Equivalent Diameter	m	2.45
Equivalent Height	m	3.66
Equivalent Radial Thickness of the Reflector	m	0.15
Equivalent Axial Thickness of the Reflector	m	0.10

NUCLEAR FUEL

Number of Fuel Assemblies		121
Number of Fuel Rods per Assembly		235
Fuel Rod Array		16x16
Fuel Rod Length	m	3.658
Clad Thickness	mm	0.572
Clad	Material	Zirlo™
Fuel Chemical Composition		UO_2
Pellet Diameter	mm	8.192
Pellet Height	mm	13.46
Total Fuel Weight	t	48.7

CONTROL RODS

Number of Control Rod Assemblies		33
Number of Absorber Rods per Assembly		20
Total Weight of Control Rod Assembly	kg	53.07
Neutron	Absorber	Ag-In-Cd

Percentage Composition	%		80-15-5
Diameter	mm		8.36
Density	g/cm^3		10.16
Clad Thickness	mm		0.445
Clad Material	Steel SS	304	

ENGINEERED SAFETY FEATURES

Passive Safety Injection System:		
No. of Pressure Vessels/ Accumulator Tanks		2
Active Safety Injection System:		
HP Safety Injection (SI)		
No. of Trains		2
No. of Pumps		2
Pump Flow Rate	m^3/s	0.044
LP Safety Injection (RHR)		
No. of Trains		2
No. of Pumps		
Pump Flow Rate	m^3/s	0.14
Emergency Core Cooling Actuation Time	s	40

TURBINE GENERATOR

Maximum Power	MWe	735
Steam Flow Rate	kg/s	1090
Fresh Steam Inlet Pressure	MPa	6.2
Fresh Steam Temperature	°C	278
Turbine Speed	rad/s	157
Steam Moisture at High-Pressure Turbine Inlet	%	0.46
Condenser Pressure (Vacuum)	kPa	5.1
Average Condensate Temp	°C	33
No. of Feedwater Pumps		3
Feedwater Pump Capacity	%	50
Generator Rated Power	MVA	850
Rated Voltage	kV	21
Generator Rated Frequency	Hz	50
Cos fi	φ	0.876
Regulated Range	%	+10-7

TRANSFORMERS

Main Transformers		
Rated Power	MVA	2x 500
Voltage Ratio	kV	21/400

Load Tap Changing	%	±10
Impedance Voltage	%	15/13
Unit Transformers		
Maximum Permissible		
Continuous Power	MVA	2x30
Voltage Ratio	kV	21/6.3
Impedance Voltage	%	10
Auxiliary Transformer		
Maximum Permissible		
Continuous Power	MVA	60
Voltage Ratio	kV	105/6.3/6.3
Load Tap Changing	%	±15
Impedance Voltage	%	12

1.1.3.2 Dedicated Spent Fuel Storage – SFDS

Name	Dedicated Spent Fuel Storage
License	Nuklearna elektrarna Krško, d.o.o.
Type of facility	Dedicated dry storage facility
Year of operating license or first criticalyity	2023
Scheduled end of operation date (if any)	2123

1.1.3.3 Waste Storage Facilities – Krško NPP

1.1.3.3.1 Radwaste Storage Facility - RWSF

Name	Radwaste Storage Facility (RWSF)
License	Nuklearna elektrarna Krško, d.o.o.
Type of facility	Storage facility
Year of operating license or first criticalyity	1983
Scheduled end of operation date (if any)	2078

1.1.3.3.2 Waste Manipulating Building - WMB

Name	Waste Manipulating Building - WMB
License	Nuklearna elektrarna Krško, d.o.o.
Type of facility	Storage facility
Year of operating license or first criticalyity	2018
Scheduled end of operation date (if any)	Part of Krško NPP

1.1.3.3.3 Decontamination Building - DB

Name	Decontamination Building (DB)
License	Nuklearna elektrarna Krško, d.o.o.
Type of facility	Storage facility
Year of operating license or first criticalyity	2000
Scheduled end of operation date (if any)	Part of KrškoNPP

1.1.4 Approach to Development of NAR for the National Selection

NAR is prepared in accordance with the WENRA Topical Peer Review 2023, Fire Protection, Technical Specification for the National Assessment Reports [136]. SNSA confirmed to ENSREG that there are three nuclear installations selected in Slovenia for NAR.

Since all three selected nuclear installations are on the site of the Krško NPP, the SNSA presented the process of the TPR II to the NPP's staff in July 2022. The presentation included detailed descriptions of technical specifications for the assessment of fire protection in nuclear facilities and for the preparation of NAR with the time schedule for certain actions. Legislative bases for the execution of the TPR II were presented as well. Namely, the Ionising Radiation Protection and Nuclear Safety Act [22] states in the Article 5, Paragraph 7, that the operator of a nuclear facility shall:

- prepare the assessment on nuclear safety /.../ for its facility and obtain the opinion of an authorized expert for radiation and nuclear safety on it;
- report to the authority competent for nuclear safety on the results of the assessment;
- carry out measures prescribed by the authority competent for nuclear safety and which arise from the findings of the international expert review /.../.

In accordance with the mentioned Act, the SNSA issued a decree to the Krško NPP in September 2022 [177] with the request for the NPP to carry out the fire safety assessment, to provide the SNSA with the proposition of the NAR, and to provide the SNSA with an independent expert review of the final draft of the NAR.

The Krško NPP has prepared a proposition of the NAR as per the SNSA letter [177]. The chapters for the NAR were prepared by the operators of the units. These chapters were independently verified by an authorised institution before being sent to the SNSA. Apart from that, the Krško NPP conducted a self-assessment in line with the chapters of the WENRA Technical Specifications [136] that resulted in several new fire hazard analyses and revisions of some existing programmes and procedures.

After the draft proposition of the NAR was received in May 2023 by the SNSA, the latter commented the NAR, prepared the regulatory chapters, and sent the draft version of the NAR with comments back to the Krško NPP. The independent expert review of the corrected draft version of the NAR was done by a relevant Technical Support Organization in Summer 2023. Additional meetings were organized between the SNSA and the Krško NPP, including a 2-day thematic inspection on fire protection, to finalize the NAR by the end of October 2023.

The chapters of the NAR follow closely the pattern shown in the Appendix 2 of the WENRA Technical Specifications [136] or, alternatively, the listed requirements for details that the NAR should describe for each selected nuclear installation. In some cases (e.g., Chapter 3 – Fire Protection Concept and Its Implementation) all selected nuclear installations are dealt with together within a particular subchapter (i.e., there are no separate subchapters for each installation), for they are all on the Krško NPP's site where several concepts are common for the whole site. In this way, the unnecessary duplication of subchapters in the NAR is avoided.

1.2 National Regulatory Framework

The Slovenian Nuclear Safety Administration (SNSA) is a body within the Ministry of Natural Resources and Spatial Planning. The Administration performs professional, administrative, supervisory and development tasks in the areas of radiation and nuclear safety, radiation practices and the use of radiation sources (except in healthcare or veterinary medicine), protection of the environment against ionising radiation, physical protection of nuclear material and facilities, non-proliferation of nuclear weapons, and protection of nuclear goods.

1.2.1 National Regulatory Requirements and Standards

ZVISJV-1 regulates ionising radiation protection for the purposes of reducing, to the maximum possible level, damage to human health due to ionising radiation exposure and radiation contamination of the living environment and at the same time allows the development, production and use of radiation sources and the performance of activities involving radiation.

The Act transposes into Slovenian law the Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom (OJ L 13, 17.1.2014, p. 1), last amended with the Corrigendum to Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom (OJ L 72, 17.3.2016, p. 69), (hereinafter: Directive 2013/59/Euratom), the Council Directive 2009/71/Euratom of 25 June 2009 establishing a Community framework for the nuclear safety of nuclear installations (OJ L 172, 2.7.2009, p. 18), last amended with the Council Directive 2014/87/Euratom of 8 July 2014 amending Directive 2009/71/Euratom establishing a Community framework for the nuclear safety of nuclear installations (OJ L 219, 25.6.2014, p. 42; hereinafter: Directive 2014/87/Euratom), (hereinafter: Directive 2009/71/Euratom), the Council Directive 2011/70/Euratom of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste (OJ L 119, 2.8.2011, p. 48; hereinafter: Directive 2011/70/Euratom) and the Council Directive 2006/117/Euratom of 20 November 2006 on the supervision and control shipments of radioactive waste and spent nuclear fuel (OJ L 337, 5.12.2006, p. 21, hereinafter: Directive 2006/117/Euratom).

Decrees and Rules:

- Decree on activities involving radiation (UV1) (Official Gazette of the Republic of Slovenia [*Uradni list RS*], No. 19/18)
- Decree on dose limits, radioactive contamination and intervention levels (UV2) (Official Gazette of the Republic of Slovenia [*Uradni list RS*], No. 18/18)
- Decree on areas of restricted use due to nuclear facilities and on the conditions of facility construction in these areas (UV3) (Official Gazette of the Republic of Slovenia [*Uradni list RS*], No. 36/04)
- Decree on national radon programme (UV4) (Official Gazette of the Republic of Slovenia [*Uradni list RS*], No. 18/18)
- Decree amending the Decree on national radon programme (UV4) (Official Gazette of the Republic of Slovenia [*Uradni list RS*], No. 86/18)
- Decree on the reduction of exposure due to natural radionuclides and existing exposure situations (UV5) (Official Gazette of the Republic of Slovenia [*Uradni list RS*], No. 38/18)
- Decree on safeguarding of nuclear materials (UV6) (Official Gazette of the Republic of Slovenia [*Uradni list RS*], No. 34/08)
- Decree on the checking of the radioactivity of consignments that could contain orphan sources (UV11) (Official Gazette of the Republic of Slovenia [*Uradni list RS*], No. 10/19)
- Rules on the specialist council on radiation and nuclear safety (JV1) (Official Gazette of the Republic of Slovenia [*Uradni list RS*], No. 35/03)
- Rules on the use of radiation sources and on activities involving radiation (JV2/SV2) (Official Gazette of the Republic of Slovenia [*Uradni list RS*], No. 27/18)
- Rules on authorised radiation and nuclear safety experts (JV3) (Official Gazette of the Republic of Slovenia [*Uradni list RS*], No. 50/16)
- Rules on providing qualification for workers in radiation and nuclear facilities (JV4) (Official Gazette of the Republic of Slovenia [*Uradni list RS*], No. 32/11)

- Rules on radiation and nuclear safety factors (JV5) (Official Gazette of the Republic of Slovenia [*Uradni list RS*], No. 74/16)
- Rules on radioactive waste and spent fuel management (JV7) (Official Gazette of the Republic of Slovenia [*Uradni list RS*], No. 49/06)
- Rules on the safety assurance of radiation and nuclear facilities (JV9) (Official Gazette of the Republic of Slovenia [*Uradni list RS*], No. 81/16)

Requirements regarding Operation

Most of requirements regarding operation are written in JV9 - Rules on the safety assurance of radiation and nuclear facilities, which (among other topics) defines requirements for:

- Facility Management
- Operational Experience Feedback
- Ageing Management
- SSC Maintenance
- Reporting on Radiation and Nuclear Safety
- Classification and Assessment of Modifications
- Application of Probabilistic Safety Analyses in Assessing Modifications
- Notification of and informing on Modifications
- Periodic Safety Review
- Probabilistic Safety Analyses

The requirements regarding internal fire hazards are written in JV5, "Rules on radiation and nuclear safety factors", which defines the following:

- Fire-protection objectives which shall observe the defence-in-depth principle
- Fire-protection design bases
- Building fire safety
- Fire-risk analysis
- Fire-protection systems
- Fire-safety surveillance and maintenance
- Fire-protection organisational arrangements

After Fukushima (March 2011), the European Commission took the initiative to develop the EU stress tests. In October 2011, Krško NPP submitted its stress test report to the SNSA. Subsequently, SNSA requested Krško NPP to integrate the results of the action plan into a Program which was named as the "The Krško NPP Safety Upgrade Program" (SUP), DCM-RP-083 [55].

1.2.1.1 Fire Protection Act

In addition, all Slovenian organisations, including Krško NPP have to comply with the "National Fire Safety Code" - Zakon o varstvu pred požarom (ZVPoz) [101], which is under the jurisdiction of Ministry of Defense. The Fire Protection act includes the organization, planning, implementation, control and financing of fire protection activities and measures.

Supervision over the implementation of this law and other regulations governing protection against fire is carried out by the Inspectorate of the Republic of Slovenia for Protection Against Natural and Other Disasters.

The Inspectorate for Protection Against Natural and Other Disasters is a body within the Ministry of Defense that carries out supervision in the areas of fire protection, protection and rescue, and protection against drowning. It co-designs system solutions for protection against natural and other disasters and develops areas of inspection control.

Inspectors for protection against natural and other disasters (hereinafter: inspector) cooperate with other inspectorates in supervising the implementation of regulations issued in accordance with the provisions of this Act, which regulate the planning and implementation of fire protection measures in individual areas or activities.

1.2.2 Implementation/Application of International Standards and Guidance

1.2.2.1 US NRC Regulations - Regulatory Conformance Program

The Krško NPP Regulatory Conformance Program (RCP) [154] establishes a process by which the Krško NPP can demonstrate continued compliance with the U.S. regulatory requirements as these have evolved over a greater than thirty-five-year period. The Krško NPP RCP is intended to be a "living" document and process, updated periodically to ensure that Krško NPP compliance continues to be assessed as U.S. regulatory requirements may evolve in the future.

The RCP systematically identifies and defines the U.S. Nuclear Regulatory Commission (NRC) regulatory requirements deemed to be of safety significance which NRC has imposed since calendar year 1972 to the present.

The NRC issues documents that licensees (in the U.S.) are required to follow, such as regulations and orders, and documents that request or recommend actions, such as generic letters, bulletins, regulatory guides, and policy statements. Licensees may adopt the NRC recommendations, propose alternative measures or not adopt the recommendations. However, if such recommendations are not followed and NRC has evidence that the public health and safety are not adequately protected or a licensee is not in compliance with the provisions of its license, NRC would then establish the recommendations as requirements imposed on licensees.

1.2.2.2 WENRA SRL 2020

Following the 2011 accident in Fukushima, WENRA mandated its Reactor Harmonization Working Group (RHWG) to review and revise the safety reference levels (SRLs) for existing reactors. The aim of the revision was to integrate the lessons learned from the accident to prevent or control future accidents from similar causes.

By revising SRLs, RHWG took into consideration the IAEA's work to revise its safety requirements, the conclusions of the Second Extraordinary meeting of the Convention on Nuclear Safety, the ENSREG recommendations and suggestions as well as national requirements in the WENRA member states.

The publication of the revised SRLs reaffirms two of WENRA's main objectives: a harmonized approach to nuclear safety in Europe and the introduction of continuous improvement of reactor safety into the national regulatory framework.

Technical report NEK ESD-TR-23/15 [155] represents the Krško NPP response to the September 2014 revision of the WENRA Safety Reference Levels (SRL) [178]. All chapters of WENRA SRL were reviewed and status has been presented in that technical report.

The purpose of NEK ESD-TR-04/22 [156] technical report is to evaluate the Krško NPP compliance with revised WENRA Safety Reference Level for Existing Reactors 2020 [132], issued on 17 February 2021. Review against changes in knowledge, international standards and other factors have identified the need to introduce the notion of leadership into Issue C (Leadership and Management for Safety) and obsolescence into Issue I (Ageing Management), which also addresses the outcome of the recent ENSREG Topical Peer Review on the topic.

There was also a need to complete the hazards to be addressed in the safety demonstration. To achieve this, Issue S (Protection against Internal Fires) has been extended to cover all internal hazards (Issue SV), and

Issue T (Natural Hazards) has been extended to address all external hazards (Issue TU).

This report with its appendices covers the Krško NPP review of fire hazard regarding the WENRA Safety Reference levels 2020 [132].

1.2.2.3 IAEA Safety Standards

Slovenian nuclear legislation was prepared and is aligned with the international safety standards and sources primarily the IAEA Safety Standards, EU directives, OECD/NEA documents, WENRA reference levels and others (HERCA, ENSREG). National legislation and regulations in Slovenia are based on the IAEA safety guides and standards. Plant operation is in compliance with national regulation and this consequentially assures that the Krško NPP is operated in accordance with the IAEA safety practices, policies, guides and standards. Krško NPP is in compliance with requirements from the IAEA safety standards SSG-64 "Protection against Internal Hazards in the Design of NPP's" [139] and SSG-77, "Protection Against Internal and External Hazards in the Operation of Nuclear Power Plants" [138].

2 Fire Safety Analyses

2.1 Nuclear Power Plants

2.1.1 Types and Scope of the Fire Safety Analyses

The fire hazard analysis for nuclear power plants is to be carried out, and kept updated to demonstrate that the fire safety objectives for the plant are met through the fire design principles satisfied, and that the fire protection measures are appropriately designed, and any necessary administrative provisions are properly identified and implemented in accordance with the Slovenian regulation "Rules on Radiation and Nuclear Safety Factors", Official Gazette of the Republic of Slovenia No. 74/2016 of 18.11.2016 [21], and also in accordance with the requirements of the WENRA Safety Reference Levels for Existing Reactors - Issue E: Design Basis Envelope for Existing Reactors and Issue SV: Internal Hazards #SV6.1 [132].

Krško NPP has two approaches to assure fire safety. A comprehensive deterministic fire hazard analysis determines the adequacy of the fire protection measures, while a probabilistic risk assessment methodology is driven by and in support of the development of risk-informed performance-based fire safety engineering. The intent is to minimize risk in terms of probability and potential consequences.

Fire probabilistic safety (risk) assessment (FPSA) is a systematic and comprehensive methodology to evaluate safety (risks) from fire events at the plant. Risk in FPSA is defined as a feasible detrimental outcome of an activity or action. In FPSA, risk is characterized by two quantities:

- the magnitude (severity) of possible adverse consequences and
- the likelihood (frequency) of occurrence of each consequence.

Consequences are expressed numerically and their likelihoods of occurrence are expressed as frequencies (usually number of occurrences per year). The total fire risk is the occurrence of core damage due to fire events, provided as the sum of the consequences that lead to core damage.

2.1.1.1 Deterministic Fire Hazard Analysis

The purpose of the fire hazard analysis is to demonstrate the ability of the Krško NPP to shut down the reactor and maintain it in a safe shutdown condition, to cool down the plant to the cooldown condition, to maintain the removal of the Spent Fuel Pool (SFP) decay heat and to prevent or minimize radioactive releases to the environment in the event of a fire. It implements the philosophy of defence-in-depth protection against the hazards of fire and its associated effects on safety-related equipment.

The fire hazard analysis has the following objectives:

a. to consider potential fixed and transient fire hazards;

b. to determine the effects of a fire in any location in the plant on the ability to safely shut down the reactor, maintain safe shutdown condition, remove SFP decay heat and to prevent or minimize the release of radioactivity to the environment; and

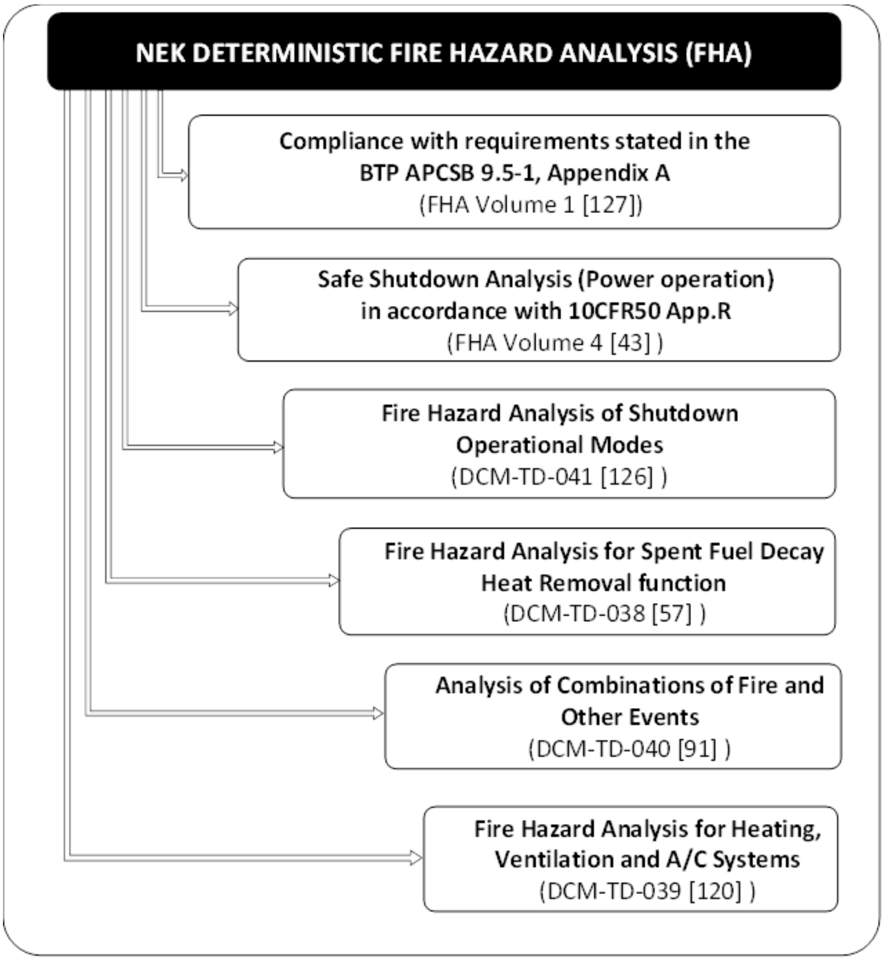
c. to specify measures for fire prevention, detection, suppression, and containment for each fire area containing SSCs important to safety, in accordance with the NRC guidelines and regulations.

Original 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. A separate analysis "Deterministic Analysis of Combinations of Fire and Other Events" was performed and takes into account also the combination of fire and other probable events [91].

The complete Fire Hazard Analysis consists therefore of several parts, as shown in Figure 3, below:

1. Compliance with requirements stated in the BTP APCSB 9.5-1, Appendix A "Guidelines for Fire Protection for Nuclear Power Plants" [127];
2. Safe Shutdown Analysis in accordance with 10CFR50 Appendix R [43];
3. Deterministic Fire Hazard Analysis of Shutdown Operational Modes [126];
4. Fire Hazard Analysis for Spent Fuel Heat Decay Removal Function [57];
5. Deterministic Analysis of Combinations of Fire and Other Events [91];
6. Fire Hazard Analysis for Heating, Ventilating and Air Conditioning Systems (HVAC) [120].

Figure 3: Deterministic Fire Hazard Analysis



Additional analyses for the SF Decay Heat Removal Function [57], the deterministic FHA for the Ventilation systems [120] and deterministic FHA of Shutdown Operational Modes [126], which cover heat removal function from SFP, the HVAC operation and lower operational modes, respectively, were performed during the preparation of this TPR2 report by WENRA TPR2 Technical Specifications [136].

2.1.1.2 Fire Probabilistic Safety Assessment

In 1996, Krško NPP performed individual plant examination for external events (IPEEE) [4], which contained among external events also internal fire analyses, as a part of the implementation of the U.S. NRC policy statement on severe accidents in nuclear power plants (Generic Letter 88 20, Supplement No. 4, on June 28, 1991), requesting that each United States licensee conducts IPEEE for severe accident vulnerabilities. Fire analyses in scope of IPEEE analyses were performed for power operation. Plant shutdown was assumed and capability for long-term plant cooling was evaluated in the light of probabilistic safety assessment. The Fire PSA analyses were reviewed by the IPERS mission in 1998 [20]. Final analyses which covered Level 1 [5] and Level 2 [6] PSA analyses were issued in 1999 after the review.

In 1998, analyses for the shutdown PSA model were performed for cold shutdown and refuelling plant modes. PSA was modelled in the ORAM tool, with a quantitative internal initiating events model and a qualitative internal fire and internal flooding model.

In 2008, additional fire analyses were performed within Probabilistic Safety Assessment for Modes from Operation to Hot Shutdown study [29], e.g. the fire PSA was expanded for the low power mode, hot standby mode and hot shutdown mode of plant operation states. With these analyses, the Technical Specification plant modes from 1 to 4 were covered for Level 1 PSA analyses. The objective of the work/analysis performed was to demonstrate that the plant can be safely brought to hot shutdown following all Initiating Events (IE), in particular following a Safe Shutdown Earthquake (SSE). Later, in 2022, transition modes Level 1 PSA model was upgraded with Level 2 model for low power mode, hot standby mode and hot shutdown mode of operation [30].

Finally, in 2015 the PSA of Cold Shutdown and Refuelling States was performed [31], and later in 2019 upgraded ([32], [33], [34]). With these analyses, the Krško NPP fire PSA was expanded also for cold shutdown and refuelling modes of operation. The Technical Specification modes 5 and 6 were covered for Level 1 analyses.

As described in chapters that follow for spent fuel storage facilities, the PSA models for spent fuel pool and dry storage are described. First analyses for Level 1 and Level 2 fire PSA for spent fuel pool were available in 2016 [36], and Level 2 analyses for dry storage were available in 2023 [37].

To sum up, Krško NPP has the following Level 1 and Level 2 fire PSA analyses available in accordance with the national legislation for all suitable and reasonable conditions of the power plant (second point of the third paragraph of Article 50 of Ionising Radiation Protection and Nuclear Safety Act [22]):

- TS Mode 1, Power Operation, Level 1 and Level 2 fire PSA
- TS Mode 2, Startup (Low Power Operation), Level 1 and Level 2 fire PSA
- TS Mode 3, Hot Standby, Level 1 and Level 2 fire PSA
- TS Mode 4, Hot Shutdown, Level 1 and Level 2 fire PSA
- TS Mode 5, Cold Shutdown, Level 1 fire PSA
- TS Mode 6, Refuelling, Level 1 fire PSA
- Spent fuel pool, Level 1 and Level 2 fire PSA
- Dry storage, Generic Annual (Fire) Risk Estimation

Additionally, in 2019 Krško NPP performed extensive analyses of combinations of fire triggered events with other events [23]. The results of engineering judgment, deterministic and probabilistic safety assessments indicate that combinations of events could lead to anticipated operational occurrences or to accident conditions. Consideration of credible combination of fire and other events likely to occur independently of a fire are to be analysed in accordance with the given combinations. The combinations of fire and other postulated initiating events with their impact are analysed. It generally includes the following combinations:

- Fire and Internal Initiating Event
- Fire and Internal Hazard (Internal Flooding and HELB)
- Fire and Seismic Initiating Event
- Fire and Other External Events
- Fire and Explosion
- Multiple Compartment Fire Interaction Analysis

2.1.2 Key Assumptions and Methodologies

2.1.2.1 Compliance with Requirements Stated in the BTP APCSB 9.5-1, Appendix A

This part of FHA was performed in order to determine compliance with the fire protection requirements defined in the US regulation. Based on the period of the initial operation of Krško NPP (Fuel load - Operating License – 7 May 1981), the criteria of Branch Technical Position BTP APCSB 9.5-1, Appendix A "Guidelines for Fire Protection for Nuclear Power Plants" [127] serves as the basis of the fire protection requirements that apply to Krško NPP. The BTP addresses Fire Protection Programs for safe shutdown systems and equipment and for other plant areas containing fire hazards that could adversely affect safe shutdown systems. The Fire Protection Program implements the philosophy of defense-in-depth protection against hazards of fire and its associated effects on safe shutdown equipment.

The primary objective of Fire Protection Program is to minimize both the probability and consequences of postulated fires. Defense-in-depth concept entails the use of administrative controls, fire protection systems and features, and safe shutdown capability to achieve following objectives:

- Prevention - prevent fire from starting
- Mitigation - detect rapidly, control, and promptly extinguish fires
- Protection - protect SSCs important to safety, so that fire that is not promptly extinguished by the fire suppression activities will not prevent the safe shutdown of the plant or cause radioactive release to the environment

Evaluation of requirements is performed with the item-by-item assessment of the Krško NPP status and compliance with the positions set forth in BTP APCSB 9.5-1, Appendix A (Figure 4) [127]. Details of evaluation are presented in the Fire Hazard Analysis; Volume 1 [3]. Individual subsection numbers are keyed to the corresponding item numbers in the BTP. Krško NPP is in compliance with BTP APCSB 9.5-1, Appendix A requirements, as presented in the existing FHA [3].

Figure 4: BTP APCSB 9.5-1, App. A requirements

BTP APCSB 9.5-1, App.A REQUIREMENTS

A. OVERALL REQUIREMENTS

A.1. Personnel
A.2. Design Bases
A.3. Backup
A.4. Single Failure Criteria
A.5. Fire Suppression Systems
A.6. Fuel Storage Area
A.7. Fuel Loading
A.8. Multiple Reactor Sites
A.9. Simultaneous Fires

B. ADMINISTRATIVE PROCEDURES, CONTROLS, AND FIRE BRIGADE

B.1. Administrative procedures
B.2. Storage of combastible materials, hosekeepeng
B.3. Hot works
B.4…Outside fire brigade response
B.5. Testing and maintenance of the fire protection equipment, training,

C. QUALITY ASSURANCE PROGRAM

C.1. Design Control and Procurement Control
C.2. Instructions, Procedures, and Drawings
C.3. Control of Purchased Material, Equipment and Services
C.4. Inspection
C.5. Test and Test Control
C.6. Inspection, Test and Operating Status
C.7. Non-Conforming Items
C.8. Corrective Action
C.9. Records
C.10.. Audits

D. GENERAL GUIDELINES FOR PLANT PROTECTION

D.1. Building Design
D.2. Control of Combustible
D.3. Electric Cable Construction, Cable Trays and Cable Penetrations
D.4. Ventilation
D.5. Lighting and Communication

E. FIRE DETECTION AND SUPPRESSION

E.1. Fire Detection
E.2. Fire Protection Water Supply Systems
E.3. Water Sprinklers and Hose Standpipe Systems
E.4. Halon Suppression Systems
E.5. Carbon Dioxide Suppression Systems
E.6. Portable Extinguishers

F. GUIDELINES FOR SPECIFIC PLANT AREAS

F.1. Primary and Secondary Containment
F.2. Control Room
F.3. Cable Spreading Room
F.4. Plant Computer Room
F.5. Switchgear Rooms
F.6. Remote Safety Related Panels
F.7. Station Battery Rooms
F.8. Turbine Lubrication and Control Oil Storage and Use Areas
F.9. Diesel Generator Areas
F.10. Diesel Fuel Oil Storage Areas
F.11. Safety Related Pumps
F.12. New Fuel Area
F.13. Spent Fuel Pool Area
F.14. Radwaste Building
F.15. Decontamination Areas
F.16. Safety Related Watre Tanks
F.17. Cooling Towers
F.18. Miscellaneous Areas

G. SPECIAL PROTECTION GUIDELINES

G.1. Welding and Cutting, Acetylene, Oxigen Fuel Gas Systems
G.2. Storage Areas for Dry Ion Exchange Resins
G.3. Hazardous Chemicals
G.4. Materials Containing Radioactivity

2.1.2.2 Safe Shutdown Analysis (SSA)

2.1.2.2.1 Purpose of SSA

The goal of post-fire safe shutdown is to assure that a single fire in any plant fire area will not result in any fuel cladding damage, rupture of the primary coolant boundary or rupture of the primary containment. This goal serves to prevent an unacceptable radiological release from the reactor core because of the fire. A safe shutdown analysis was performed in accordance with requirements defined by 10CFR50, Appendix R, Section III.G [43], and the ancillary US NRC regulatory guidance, which basically require that:

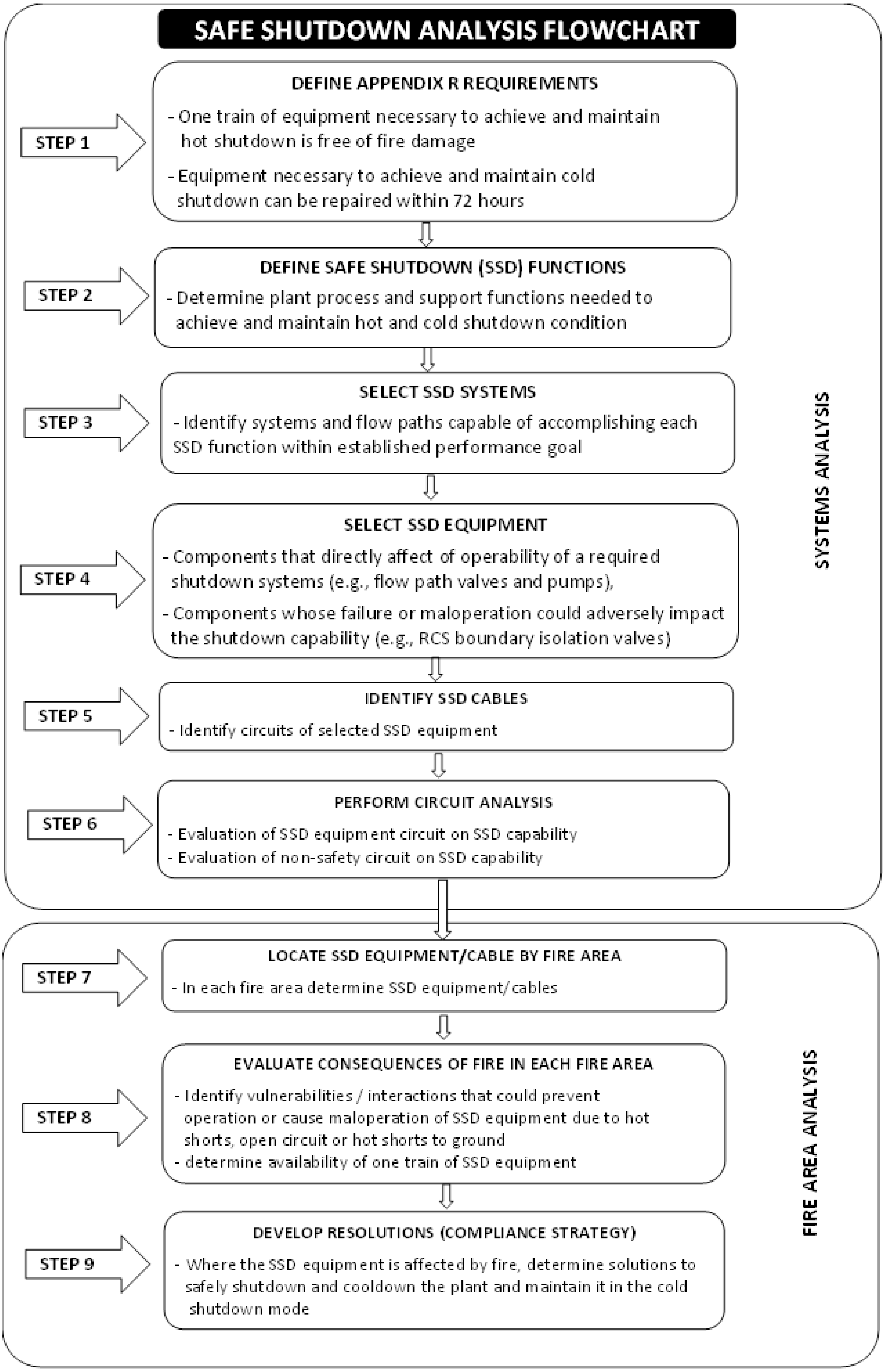
- One train of the equipment necessary to achieve hot shutdown from either the control room or emergency control station(s) must be maintained free of fire damage by a single fire.
- Both trains of the equipment necessary to achieve cold shutdown may be damaged by a single fire, including an exposure fire, but damage must be limited so that at least one train can be repaired or made operable within 72 hours using onsite capability.

2.1.2.2.2 Scope of SSA

The scope of Safe Shutdown Analysis is defined by the following steps of SSA development (as presented in Figure 5):

- Define Appendix R requirements (Step 1)
- Define safe shutdown functions (Step 2)
- Select safe shutdown systems (Step 3)
- Select safe shutdown equipment (Step 4)
- Identify safe shut down cables (Step 5)
- Perform circuit analysis (Step 6)
- Locate safe shutdown equipment/cables by fire areas (Step 7)
- Evaluate consequences of fire in each fire area (Step 8)
- Develop resolution (compliance strategy) (Step 9)

Figure 5: Safe Shutdown Analysis Flowchart



Step 1: Define Appendix R requirements

Requirements for safe shutdown of the plant in case of fire are defined in section III.G of 10CFR50 Appendix R [43]:

1. Fire protection features shall be provided for structures, systems, and components important to safe shutdown. These features shall be capable of limiting fire damage so that:
   a. One train of systems necessary to achieve and maintain hot shutdown conditions from either the control room or emergency control station(s) is free of fire damage; and
   b. Systems necessary to achieve and maintain cold shutdown from either the control room or emergency control station(s) can be repaired within 72 hours.
2. Except as provided for in paragraph G.3 of this section, where cables or equipment, including associated non-safety circuits that could prevent operation or cause maloperation due to hot shorts, open circuits, or shorts to ground, of redundant trains of systems necessary to achieve and maintain hot shutdown conditions are located within the same fire area outside of primary containment, one of the following means of ensuring that one of the redundant trains is free of fire damage shall be provided:
   a. Separation of cables and equipment and associated non-safety circuits of redundant trains by a fire barrier having a 3-hour rating. Structural steel forming a part of or supporting such fire barriers shall be protected to provide fire resistance equivalent to that required of the barrier.
   b. Separation of cables and equipment and associated non-safety circuits of redundant trains by a horizontal distance of more than 20 feet with no intervening combustible or fire hazards. In addition, fire detectors and an automatic fire suppression system shall be installed in the fire area; or
   c. Enclosure of cable and equipment and associated non-safety circuits of one redundant train in a fire barrier having a 1-hour rating, in addition, fire detectors and an automatic fire suppression system shall be installed in the fire area; inside non-inerted containments one of the fire protection means specified above or one of the following fire protection means shall be provided;
   d. Separation of cables and equipment and associated non-safety circuits of redundant trains by a horizontal distance of more than 20 feet with no intervening combustibles or fire hazards;
   e. Installation of fire detectors and an automatic fire suppression system in the fire area; or
   f. Separation of cables and equipment and associated non-safety circuits of redundant trains by a noncombustible radiant energy shield.
3. The shutdown capability for specific fire areas may be unique for each such area, or it may be one unique combination of systems for all such areas. In either case, the alternative shutdown capability shall be independent of the specific fire area(s) and shall accommodate postfire conditions where offsite power is available and where offsite power is not available for 72 hours. Procedures shall be in effect to implement this capability.
4. If the capability to achieve and maintain cold shutdown will not be available because of fire damage, the equipment and systems comprising the means to achieve and maintain the hot standby or hot shutdown condition shall be capable of maintaining such conditions until cold shutdown can be achieved. If such equipment and systems will not be capable of being powered by both onsite and offsite electric power systems because of fire damage, an independent onsite power system shall be provided. The number of operating shift personnel, exclusive of fire brigade members, required to operate such equipment and systems shall be on site at all times.
5. Equipment and systems comprising the means to achieve and maintain cold shutdown conditions shall not be damaged by fire; or the fire damage to such equipment and systems shall be limited so that the systems can be made operable and cold shutdown can be achieved within 72 hours. Materials for such repairs shall be readily available on site and procedures shall be in effect to implement such repairs. If such equipment and systems used prior to 72 hours after the fire will not be capable of being powered

by both onsite and offsite electric power systems because of fire damage, an independent onsite power system shall be provided. Equipment and systems used after 72 hours may be powered by offsite power only.

6. 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.
7. Safe shutdown equipment and systems for each fire area shall be known to be isolated from associated non-safety circuits in the fire area so that hot shorts, open circuits, or shorts to ground in the associated circuits will not prevent operation of the safe shutdown equipment. The separation and barriers between trays and conduits containing associated circuits of one safe shutdown division and trays and conduits containing associated circuits or safe shutdown cables from the redundant division, or the isolation of these associated circuits from the safe shutdown equipment, shall be such that a postulated fire involving associated circuits will not prevent safe shutdown.

Step 2: Define safe shutdown functions

1. Reactivity Control - Insert sufficient negative reactivity to achieve and maintain cold shutdown conditions.
2. Reactor Coolant System Inventory and Pressure Control - Maintain the reactor coolant inventory within the indicating range of the pressurizer level instrumentation, and control reactor coolant system pressure.
3. Decay Heat Removal - Remove decay heat through cold shutdown conditions.
4. Plant Monitoring Instrumentation - Provide direct reading of safe shutdown process variables.
5. Support Functions - Provide electrical power, cooling, etc., as required to achieve all of the above performance goals. Ventilation systems (HVAC) as support to safe shutdown are analyzed in separate analysis DCM-TD-039 “Fire Hazard Analysis for Heating, Ventilating and Air Conditioning” [120].

Step 3: Select SSD systems

For each safe shutdown function the systems needed for accomplishing the safe shutdown functions are identified (Table 1):

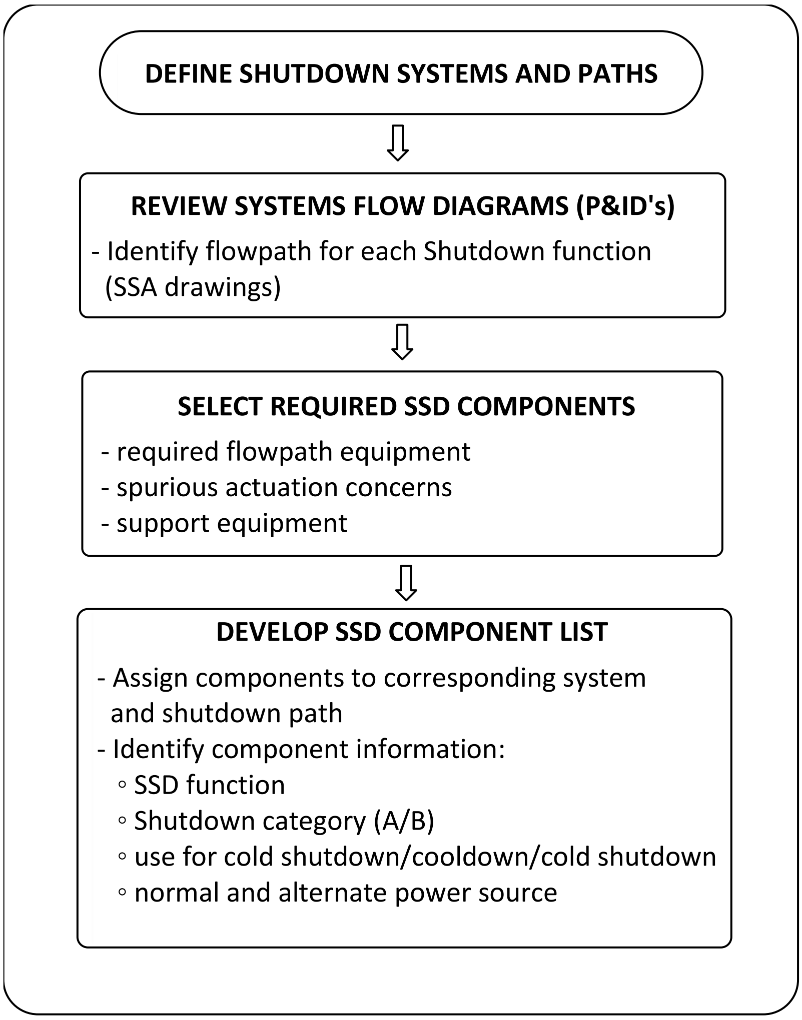
Table 1: Safe Shutdown Functions and Related Systems

Safe shutdown functions	Systems
Reactivity Control	**Control Rod Drive/Reactor Protection System** **Chemical and Control Volume System (CS)**
Reactor Coolant System Inventory and Pressure Control	**Chemical and Volume Control System (CS)** **Reactor Coolant System (RC)** **Safety Injection System (SI)** **Refuelling Water Storage (WS)**
Decay Heat Removal	**Auxiliary Feedwater System (AF)** **Condensate System (CY)** **Main Steam System (MS)** **Main Feedwater System (FW)** **SG's Blowdown System (BD)** **Residual Heat Removal System (RH)**
Plant Monitoring Instrumentation	**CS, RC, SI, WS, AF, CY, MS, FW, BD, RH, CC, SW, DG,**
Support Functions	**Component Cooling System (CC)** **Essential Service Water System (SW)** **Electrical Distribution Systems (EE, ES, DC)** **Diesel Generator Systems (DG)** **Heating, Ventilation and Air Conditioning Systems (HVAC)**

Step 4: Select safe shutdown equipment

Using flow diagrams (P&IDs), specific flow paths were highlighted for each system in support of each shutdown path. All safe shutdown equipment was determined based on these flow paths. Using the flow diagrams, electrical drawings, instrumentation loop diagrams, and electric cable database, the SSD component index was developed (Figure 6).

Figure 6: Safe Shutdown Systems and Components Selection



Step 5: Identify safe shutdown cables

The identified list of all cables of safe shutdown equipment includes more than those cables that are directly connected to the equipment. The relationship between a cable and affected equipment must be based on the review of electrical or elementary wiring diagrams. In addition to the cables that are physically connected to the equipment, the list of required cables includes any cables interlocked to the primary electrical schematic through secondary schematics. To ensure that all cables that could affect the operation of the safe shutdown equipment are identified, the power, control, instrumentation, interlock, and equipment status indications shall be investigated.

Step 6: Perform circuit analysis

The integrity of insulation and external jacket material for electrical cables is susceptible to fire damage. Damage may assume several forms including deformity, loss of structure, cracking, and ignition. Fire-induced damage to the cable causes a conductor-to- conductor fault (short), a conductor-to-ground fault, or causes one or both conductors to open (broken). The relationship between exposure of electrical cable insulation to fire conditions, the failure mode, and time to failure may vary with the configuration and cable type. To accommodate these uncertainties in a consistent and conservative manner, this analysis assumes that the functional integrity of electrical cables is immediately lost when exposed to a postulated fire in an area.

Evaluation is performed in order to identify all cables related to safe shutdown components, including associated non-safety circuits that could prevent operation or cause maloperation (attributable to hot shorts, open circuits, or shorts to ground) of redundant trains of systems necessary to achieve and maintain hot shutdown conditions. An associated circuit of concern to post-fire safe shutdown may include any circuit or cable that, while not needed to support the proper operation of required shutdown equipment (i.e., a non-safety circuit), could adversely affect the plant's ability to achieve and maintain safe shutdown conditions. Associated circuits of concern may be found to be associated with circuits of required systems through any of the following configurations:

- Circuits that share a common power source (e.g. SWGR, MCCs, fuse panel) with circuits of equipment required to achieve safe shutdown
- Circuits that share a common enclosure, (e.g. raceway, conduit, junction box, etc.) with cables of equipment required to achieve safe shutdown
- Circuits of equipment of which spurious operation or maloperation may adversely affect the shutdown capability

Key assumptions:

- A basic assumption is that there will be fire damage to all systems and equipment located within a common fire area or cell. 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.
- In FHA, a fire is not considered to occur simultaneously with non-fire related failures in safety systems, plant accidents, or the most severe natural phenomena, except the loss of off-site power.
- A fire is postulated wherever fixed or transient combustible material is located.
- Only one fire is postulated to occur at any time. Consequential fire spread to adjacent area should be considered.
- The fire is postulated whatever the normal operating status of the plant, whether at power or during shutdown.
- No equipment required for safe shutdown is assumed to be out of service for maintenance except that which is allowed by technical specifications.
- All components whose maloperation could possibly affect required safe shutdown systems are analyzed to consider the effects of spurious signals.
- Spurious operations due to the application of stray voltages between cables within a common raceway resulting from fire-induced damage is considered a credible event, and is addressed in the analysis. However, spurious operation due to three-phase stray voltages between cables is not considered a credible event.
- Spurious operations due to stray voltages between circuits within equipment (control panels, switchgear, Motor Control Centers), is considered in the analysis.
- Cable-to-cable fire-induced "hot" shorts between direct current circuits are not considered to be credible.

Step 7: Locate safe shutdown equipment/cables by fire areas

The routings / raceways of safe shutdown cables identified in Step 6 were determined by using cable tray, conduit and cable layout drawings. The cable routing information was then used as the basis for manually tracing each safe shutdown circuit, in conjunction with the Fire Hazards Analysis Fire Area Layout drawings. Through this process, each raceway associated with a given safe shutdown cable was identified, the fire area location was determined, and the data was entered into a computer database application specifically designed for safe shutdown analysis purposes.

Finally, each fire area report contains all cables which can jeopardize safe shutdown, cooldown and maintain plant in cold shutdown in case of fire.

Step 8; Evaluate consequences of fire in each fire area

In accordance with Fire Hazard Analysis [3] technological part of Krško NPP is divided to 124 fire areas and several fire zones as part of fire areas. Based on cable/component routing evaluation of consequences is performed on fire area basis. For each designated safe shutdown function, the post-fire availability of the function is defined, by assigning one of the summary categories:

1. Free from fire damage;
2. Available with operational changes/manual actions;
3. Function is available using alternative equipment.

Step 9: Develop resolution (compliance strategy)

This step is described in detail in Section 2.1.4.2.

2.1.2.3 Deterministic Fire Hazard Analysis of Shutdown Operational Modes

2.1.2.3.1 Purpose of Analysis

During shutdown and refuelling outages, activities that take place in the plant may increase fire hazards in safety-related systems that are essential to the plant's capability to maintain core cooling. The plant's Technical Specifications (TS) [2] allows various safety systems to be taken out of service to facilitate system maintenance, inspection, and testing. In addition, during plant shutdown and refuelling outages, major plant modifications are fabricated, installed, and tested. In support of these outage-related activities, increased 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) present additional fire risks to those plant systems maintaining shutdown cooling.

The 10 CFR 50 Appendix R [43] fire protection criteria for the protection of the safe shutdown capability do not include post-fire requirements to ensure an adequate level of shutdown cooling during non-power modes of operation. However, Appendix R, Sections III.G and III.L allow certain repairs to cold-shutdown components to restore system operability and the ability to achieve and maintain cold-shutdown conditions.

Therefore, deterministic fire hazard of shutdown operational modes was performed and presented in the report DCM-TD-041 "Deterministic fire hazard analysis of shutdown operational modes" [126], with the purpose to evaluate how fire could affect systems or components needed for maintaining safe operation of plant during shutdown and to develop strategies when key safety functions are jeopardized because of fire.

2.1.2.3.2 Scope of Deterministic Fire Hazard Analysis of Shutdown Operational Modes

The scope of deterministic fire hazard analysis of shutdown operational modes is presented in the following steps (Figure 7):

- Establish requirements for analysis (Step 1);
- Define shutdown modes (states) (Step 2);
- Define Key Safety Functions (KSF) for each POS (Plant Operating State) (Step 3);

- Select Key Safety Function (KSF) systems/equipment (Step 4);
- Identify KSF equipment cables (Step 5);
- Perform circuit analysis (Step 6);
- Locate KSF equipment/cable by fire area (Step 7);
- Evaluate consequences of fire in each fire area (Step 8);
- Develop resolutions (compliance strategy) (Step 9).

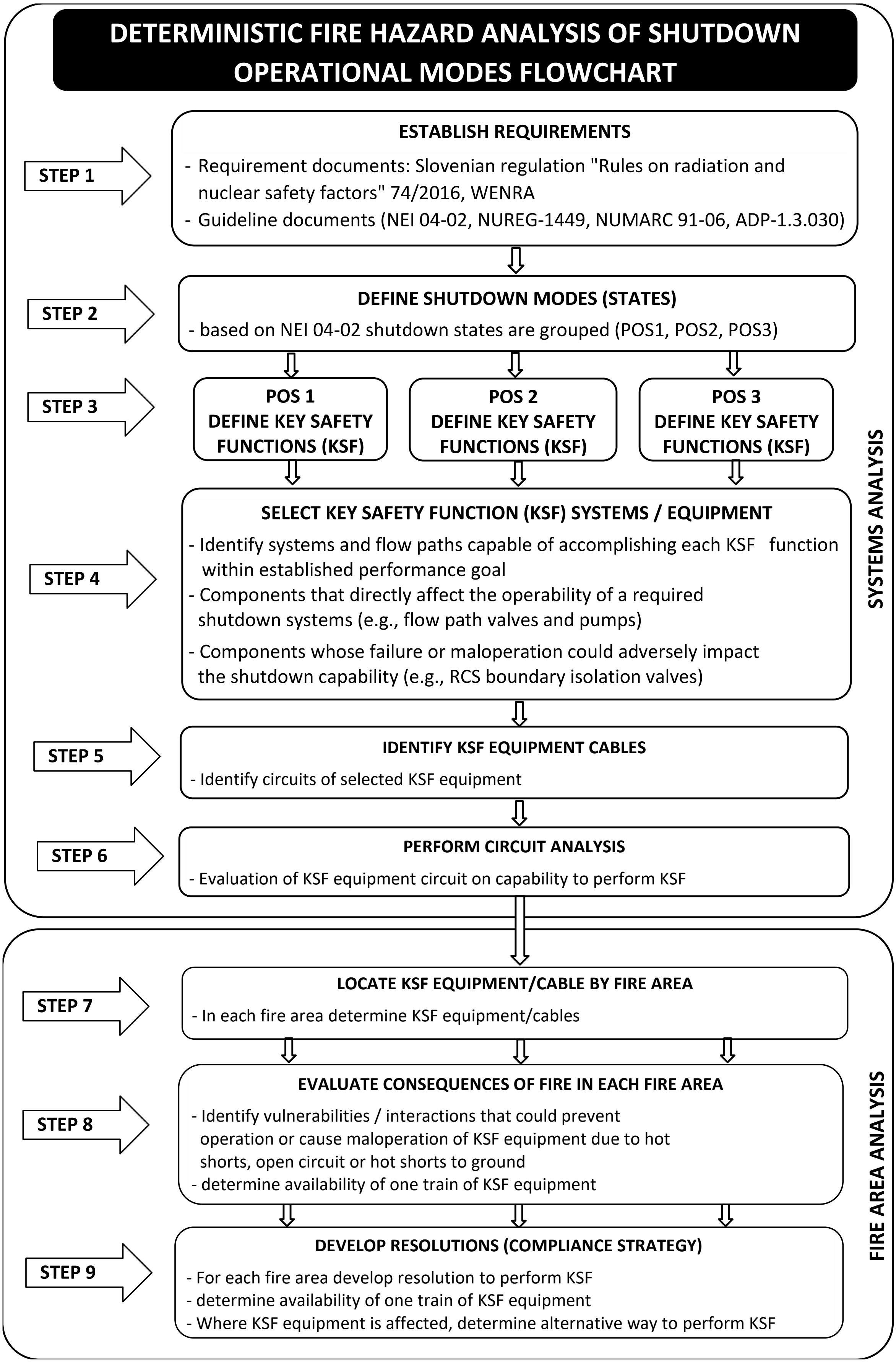
Step 1: Establish requirements

Slovenian regulation "Pravilnik o dejavnikih sevalne in jedrske varnosti", Uradni list RS, št. 74/2016 (Rules on radiation and nuclear safety Factors, Official Gazette of the Republic of Slovenia No. 74/2016 as of 18 November 2016) [21], which is also in aligned with the requirements of the WENRA Safety Reference Levels for Existing Reactors - Issue E: Design Basis Envelope for Existing Reactors and Issue SV: Internal Hazards #SV6.1 [132]; they both require that a fire hazard analysis should consider not only power operation, but also shutdown states.

Guidelines documents used to perform the analysis are the following:

- NEI 04-02 "Guidance for implementing a risk-informed, performance-based Fire Protection Program under 10 CFR 50.48 (c)" [133]
- NUREG-1449 "Shutdown and Low-Power Operation at Commercial Nuclear Power Plants in the United States" [134]
- Krško NPP ADP-1.3.030 "Plant Safety during Shutdown", [135]

Figure 7: Deterministic Fire Hazard Analysis of Shutdown Operational Modes – Flowchart



Step 2: Define shutdown modes (states)

As defined by the Krško NPP's Technical specification (TS) [2], the modes/Shutdown (SD) modes are "cold shutdown" (T.S. MODE 5), and the "state of refuelling" (T.S. MODE 6 – Refuelling). The third shutdown mode is not defined in Krško NPP's TS, but in the Shutdown Safety procedure (ADP-1.3.030 [135]), and that is the state when the fuel is not in the reactor vessel (SD MODE 0).

TS MODE 5 is divided into 5 SD states, TS MODE 6 is divided into 3 SD states, and SD MODE 0 consists of 1 SD state. Therefore, there is a total of 9 different states that are recognized by ADP-1.3.030 [135].

Shutdown states according to ADP-1.3.030 [135] are:

1. RCS CLOSED and full of water.
2. RCS CLOSED and drains to CL+170 cm, SG U-tubes are full of water.
3. 2* RCS CLOSED and drains to CL+8 cm, vacuuming and filling of RCS to full pressurizer.
4. RCS is OPEN, level is CL+170 cm, SG U-tubes are full.
5. 3* RCS is OPEN, level is CL+20 cm, SG U-tubes are empty.
6. RCS is OPEN, level is CL+20 cm, U-tubes of SG-s are empty (primary SG side is open, caps on primary piping of SG-s (nozzle dams) are installed). SD state 4 is performed exceptionally, depending on outage plan.
7. Reactor head installed, RCS is open, level CL+20 cm (SG primary side is open, caps on primary piping of SG-s (nozzle dams) are installed. SD state 5 is performed exceptionally, depending on the outage plan.
8. The reactor head is/is being removed or is/are being installed, the upper internals of the reactor has not been removed.
9. The reactor pool/cavity is flooded, the upper internals of the reactor is removed, there is no fuel movement.
10. The reactor pool/cavity is flooded, fuel change and movement are in progress.
11. The reactor is without fuel. All fuel is in the SFP.

* After the refuelling, shutdown states are repeated in reverse number order with the same features as before refuelling. Exceptions are shutdown states 2 and 3 after refuelling, marked with (*), where RCS and SG level are something different in comparison with shutdown states 2 and 3 before refuelling.

Furthermore, the NEI 04-02, Appendix F [133] provides a simplification of all shutdown states and defines Plant Operating States (POSs). Simplification means that it is not necessary to analyse each shutdown state in particular, but is recommended to combine a few shutdown states that share similar features. Based on NEI 04-02 [133] shutdown states are grouped into POS 1, POS 2 and POS 3.

Step 3: Define Key Safety Functions (KSF) for each POS (Plant Operating State)

Table 2 shows a simplified correlation between the Krško NPP TS modes, Shutdown States, Plant Operating States (POSs) and Key Safety Functions (KSFs).

Table 2: Correlation between Krško NPP TS Modes, Shutdown States, POSs and KSFs

<table>
<tr><td>TS/SD MODES</td><td>TS MODE 1,2,3,4</td><td colspan="5">TS MODE 5</td><td colspan="3">TS MODE 6</td><td>SD MODE 0</td></tr>
<tr><td>SHUTDOWN STATES</td><td>N/A</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td></tr>
<tr><td>POS</td><td>N/A</td><td colspan="2">POS 1</td><td colspan="4">POS 2</td><td colspan="2">POS 3</td><td>N/A</td></tr>
<tr><td rowspan="4">KSF</td><td rowspan="4">SSA*
Chapter 2.1.2.2</td><td colspan="2" rowspan="4">N/A</td><td colspan="4">DHR</td><td colspan="2">DHR</td><td rowspan="4">SFP**</td></tr>
<tr><td colspan="4">INV</td><td colspan="2">INV</td></tr>
<tr><td colspan="4">SCS</td><td colspan="2">SCS</td></tr>
<tr><td colspan="4">ELE</td><td colspan="2">ELE</td></tr>
</table>

a. * Safe Shutdown Analysis (SSA), described in chapter 2.1.2.2 of this document, is generally written for power operation (TS Mode 1). In TS Modes 2, 3 and 4 there are practically no difference regarding the protected equipment and TS requirements compared to Mode 1, therefore the same safe-shutdown equipment is available as in TS Mode 1. In these modes, decay heat is also at lower values which also gives additional time for additional actions.

b. ** SFP (Spent fuel pool cooling) safety function is described in detail in another analysis, DCM-TD-038 "Fire Hazard Analysis for Spent Fuel Heat Decay Removal Function" [57] and will not be the subject of this analysis.

Shutdown functions stated in ADP-1.3.030 [135] are:

2. REC – reactivity control
3. DHR – decay heat removal
4. INV – inventory
5. SFP – SFP cooling
6. ELE – electricity
7. SCS – support cooling systems
8. CNT – containment closure

Plant Operating State 1 (POS 1)

This POS starts when the RHR system is put into service. RCS is closed so that steam generators could be used for decay heat removal, if the secondary side of a steam generator is filled. RCS may have a bubble in the pressurizer. This POS ends when RCS is vented such that the steam generators cannot sustain core heat removal. This POS typically includes MODE 4 (hot shutdown) and portions of MODE 5 (cold shutdown) [NEI 04-02].

In Krško NPP, POS 1 represents shutdown states 1 and 2. Comparing the NEI 04-02, Appendix F [133] and the Krško NPP procedure ADP-1.3.030 [135], it can be noted that during the entire POS 1 phase, U-tubes are full of water in Krško NPP. Therefore, if SGs are available in addition to RHR, significant redundancy and diversity exists for heat removal. Just having inventory in the SGs can provide substantial passive heat removal, providing additional time to recover other heat removal methods. In this POS there are also available AF and CS systems, which provide additional redundancy and diversification.

The conclusion is that in this POS there is non-significant HRE (Higher Risk Evolutions) and no additional reviews are required under NEI 04-02 based upon previous risk reviews. Provision of appropriate fire protection / prevention is required.

Plant Operating State 2 (POS 2)

This POS starts when RCS is vented such that: (1) the steam generators cannot sustain decay heat removal and (2) a sufficient vent path exists for feed and bleed. This POS includes portions of MODE 5 (cold shutdown) and MODE 6 (refuelling). Reduced inventory operations and midloop operations with a vented RCS are subsets of this POS [133].

In Krško NPP, POS 2 represents shutdown states 3, 4, 5 and 6. This is generally the highest risk configuration/POS. Due to low inventory, times to core boil are low, typically on the order of 2 hours or less.

Therefore, HRE in POS 2 can be evaluated and limited to Decay heat removal (DHR) function, Inventory (INV) function, Support Cooling Systems (SCS) function and Electricity (ELE) function.

DHR

In ADP-1.3.030, during POS 2, both RHR trains are protected and no maintenance is allowed. Also, additional Alternative RHR (ARHR) system is available in POS 2, due to prohibition of preventive maintenance in outage period. Existing outage management process therefore recognizes the critical points, and provides several redundancy options to protect KSF components for DHR. Therefore, all 3 options are available and no maintenance is performed on any of them.

Regardless, all equipment for DHR was analyzed with associated flow paths and their power and support systems.

INV

The loss of the RCS inventory due to a fire event can only occur if the event causes undesired and/or spurious opening of a MOV valve that represents the boundary system isolation. In POS 2, RCS is open and depressurized and the RWST volume is always available to establish gravity flow to RCS. Because of typically lower time to boil in POS 2, it is required that SI pumps (2 SI pumps and 1 ASI pump) are available if needed to increase the RCS level. The availability of the ASI pump represents another level of diversity, since it has completely independent power supply and control, and is also physically separated from the main buildings of the Krško power plant.

Inventory support functions SCS and ELE have also been analysed as a DHR and INV support functions.

An important equipment (KSF equipment) for INV function, is also the RCS level instrumentation which is also analysed. Level measurements LT637 and LT635 are physically separated, dislocated and at different elevations in RB. LT651 is also available although it is powered from a non-safety-related bus. If the MCR evacuation is required, the use of local RB instrument LI636 is also available.

Plant Operating State 3 (POS 3)

This POS represents the shutdown condition when the refuelling cavity water level is at or above the minimum level required for movement of irradiated fuel assemblies within containment as defined by Technical Specifications. This POS occurs during MODE 6. During this POS, substantial inventory exists to cope with an extended loss of active heat removal. Times to boil are often on the order of 16 or more hours. However, fire induced RCS drain down events can reduce margins substantially [133].

In Krško NPP, POS 3 represents shutdown states 7 and 8 (from Rx cavity > 7m to the end of defueling, and also from the start to the end of refuelling).

Therefore, HREs in POS 3 can be evaluated and limited to Decay heat removal (DHR) function, Inventory (INV) function, Support Cooling Systems (SUP) function and Electricity (ELE) function.

INV and DHR functions are protected by operation of one RHR train and enough water inventory. ARHR system is also available as an option in POS 3, the same as in POS 2.

Analysis is made for the case when RHR train A is in operation, as well as for the case when RHR train B is in operation (because in this POS one RHR train is allowed to be in maintenance). In this way, all phases of outage period for POS 3 are covered.

In the case when the operating RHR pump would be lost due to a fire in any related fire area, the ARHR system is credited in POS 3, the same as in POS 2. The main difference is that during POS 3, there is enough time (before RCS and water in cavity start to boil) to set up the alternative line-up and establish cooling of the ARHR system (pump and HEX) from the Sava River using mobile equipment. Support cooling function (CC/SW) in that case is not needed. Likewise, power supply for the ARHR system is independent from the main power distribution sources (physically and electrically), as it is dislocated from the main technological part of the plant (located in BB1).

ASI pump and ASI system can also be used to reduce the Rx cavity water temperature and prevent/compensate the water that has begun to evaporate.

Defining KSFs

Considering Higher risk evolutions (HRE) demand, which depends on time to core boil, RCS and SFP inventory and decay heat removal capabilities, the following Key Safety Functions (KSF) are defined [133]:

- **DHR** – decay heat removal
- **INV** – inventory
- **SCS** – support cooling systems
- **ELE** – electricity – the only power source for the KSF required equipment (DHR, INV and SUP)

The remaining safety functions that are listed in the Krško NPP document ADP-1.3.030 [135] are evaluated and have not been recognized as a KSF equipment as explained bellow.

REC (Reactivity control) is satisfied by several different mutually independent ways. All unborated water sources have been tagged and secured since TS MODE 4. After MODE 4 it is already present refuelling boron concentration of 3000 ppm. Additionally, there are several different systems and components, also flow paths, to control reactivity in the case of fire.

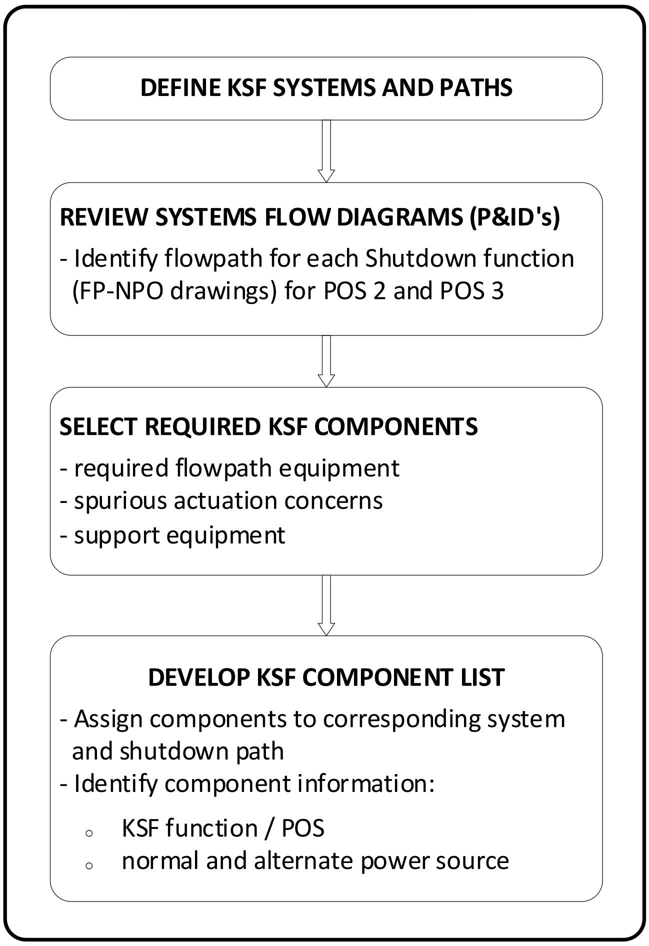
SFP (Spent fuel pool cooling) safety function is not the subject of this analysis, as it is detailly described in another analysis, DCM-TD-038 "Fire Hazard Analysis for Spent Fuel Heat Decay Removal Function" [57] (see Chapter 2.1.2.4).

CNT (Containment closure) safety function is required in TS MODE 5 (when RCS is open) and in TS MODE 6. In the case of fire some valves can be open, which are required to be closed, but considering that a combination of other events is not predicted simultaneously, by the manual operator actions it can quickly be closed again. Additionally, an event like that is unlikely to cause a loss of any KSF and to affect HRE.

Step 4: Select Key Safety Function (KSF) systems / equipment

Using flow diagrams (P&IDs), specific flow paths were highlighted for each system in support of each KSF equipment path. All KSF equipment was determined based on flow paths. Using flow diagrams (Figure 8), electrical drawings, instrumentation loop diagrams, and electric cable database, the KSF component list was developed.

Figure 8: Key Safety Function Systems and Equipment selection



Step 5: Identify KSF equipment cables

The identified list of all cables of the KSF equipment includes more than those cables that are directly connected to the equipment. The relationship between cable and affected equipment must be based on the view of electrical or elementary wiring diagrams. In addition to the cables that are physically connected to the equipment, the list of required cables includes any cables interlocked to the primary electrical schematic through secondary schematics. To ensure that all cables that could affect the operation of the KSF equipment are identified, the power, control, instrumentation, interlock, and equipment status indications are investigated.

Step 6: Perform circuit analysis

The integrity of insulation and external jacket material for electrical cables is susceptible to fire damage. Damage may assume several forms including deformity, loss of structure, cracking, and ignition. Fire-induced damage to the cable causes a conductor-to-conductor fault (short), a conductor-to-ground fault, or causes one or both conductors to open (broken). The relationship between exposure of electrical cable insulation to fire conditions, the failure mode, and time to failure may vary with the configuration and cable type. To accommodate these uncertainties in a consistent and conservative manner, this analysis assumes that the functional integrity of electrical cables is immediately lost when exposed to a postulated fire in an area.

Evaluation is performed to identify all cables related to the KSF components, including associated non-safety circuits that could prevent the operation or cause the maloperation (attributable to hot shorts, open circuits, or shorts to ground) of redundant equipment necessary to maintain KSFs. An associated circuit of concern to post-fire cooling may include any circuit or cable that, while not needed to support the proper operation of the required KSF equipment (i.e., a non-safety circuit), could adversely affect the plant's ability to maintain KSFs. Associated circuits of concern may be found to be associated with circuits of required systems through any of the following configurations:

- Circuits that share a common power source (e.g. SWGR, MCCs, fuse panel) with circuits of equipment required to maintain KSFs;
- Circuits that share a common enclosure, (e.g. raceway, conduit, junction box, etc.) with cables of equipment required to maintain KSFs;
- Circuits of equipment of which spurious operation or maloperation may adversely affect KSFs.

Step 7: Locate KSF equipment/cable by fire area

The routings / raceways of KSF cables identified in Step 6 were determined by using cable tray, conduit and cable layout drawings. The cable routing information was then used as the basis for manually tracing each KSF circuit, in conjunction with the Fire Hazards Analysis Fire Area Layout drawings. Through this process, each raceway associated with a given KSF cable was identified, the fire area location was determined, and the data was entered into a computer database specifically designed for "Krško NPP Deterministic Fire Analysis of Shutdown Operational Modes" purposes.

Finally, each fire area report contains all cables which can jeopardize KSF in case of fire.

Step 8: Evaluate consequences of fire in each fire area

To simplify the analysis in a conservative manner, it is assumed that all KSF cables are damaged from fire in the affected fire area, and so all related equipment (of which cables are routed in the affected fire area) becomes unavailable. 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.

Based on cable/component routing an evaluation of consequences in terms of availability of KSFs is performed for each fire area. For each designated KSF, the post-fire availability of the function is defined, by assigning one of the summary categories:

1. Free from fire damage;
2. Available with operational changes/manual actions;
3. Function is available using alternative equipment.

Step 9: Develop resolutions (Compliance strategy)

Three different resolution/compliance actions have been developed for each fire area in the case of a single fire event. This step is described in detail in Section 2.1.4.3.

2.1.2.4 Fire Hazard Analysis for Spent Fuel Pool Decay Heat Removal Function

2.1.2.4.1 Purpose of Analysis

The main purpose of this analysis is to prove that in the event of fire in any part of Fuel Handling Building (FHB) or outside FHB, the Spent Fuel Decay Heat Removal function will be maintained, and the radioactivity will not be released into the environment. The analysis is performed by engineering evaluation of Fire Hazards Analysis (FHA) for the Spent Fuel Pool (SFP and associated Spent Fuel Pool Decay Heat Removal Function) located in the Fuel Handling Building (FHB) of Krško NPP.

The deterministic fire hazard analysis for the spent fuel pool heat removal function was performed and documented in the report DCM-TD-038 "Fire Hazard Analysis for Spent Fuel Heat Decay Removal function" [57], to be understood as the addendum to the Krško NPP Fire Hazard Analysis [3] prepared in accordance with the assumption and requirements similar to 10 CFR 50 Appendix R [43], evaluating, however, the capability of the Spent Fuel Pool Decay Heat removal.

2.1.2.4.2 Scope of Fire Hazard Analysis for Spent Fuel Pool Decay Heat Removal Function

The scope of the spent fuel pool decay heat removal function deterministic analysis is presented with the following steps (Figure 9):

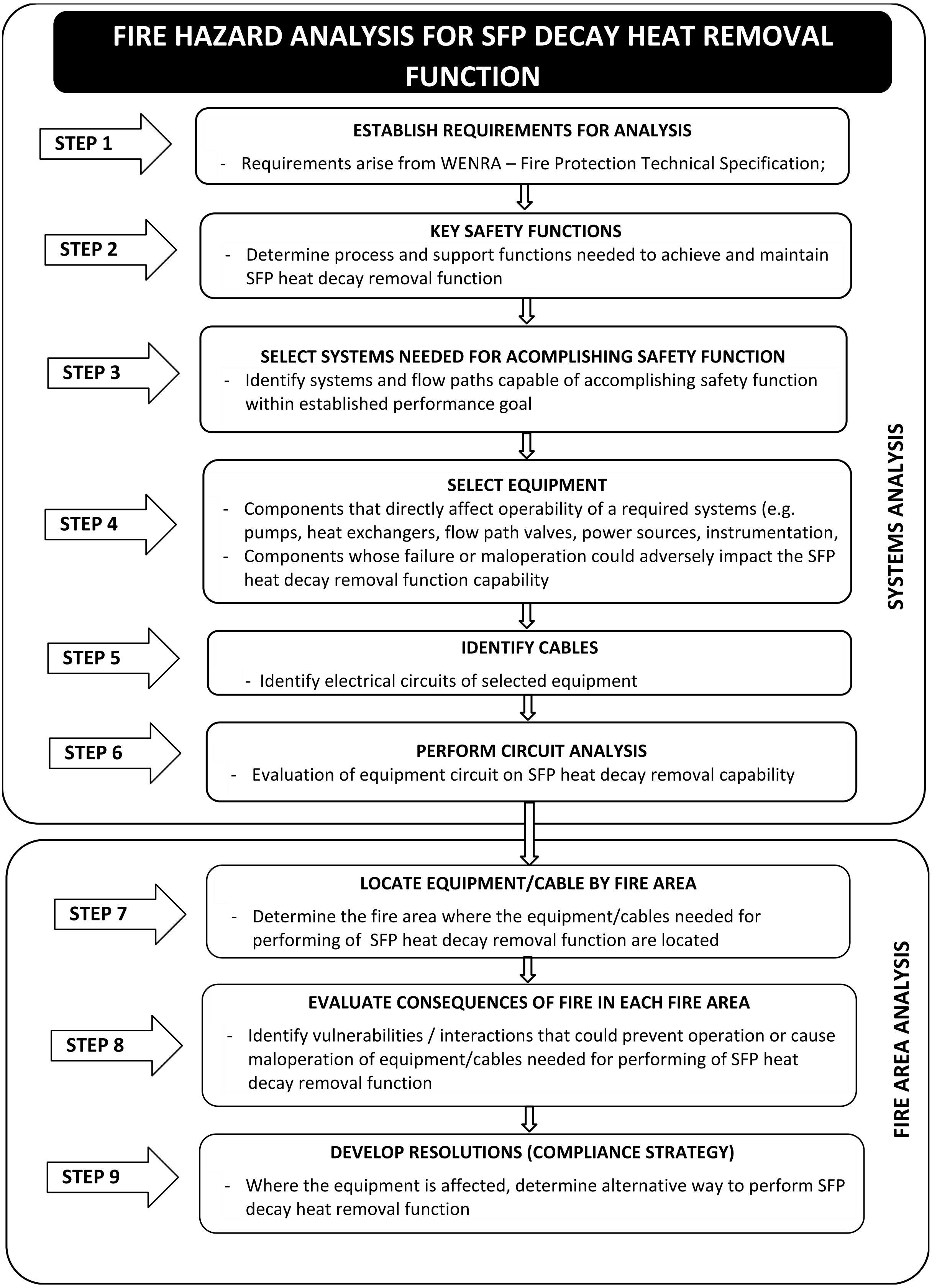
- Establish requirements for analysis (Step 1)
- Determine key safety functions (Step 2)
- Select systems needed for accomplishing safety function (step 3)
- Select equipment (Step 4)
- Identify cables (Step 5)
- Perform circuit analysis (Step 6)
- Locate equipment/cable by fire area (Step 7)
- Evaluate consequences of fire in each fire area (Step 8)
- Develop resolutions (compliance strategy) (Step 9)

Step 1: Establish requirements for analysis

The engineering evaluation of the Fire Hazards Analysis (FHA) for the Spent Fuel Pool (SFP and associated Spent Fuel Decay Heat Removal Function) of Krško NPP was performed in accordance with the 10 CFR 50 Appendix R [43], as an addendum to the existing Krško NPP FHA [3].

In accordance with the requirements of the WENRA Fire Protection Technical Specification, the fire hazard analysis should take into account not only equipment and systems needed for performance of safe shutdown, but also decay heat removal function from the SFP, as well as instrumentation needed for determining the status of SFP. The FHA should consider means for removing residual heat from the spent fuel storage, during and after anticipated operational occurrences and design basis accidents.

Figure 9: Fire Hazard Analysis for SFP Decay Heat Removal Function



Step 2: Determine Key Safety Functions

The Spent Fuel Pool (SFP) is designed to provide storage for fuel assemblies, and it is located in the Fuel Handling Building (FHB). The removal of heat from SFP and maintaining the SFP inventory are the main safety functions, which ensure long-term cooling of spent fuel and SFP integrity, and thus maintains spent fuel in the safe and stable condition in order to prevent any uncovering and damage of spent fuel and radioactive release of the spent fuel pool in different operational states. This safety function can be satisfied as long as there is water above spent fuel and the temperature of the water is controlled. The water level above spent fuel in SFP guarantees that the temperature of spent fuel is below accident release temperatures and radiation shielding is provided for personnel. The Spent Fuel Pool Cooling system is designed to remove the decay heat generated by the spent fuel assemblies stored in SFP in conjunction with its support systems (electrical power and component cooling systems). Additionally, Alternative SFP Cooling system provides SFP cooling using the mobile heat exchanger or spray systems, in case when the SFP Cooling system is unavailable.

Step 3: Select systems needed for accomplishing safety function

The main system which accomplishes the removal of heat from SFP is the SFP cooling system and corresponding support systems and instrumentation for verifying the SFP is being cooled.

The SFP Cooling system has its maximum duty during the refuelling operation when the decay heat from the spent fuel is the highest and that configuration is considered as the worst-case scenario. Fire hazards which could damage the intended functions of supporting systems to the SFP which would lead to the SFP uncovering is evaluated.

In the case that the normal SFP cooling is lost as a result of the fire (SFP pump, SFP-related piping, SFP-related CCW system or electrical power system failure), and the operators are unable to restore it, SFP cooling will be established by means of the SFP Alternative Cooling system with mobile heat exchanger or by the SFP makeup, with normal or alternative means, will be established in order to compensate for the evaporation losses (and small leakages).

Step 4: Select equipment

Based on the selected system needed for accomplishing the safety function, the main components which perform the SFP cooling are identified, i.e. the SFP pumps and instrumentation for level and temperature monitoring for verification that SFP is being cooled. In case of any fire event in fire areas, where these components and their corresponding power sources, power and control cables are located, a loss of these components is a potential reason for the unavailability of the SFP Cooling function.

The mechanical components (valves, piping, and non-combustible tubing) were not identified as critical, since a fire is not assumed to cause a valve or other mechanical component to change position unless the fire also affects the electrical equipment or circuit associated with the component. In addition, it was assumed that exposure to a fire will not prevent the manual stroking of the valve following fire extinguishment [3]. Therefore, mechanical components are excluded in the evaluation.

Step 5: Identify cables

After the main components are selected, their power sources, power and control cables are identified, since their unavailability due to fire also present potential reason for the inoperability of the particular Spent Fuel Cooling system (SFP pumps and instrumentation). The list of corresponding cables is provided in a separate document DCM-TD-038 [57].

Step 6: Perform circuit analysis

Except that both SFP cooling pumps are located in the same fire area, the detailed circuit analysis was identified that their power and control cables are routed using the same cable trays, through some fire areas. Since the fire separation between the pumps' cable trains is not ensured and the physical separation of cables is not possible in those fire areas, it can be considered that postulated fire in any of these common fire areas can potentially jeopardize the Spent Fuel Heat Decay Removal Function by losing both SFP pumps. The power sources for the SFP pumps are safety-related, belong to the redundant trains and are properly fire separated, and if fire affects one power source, only one SFP pump will be affected, and the other SFP pump will perform its function. The detailed circuit analysis is performed in a separate document DCM-TD-038 [57].

Additionally, fire events in the SFP area or in any fire area inside FHB could affect the equipment important for Spent Fuel Decay Heat Removal Function, but only if the fire occurs in close proximity of equipment since the combustible loads in those fire areas are negligible and there is no intervening combustible materials or ignition sources. The combustible material and the intervening combustible loads are controlled through the Krško NPP administrative procedure ADP-1.1.105, "Controlled disposal and storage of material" [61].

Step 7: Locate equipment/cable by fire area

The routings/raceways of cables identified in previous steps were determined by using cable tray, conduit and cable layout drawings. The cable routing information was then used as the basis for manually tracing each circuit, in conjunction with the Fire Hazards Analysis Fire Area Layout drawings. Through this process, each raceway associated with a given cable was identified, the fire area location was determined, and the data was entered into a computer database specifically designed for "Krško NPP Deterministic Fire Analysis of Shutdown Operational Modes" purposes.

Finally, every fire area report contains all cables which can jeopardize the SFP Heat Decay Removal function in case of fire.

Step 8: Evaluate consequences of fire in each fire area

The loss of normal SFP cooling could be caused by loss of SFP cooling system's equipment or failures of required support systems following the fire event, as evaluated in a separate analysis DCM-TD-038 [57]. Anyhow, in the worst- case scenario is that both SFP cooling pumps would be lost, due to a fire event in any of the fire areas where the components of both trains of the SFP cooling pumps system (pumps, power supplies, corresponding power and control cables, instrumentation and/or supporting systems) are located, except in the fire areas where the power sources for SFP pumps are located. The critical parameters, which verify the SFP is being cooled, are monitored with different instruments, which are independent from each other and any fire event cannot disable channel simultaneously.

Under these circumstances, the loss of SFP cooling will lead to a slow increase in SFP temperature to boiling, and consequently a reduction in SFP inventory (determined as a function of the total fuel loading in the SFP and primarily dependent on the time since the last fuel off-load from the reactor). In these cases the SFP inventory can be maintained despite the loss of SFP cooling by a wide variety of available make-up systems, and with SFP Alternative Cooling system.

Step 9: Develop resolutions (compliance strategy)

This step is described in detail in Section 2.1.4.4.

2.1.2.5 Deterministic Analysis of Combination of Fire and Other Events

2.1.2.5.1 Purpose of Analysis

The Slovenian regulations "Rules on radiation and nuclear safety factors - JV5" (paragraph #3.4.3 in the Attachment 1) [21], as also in accordance with the requirements of the WENRA Safety Reference Levels for Existing Reactors - Issue E: Design Basis Envelope for Existing Reactors and Issue SV: Internal Hazards #SV6.1 [132], and IAEA SSR-2/1, Rev. 1 - Safety of Nuclear Power Plants: Design [39], require that a fire hazard analysis should consider not only a single fire, but also the combinations of fire and other postulated initiating events, that are likely to occur independently of the fire.

Fire Hazard Analysis should demonstrate that the threats from fire and other hazards which could happen simultaneously (and probability is high enough) are either removed or tolerated and minimized. This is done by demonstrating that items important to safety are appropriately designed to meet the required performance criteria. Hazards, such as fire and other internal hazards, by their nature cannot be treated in isolation and often will give rise to further hazards, thus the plant may be exposed to the challenges from multiple hazards. Consideration should therefore be given to the effects of combined hazards.

The potential for a combination of hazards to affect safety should take account of the potentially widespread effects of external and internal hazards (including concurrent and consequential hazards) which may challenge multiple safety functions and locations simultaneously. The approach taken to identify a combined hazard event should be systematic and comprehensive. For each internal or external hazard or combination which cannot be excluded on the basis of either low frequency or insignificant consequence, or engineering judgement, should be analysed.

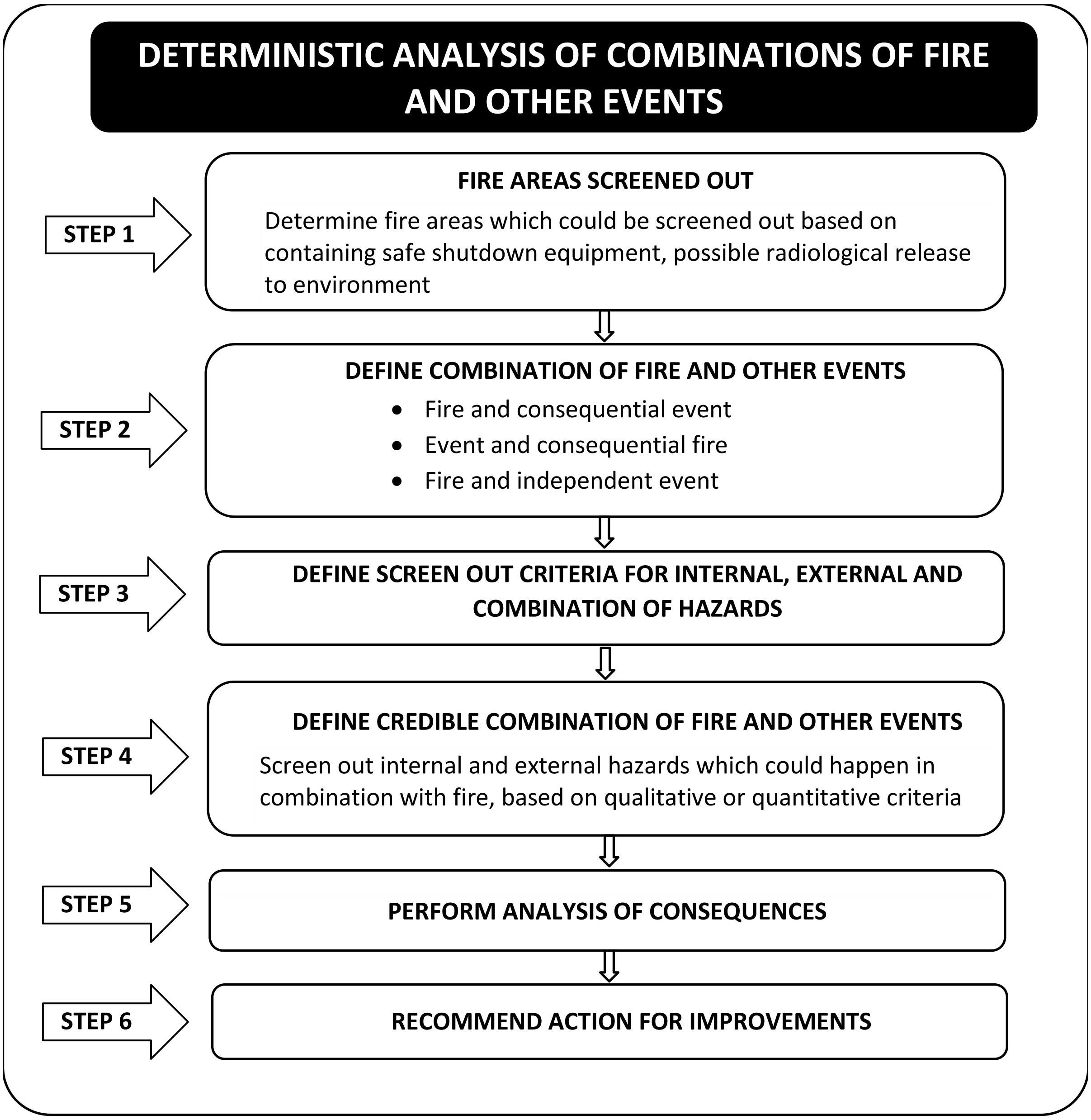
Therefore, deterministic analysis of combination of fire and other events were performed and presented in the report DCM-TD-040 "Deterministic Analysis of Combinations of Fire and Other Events" [91].

2.1.2.5.2 Scope of Deterministic Analysis of Combinations of Fire and Other Events

The scope of deterministic analysis of combination of fire and other events was presented in the following steps (Figure 10):

- Screen out Fire Areas which shall not be considered in the analysis (Step 1)
- Define combination of fire and other events (Step 2)
- Define screen out criteria for internal, external and combination of hazards (Step 3)
- Define credible combination of fire and other events (Step 4)
- Perform analysis of consequences (Step 5)
- Recommend action for improvements (Step 6)

Figure 10: Deterministic Analysis of Combinations of Fire and Other Events



STEP 1: Screen out Fire Areas

In accordance with Fire Hazard Analysis [3], the technological part of the Krško NPP is divided to 124 fire areas and several fire zones as part of fire areas. The first step in this methodology was to screen out (eliminate) fire areas based on the absence of safe shutdown equipment or potential for radioactive release, except SFP and equipment needed for the SFP decay heat removal. Several fire areas without safe shutdown equipment were additionally analysed based on substantial consequences of fire. In this category fire areas in the turbine building were analysed in case of fire and other events.

Table 3: Combination of Fire and Other Events

Combination of fire and other events	Credible? Y/N	Reason for not analyzed
Fire and consequential event:		
fire and consequential high energy arc failure (HEAF)	Y	N/A
fire and consequential (internal) flooding	Y	N/A
fire and consequential fire	Y	N/A
fire and consequential explosion	Y	N/A
Event and consequential fire:		
internal explosion and consequential fire	Y	N/A
high energy arc failure (HEAF) and consequential fire	Y	N/A
missiles with consequential fire	Y	N/A
internal flooding and consequential fire	N	8 [147]
electromagnetic or radio frequency interface and consequential fire	N	1 [21]
high energy line break (HELB) with consequential fire	N	8 [147]
earthquake and consequential fire	Y	N/A
high wind and consequential fire	N	8 [147]
drought and consequential fire	N	8 [147]
lighting and consequential fire	Y	N/A
release of chemicals from on-site storage	N	8 [147]
solar storm and consequential fire	N	1 [21]
ice storm/freezing rain and consequential fire	N	8 [147]
external fire and consequential fire	N	2 [132]
external explosion and consequential fire	N	2 [132]
aircraft crash and consequential fire	Y	N/A
transportation accidents and consequential fire	N	8 [147]
heavy load drops and consequential fire	N	8 [147]
Fire and independent event:		N/A
fire and independent initiating event	N	8 [147]
fire and independent fire	N	8 [147]
internal explosion and independent fire	N	8 [147]
earthquake and independent fire	Y	N/A
fire and internal electromagnetic events	N	1 [21]
drop load and independent fire	N	8 [147]
aircraft crash and independent fire	N	8 [147]
internal flooding and independent fire	Y	N/A
external flooding and independent fire	Y	N/A
plant external electromagnetic events	N	4 [146]
high wind and independent fire	N	8 [147]

STEP 2: Define combination of fire and other events

Combination of events which could happen together with fire were considered based on following documents:

- WENRA Report "Safety Reference Level for Existing Reactors 2020", February 2021 [132]
- Nuclear Safety NEA/CSNI/R (2016)7, Event Combinations of Fire and Other Events, The Fire Incidents Records Exchange Project Topical Report No. 3, 2016 [38]
- IAEA Specific Safety Guide No. SSG-77, PROTECTION AGAINST INTERNAL AND EXTERNAL HAZARDS IN THE OPERATION OF THE NUCLEAR POWER PLANTS, 2022 [138]
- IAEA Specific Safety Guide No. SSG-64, Protection Against Internal Hazard in the Design of Nuclear Power Plants, 2021 [139]
- IAEA Safety Standards No. SSR-2/1, Rev. 1, SAFETY OF NUCLEAR POWER PLANTS: DESIGN, 2016 [39]

Combination of fire and other events are divided in three main groups relating to events that are consequential, correlated or independent from fire, as follows:

- Fire and consequential event;
- Event and consequential fire;
- Fire and independent event.

The details of each group of combination of events and reasons for a screening out of certain combinations are shown in Table 3, below and detailly evaluated in separate analysis, DCM-TD-040 "Deterministic Analysis of Combinations of Fire and Other Events", 2023 [91].

STEP 3: Screen out internal, external and combination hazards

Internal hazards are those hazards to plant, structures and personnel which originate within the site boundary but are external to the primary circuit of power reactors. Internal hazards are documented in the report NEK ESD-TR-07/17, Screening of Internal Hazards [140].

External Hazards - These hazards represent the external events that could cause damage to the plant SSCs, and eventually lead to potential accident situations. External hazards are documented in the report NEK ESD-TR-18/16, "Screening of External Hazards" [141].

Hazards were screened based on any of the below listed qualitative (1-7) or quantitative criteria (8):

1. APPLICABILITY; The event cannot occur at the site or close enough to the site to affect the plant. This is also a function of the magnitude of the event.
2. INCLUSION; The event is included in the definition of another event.
3. SEVERITY; The event has a damage potential that is less or equal to another event that the plant is already designed for.
4. INITIAL EVENT; The event does not cause an initiating event (including the need for a controlled shutdown) as well as safety system losses.
5. SIMILARITY; The hazard has a significantly lower mean frequency of occurrence than another hazard that has been screened, and the hazard could not result in worse consequences than the other screened hazard.
6. KINETICS; The hazard is slow in developing such that it can be demonstrated that there is sufficient time to eliminate the source of the threat or provide an adequate response.
7. RELEVANCY; The consequences to the plant do not result in a reactor trip or shutdown, and do not require the actuation of front-line systems. If a hazard does not result in a challenge requiring front-line systems to be actuated (i.e., not support systems) and does not result in a reactor trip or shutdown,

then it is not necessary to evaluate the consequences of the hazard.

8. FREQUENCY and CONTRIBUTION; Hazard can be screened from further consideration if any Core Damage Frequency (CDF) is very low.

STEP 4: Define credible combination of fire and other events

Credible combination of fire and other events which are not screened out are marked in Table 3 above, and credible combination is defined based on the criteria defined in STEP 3 above.

STEP 5: Perform analysis of consequences

All credible combinations of fire and other events were analysed in detail. Results were presented in the DCM-TD-040 "Deterministic Analysis of Combinations of Fire and Other Events", 2023 [91].

For every analysed combination of events a walkdown through all fire areas was performed. 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.

STEP 6: Recommend action for improvements

Since the Fire Protection system is not seismically qualified, it can become inoperable in case of an earthquake. Therefore, it is recommended to perform a survey of the system (sprinkler systems, pipelines, control panels, pumps) after a seismic event to discover possible degradations. If the Fire Protection system is degraded, an alternate method of providing fire protection functions shall be prepared (e.g. with mobile equipment). In case of inoperability of Fire Detection system, a fire watch shall be provided. It was recommended that procedure AOP-3.6 ENV-1 "Earthquake" is expanded with instructions for a survey of the FP system after a seismic event.

2.1.2.6 Fire Hazard Analysis for Heating, Ventilating and Air Conditioning

2.1.2.6.1 Purpose of Analysis

The purpose of this analysis is to provide a deterministic evaluation and fire hazards analysis for Heating, Ventilation and Air Conditioning Systems (HVAC) of Krško NPP, as support systems for systems and components necessary to achieve and maintain the safe shutdown function. This report was prepared to be understood as the addendum to the existing Krško NPP FHA, prepared in accordance with the 10 CFR 50 Appendix R [43] evaluating Krško NPP Safe Shutdown and Cold Shutdown Capability to demonstrate that the current HVAC systems configuration and overall fire safety in the associated fire areas and systems are sufficient to ensure or at least not to prevent Safe Shutdown and Cooldown of the plant and to prevent fire propagation and prevent radioactive material release to the environment.

2.1.2.6.2 Scope of Deterministic Fire Hazard Analysis for Heating, Ventilating and Air Conditioning

The scope of the deterministic fire hazard analysis for the HVAC systems was presented in the following steps (Figure 11):

- Define requirements for analysis (Step 1)
- Define safe functions (Step 2)
- Select systems needed for accomplishing safety function (step 3)
- Select equipment needed for accomplishing system safety function (Step 4)
- Identify cables (Step 5)
- Perform circuit analysis (Step 6)
- Locate equipment/cable by fire area (Step 7)

- Evaluate consequences of fire in each fire area (Step 8)
- Develop resolutions (compliance strategy) (Step 9)

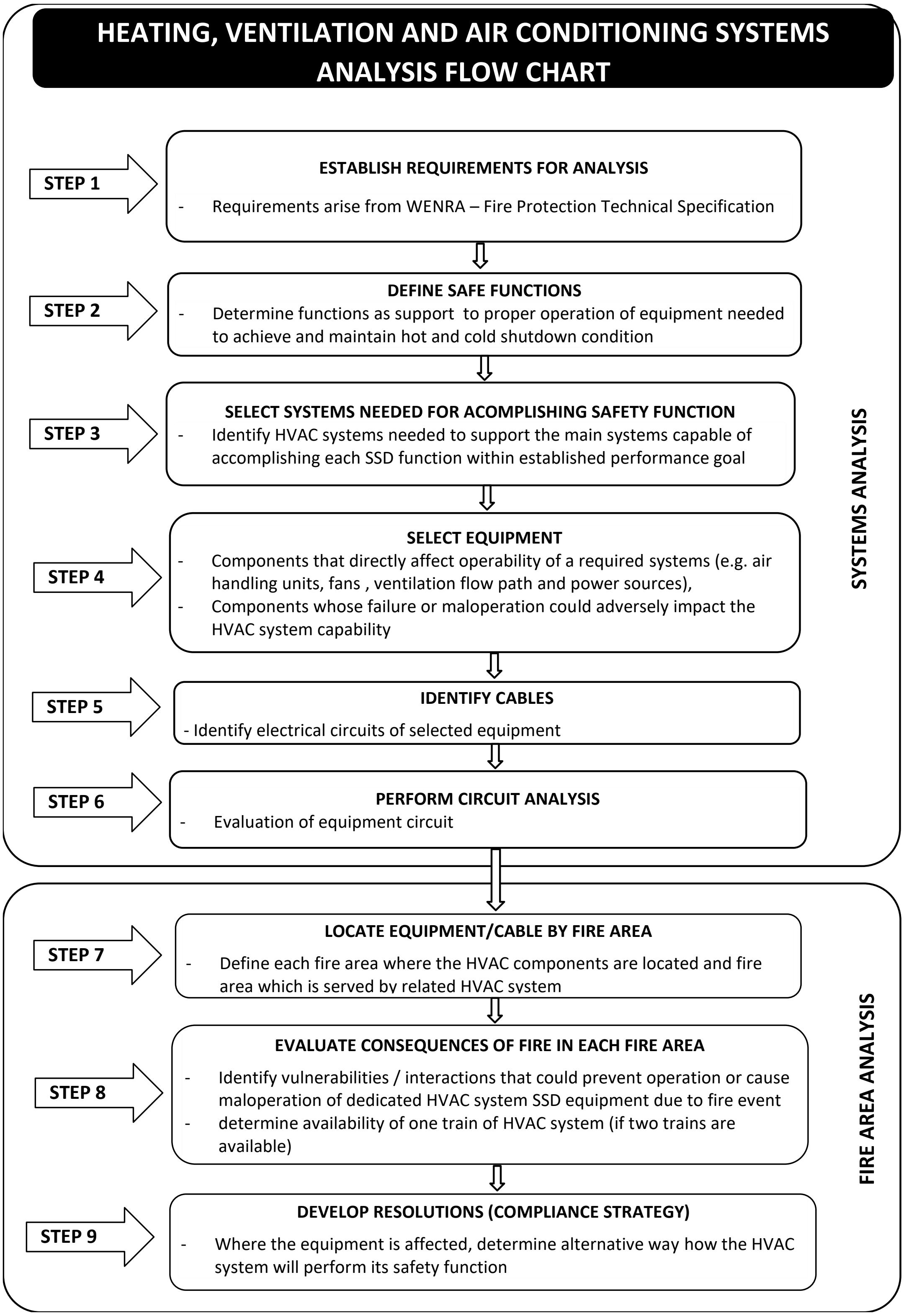
The deterministic fire hazard analysis for the Heating, Ventilation and Air Conditioning Systems (HVAC) of Krško NPP, was performed and presented in the report DCM-TD-039,"Fire Hazard Analysis for Heating, Ventilating and Air Conditioning" [120]. The HVAC systems are selected in accordance with Post-Fire Safe Shutdown Separation Analysis (SSA) [3], with added HVAC systems for proper functioning of MCR and ECR, and the SFP Area Charcoal Cleaning Exhaust System.

The analysis was prepared in accordance with the WENRA Safety Reference Levels for Existing Reactors [132], SV 6.6 and SV 6.7 requirements on internal hazards and in accordance with the WENRA Topical Peer Review 2023 [136] and it considers the following:

- how the ventilation systems are designed in order not to compromise building compartmentation and to maintain access routes for firefighting;
- how the ventilation systems in fire compartments separating redundant trains of a safety system are designed so that a fire in one compartment will not propagate to another, including fire effects such as loss of ventilation in a compartment of another redundant train;
- in case that a ventilation system serves more than one fire compartment, the provisions that are in place to maintain segregation between fire compartments to prevent the spread of fire, dangerous fire by-products, and other hazardous (e.g. asphyxiant, combustible, corrosive, toxic and/or radioactive) substances, if any, to other fire compartments;
- the fire resistance rating of ventilation systems and any possibilities to isolate the fire compartment penetrations by suitably rated fire dampers (automatically where appropriate), means available to prevent the spread of fire.

The details and conclusions of the deterministic fire analysis for Heating, Ventilation and Air Conditioning Systems are provided in Sections 2.1.4.6 and 3.3.2, as well as in the DCM-TD-039 analysis [120].

Figure 11: Deterministic Analysis of HVAC Systems



2.1.2.7 Fire Probabilistic Safety Assessment Assumptions and Methodologies

In the analysis, methodologies presented in the following chapters were used.

2.1.2.7.1 Fire Risk Assessment Methodology

The overall methodology used in the development of the Krško Fire IPEEE conforms with the guidance provided by Generic Letter 88-20, Supplement 4 [166] and detailed guidance provided by NUREG-1407 [165], and has made use of past PSA experience, generic databases, and other defensible simplifications to the maximum extent possible. Besides simplification in terms of cost reduction and minimization of execution time, the fire risk assessment described also met the following additional objectives:

- To be consistent with internal events analysis. The same event trees, system success criteria, and recovery analysis assumptions will be used as those developed and used in the IPE report [5].
- To be transparent. A standard report format should enable the reader to understand and reproduce any of the results presented in the document.
- To be realistic. Best estimate data and models will be used as much as possible. Important plant-specific failure modes will be analyzed.

2.1.2.7.2 An Overview of the Fire PSA Level 1 Methodology

1) The initiation of the fire PSA study was performed with initial plant walkdowns. The general location of cables and components of the systems of interest was determined. The plant walkdowns provided means of verifying the physical arrangements for each of the plant areas. The completed fire area checklist supported the screening analysis and quantification step. Also, a thorough review of firefighting procedures was conducted. This review was performed to determine the probability of manual suppression in a given length of time for all critical plant areas.

2) 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.

3) After the screening analysis has eliminated all but the probabilistically significant fire areas, quantification of dominant areas was completed as follows:

a. The temperature response in each fire area for each postulated fire was determined. The fire growth code COMPBRN with some modifications was used to calculate fire propagation and equipment damage. A comparison of Krško fire areas to those from previous analyses was made to approximate time to damage of critical components and cables for some areas. Detailed fire calculations were performed only for those fire areas that survived the screening analysis, and were not directly comparable with the previous analyses.

b. A recovery analysis was performed. In similar fashion as the internal event analysis, recovery of nonfire-related random failures was addressed.

c. The probability of a barrier failure for adjacent critical fire zones was assessed. A barrier failure analysis was conducted, for combinations of adjacent fire areas which, with or without additional random failures, remained after the screening analysis.

4) Description of the plant fixed fire suppression systems and fire brigade manual suppression analysis, is provided.

5) Detailed description of all fire scenarios with contributions to core damage frequency of greater than 1E-07 per reactor year and their associated fire area is given. A description of all factors used in the final quantification of all these fire areas is delineated.

6) The analysis of containment performance given potential fire damage is documented. A discussion of the plant walkdown findings regarding the Fire Risk Scoping Study issues are provided with discussion of issue USI A-45 [172], decay heat removal requirements, and system capabilities at Krško. A summary of the analyses and conclusions and recommendations is provided

The PSA assessment follows the above presented methodology, following the listed steps in the fire analysis:

1) Review of Plant Information
2) Plant Walkdowns
3) Fire Initiating Event Frequencies
4) Identification of Potential Fire-Induced Initiating Events
5) Evaluation of Krško Fire Areas
6) Fire Detection and Suppression
7) Screening Analysis
8) Fire Propagation Modelling
9) Operator Recovery Actions
10) Multiple Compartment Fire Interaction Analysis
11) Quantification of Unscreened Fire-Induced Core Damage Scenarios and Their Associated Fire Areas;
12) Containment Performance;
13) Treatment of Fire Risk Scoping Study Issues:
    a. Seismic/Fire Interactions
    b. Seismic Induced Fire Sources
    c. Seismic Actuation and Degradation of Fire Suppression Systems

d. Fire Barrier Qualifications

e. Manual Firefighting Effectiveness

f. Potential Adverse Effects on Plant Equipment by Combustion Products

g. Spurious or Inadvertent Fire Suppression Activation

h. Operator Action Effectiveness

14) USI A-45 - Shutdown Decay Heat Removal Requirements [172];

15) Bridge trees and Level 2 Fire PSA Analysis.

2.1.2.7.3 An Overview of the Fire PSA Level 2 Methodology

1) The Bridge Trees (BT) are used to provide the link between the core damage sequencies and plant damage states (PDS), that are input to the Level 2 containment event tree. In the assignment of core melt sequences to PDS, the top events – functions are modelled for the status of the containment systems at vessel failure as well as for the possible recovery after core damage but before vessel failure. In order for the fire PSA to provide proper input to accident strategies, it is also a top event for operator action to depressurize the primary system before vessel failure. The generic top events – functions modelled are as follows: in-vessel recovery or primary depressurization, the status of low head safety injection, containment air recirculation and cooling system, and containment sprays at vessel failure. The generic tree is then attached or linked to each dominant fire-induced core damage sequence from the Level 1 event trees. However, only certain specific paths through the generic BT are meaningful, depending on the specific core damage sequence. For example, a core melt sequence where the failure of low head recirculation is the cause of core melt implies that the low head injection and recirculation are unavailable by definition in BT. Therefore, generic BT is specialized for each fire-induced core melt sequence.

2) Plant Damage States represent the output from the bridge trees and input to the containment event tree. The total number of bridge sequences has been reduced by retaining only those with the frequency set criteria of greater than 1.00E-11/yr. The BT sequences are then grouped according to damage state and the total frequency for each damage state calculated.

3) The containment performance is assessed by evaluating, for each PDS, the conditional probability (through the containment event tree) that the damage state will result in each of the fission product Release Categories (RCs). Where a damage state is present for the fire analysis which is also present for internal events or seismic analyses, then the conditional probabilities used are taken directly from other studies. Where the damage state has not already been quantified in the internal events or seismic studies, it is quantified by analogy with other damage states, using the knowledge gained during the internal events and seismic analyses.

2.1.2.7.4 Key Analytical Assumptions

The following were the key analytical assumptions employed in the quantification of fire-induced core damage frequency or utilized to address the Fire Scoping Study (FRSS, [176]) issues:

1. The unit is at normal power operating conditions at the time a fire or inadvertent operation of an automatic fire protection system occurs;
2. The fire areas as defined in FHA and "Krško Nuclear Power Plant - Post-Fire Safe Shutdown Analysis" are used for this study;
3. As a minimum, given a significant fire, a reactor trip will be generated in any plant area that contains active safety-related equipment;

4. Fire-damaged equipment was assumed to be totally failed; i.e., partial damage states were not considered. Further, the repair or replacement of equipment or cables damaged during a fire was assumed not to be feasible during the process of establishing safe shutdown of the plant following the fire;
5. Operator recovery actions in the area where the fire occurs are not credited until one-half hour after the fire is extinguished, with the exception of a quickly suppressed (in less than six minutes) control room fire:
6. The mission time for analysis of core damage following a fire-induced initiating event is 24 hours, consistent with the Krško internal events individual plant examination (NEK IPE [5]);
7. Fire propagation was assumed to be negligible exterior to low-voltage cabinets (120 V or less) if proper penetration seals can be verified during the plant walkdown;
8. Passive fire barriers without observed (during the plant walkdown) penetration seal degradation will remain intact during the entire period for which they are rated;
9. In many locations, the cables are protected by conduits. Credit has not been taken for such conduits as a means of protection for the cables. However, credit was taken for cables in conduits not being considered as fire initiators nor intervening combustibles;
10. Fire initiating event frequencies are calculated utilizing generic fire data from NUREG/CR- 4586 [168] because employing Bayesian updating using Krško-specific fire data would not vary the predicted generic fire initiating event frequencies by more than a factor of three (NUREG-4550, Volume 3 [169]);
11. Reactor subcriticality was assumed to be successful in all cases;
12. Cables that are IEEE-383 qualified were not considered as a fire source;
13. IEEE-383 rated cable failures occur at 623ºF, which was based upon Sandia National Laboratories (SNL) fire testing experience [168];
14. The state-of-the-art at the time in fire protection engineering did not permit an adequate assessment relative to the nonthermal effects of combustion products;
15. The frequency of inadvertent and advertent suppression system actuation was calculated using generic data from NUREG/CR-5580 [170]. The potential for water intrusion from fire suppression system actuation into safety-related cabinets was assessed during the plant walkdowns;
16. The probability of active barrier failure was calculated using the generic data from NUREG/CR-4840 [171], unless obvious active barrier deficiencies were noted during the plant walkdown;

2.1.2.8 Low Power and Shutdown Fire Probabilistic Safety Assessment

Low power and shutdown model are based on full power PSA model. Therefore, the same methodology was used as described for full power PSA model in the chapter above.

The initiating events and their respective event trees were reviewed in the sense if the plant can be brought to hot shutdown following all initiating events. In addition, the fault trees linked to the functional events in the event trees were reviewed according to Plant Operating State (POS) conditions and parameters:

- Initiating events and their frequencies were reviewed and changed if needed for a specific mode of operation;
- The functional events and the branches of the event tree were reviewed and changed if needed for a specific mode of operation;
- The fault trees linked to the respective functional events of the event trees were reviewed and changed if needed for a specific mode of operation.

For low power operation from Krško NPP Technical Specification Mode 2 to 4, three PSA models were developed (Table 4).

Table 4: Link between PSA Models and Plant Parameters for Plant Operational Modes 1 to 4

Name and description of PSA model	Definition of plant operation	Plant operational mode	Plant operating state	Comments about description of the main plant parameters
Basic PSA model NEKC18SE	steady state full power operation	MODE 1	-	Plant operation at full power
NEKC18SE is assumed to be representative	Not steady state operation	MODE 1	-	Plant operation at reduced power
Changed PSA model: POS1C Less important model as the plant is recommended to be very shortly in this mode (see section 4.2.4.6 of GOP-3.1.200)	Not steady state operation	MODE 2	POS1C	Plant operation at reducing power
				Increasing power
Changed PSA model: POS2A	Hot standby	MODE 3	POS2A	Cooldown with Steam Generators, core is subcritical
				RCS heat-up with SG
Changed PSA model: POS3A	Hot shutdown	MODE 4	POS3A	AFW and RHR are in operation, plant cooling is assured by AFW, core is subcritical
				RCS heat-up

For shutdown modes of operation, 6 representative Krško NPP's Plant Operating States were identified (POSs) for both Krško NPP Technical Specification Modes 5 and 6 (Table 5). Those POSs represent grouping of plant configurations in terms to represent the plant conditions and related specific parameters into a number of Krško NPP POSs. The number of POS is small enough that the number of the PSA models is maintainable and large enough that the main differences among the plant configurations are reflected in those POS and consequently in the corresponding PSA models.

Three Krško NPP POS are identified for the Krško NPP Technical Specification Mode 5 (POS5A, POS5B, POS5C) and three are identified for the Krško NPP Technical Specification Mode 6 (POS6A, POS6B, POS6C). Separate PSA models including initiating events and corresponding event trees, their functional events and corresponding fault trees and other features of PSA models are prepared and evaluated for each of 6 Krško NPP POS. Those PSA models include consideration of internal events, seismic events, fires, floods and other external events. Welding and cutting with tools that generate heat were not explicitly modelled. Fire watch is considered that in case of fire due to works, immediate response would be organized.

Table 5: Link between PSA Models and Plant Parameters for Plant Operating Modes 5 and 6

NEK POS group	NEK outage phases	Decay heat load	RCS level representative for PSA (2)	Temperature of RCS representative for PSA (3)	RCS pressure representative for PSA
POS5A	B1, C2	8.2 MW (1)	CL+170 cm -> 107.57 m	80°C	24.5 bar (RCS closed)
POS6A	E3, E4, K4, K3	6.8 MW	CL+20 cm -> 106.07 m	50°C	RCS open
POS6B	E5, F6, J6, K5	6.8 MW	CL+20 cm -> 106.07 m	50°C	RCS open
POS6C	F7, G8, I8, J7	5.9 MW	RVF+7 m -> 114.74 m	50°C	RCS open
POS5B	L2	3.8 MW	CL+8 cm -> 105.95 m	80°C	RCS head closed, vented
POS5C	L1	3.8 MW	RCS full -> 119.64 m	93°C	24.5 bar (RCS closed)

2.1.2.9 Spent Fuel Pool Fire Probabilistic Safety Assessment Assumptions and Methodologies

Analyses of external events for the SFP were firstly provided in 2015. Methodology was based on full power PSA methodology, provided in chapter 2.1.2.7.

2.1.2.9.1 Fires in Fuel Handling Building

Fuel Handling Building (FHB) at Krško NPP is equipped with Fire Detection and Alarm System (ref. [44], [3]). In all fire areas in FHB with the exception of stair tower automatic fire detection is provided which annunciates in the Main Control Room and Fire Brigade Office. Fire detection provides only fire alarms, and does not automatically actuate any fire suppression equipment. In all cases one or more fire hose stations are provided in the vicinity for manual fire-fighting. Additionally, portable fire extinguishers (dry chemical or/and carbon dioxide) are provided within each area or in the vicinity for manual fire-fighting. Based on the combustible loading inventory and evaluation for particular fire areas fire severity was assessed for the FHB fire areas to be from 2 minutes (FH-3, with SFP Pumps) to 19 minutes (FH-2, Hot Machine Shop). Fire barriers and manual fire-fighting capabilities were established and provided accordingly, with regard to NFPA and Slovenian standards. It can, therefore, be considered likely that any fire will be detected and extinguished before it can cause damage to the spent fuel pool (SFP) cooling function to the point that it cannot be recovered in time to prevent the SFP boiling.

In the case of failure of plant personnel to recognize the loss of the SFP cooling resulting from a fire, given that a fire alarm failed or was not attended to, the indications would be available to the operators during regular walk-downs, including the effects of the fire, both visible evidence and the smell of burning, as well as the secondary effects such as loss of power or damage to the equipment producing the additional alarms. In the unlikely case that no action is taken to restore the cooling, the point of SFP boiling would eventually be reached. Time to boiling would depend on the SFP state. In the case that cooling has not been restored by the time of boiling the SFP level would start to gradually decrease due to evaporation losses. However, high area temperature and humidity, and ultimately low water level from boil-off will become increasingly evident. Operators would have several shifts to recognize the loss of the SFP level.

In the case that the normal SFP cooling and SFP makeup have been lost as a result of the fire, and operators are unable to restore it, actions would need to be taken by operators in order to cover the SFP cooling by means of the SFP Alternative Cooling (AC) with Mobile Heat Exchanger (MHX).

With regard to establishing the spent fuel pool alternative cooling (SFP AC) with mobile heat exchanger (MHX), the details are provided in SFP PSA for internal events [35]. The shortest times available, regarding the spent fuel pool states, were assessed to be longer than 6 hours or in other states the time window would be considerably longer. It is considered that even the shortest time windows are still considerably longer than the time needed to extinguish any credible fire in the relevant areas. This is particularly so as it is expected that during these states (shortest time available for mitigation) there would be continuous presence of personnel in the respective areas, due to outage activities. Time needed for establishing and initializing SFP AC with MHX is about 4 hours, as given in ref. [35].

2.1.2.9.2 Fires in Other Plant Areas

The above evaluation considers the fires which occur in the SFP/FHB areas and cause a loss of SFP cooling by direct fire impact. Additionally, there is a risk impact from potential fires which may occur at other plant areas and cause a loss of the SFP cooling through the interactions such as a loss of support system. Relevant support systems are electrical power (the SFP Cooling Pumps are powered from the safety-related 400 V buses LD11 and LD21) and Component Cooling. These fire scenarios are also addressed.

Therefore, like in the FHB scenarios considered in the previous section, actions would need to be taken by operators in order to recover the SFP cooling by means of SFP AC with MHX. With regard to SFP AC with MHX, it is considered that it can be established regardless of the impact of any of the postulated fire events, as it is independent of the mentioned support systems. The actions are performed in the yard, except of opening of the valves and checking that the system is filled and air-free, which is done in FHB and is not affected by the above postulated fires. With regard to the SFP makeup it was considered that all methods, normal and alternative, are independent from CCW ESW.

Also, since there is no leakage, the coping time is basically not an issue either for the normal of for the alternative methods (including among others the SFP spraying from the FP Tank).

2.1.2.9.3 Probabilistic Perspective on Combinations of Events for SFP

Spent fuel pool related scenarios of internal flooding with fire events relate to scenario case that the SFP cooling has been lost as a result of the fire (or flooding with fire), and the operators are unable to restore it (i.e. SFP boiling cannot be avoided), actions would need to be taken by operators to establish the SFP makeup and Alternative SFP cooling. Internal flood/fire events disabling the Fuel Pool Cooling system would still leave a very long time (several 10s of hours) until the integrity of the used nuclear fuel was challenged even under the highest possible loads of decay heat in SFP.

In case of fire with seismic events, the seismic risk itself represent the bounding scenario also for the combination of seismic events with fire. The SFP risk-related to seismic events is typically much larger than either fire or internal flooding events.

2.1.2.10 Probabilistic Safety Analysis of Combinations of Fire and Other Postulated Initiating Events Assumptions and Methodologies

The analysis of combinations of fire and other postulated initiating events with their impact are analysed [23]. It includes the following combinations:

- Fire and Internal Initiating Event
- Fire and Internal Hazard (Internal Flooding and HELB)
- Fire and Seismic Initiating Event
- Fire and Other External Events
- Fire and Explosion
- Multiple Compartment Fire Interaction Analysis

Firstly, the deterministic approach was used in order to determine fire area frequencies, as defined in NUREG/CR-6850 [25] and NUREG-2169 [26]. Among identified fire areas, 40 of them have been eliminated based on non-existence of SR equipment in fire areas. Final fire frequencies of the remaining fire areas have been developed by considering automatic fire suppression, manual fire suppression and large fire factors. Additionally, for combinations with seismic events, no automatic actions of the fire protection (FP) system were taken into account, as FP system is not seismically designed.

Secondly, the probabilistic approach has been used. From remaining areas, some areas have been screened out immediately based on FHA [3] and some were merged based on similarity of the area or physical connection between fire areas. Therefore, the PSA Models have been developed based on living RS PSAP baseline model with total 34 initiators divided into three groups (IIE, internal hazards and seismic events). CDF was calculated for each combination of fire area and postulated event. Also impact on the potential releases from the containment were evaluated.

Additionally, aspects provided in Nuclear Safety NEA/CSNI/R (2016)7 Event Combinations of Fire and Other Events [38], IAEA Safety Standards no. SSR-2/1 Rev. 1 Safety of Nuclear Power Plants: Design [39] and IAEA Specific Safety Guide No. SSG-64, "Protection Against Internal Hazards in the Design of Nuclear Power Plants" [139] were also taken into account within this analysis.

2.1.2.10.1 Key Analytical Assumptions

The following are the key analytical assumptions employed in the quantification of fire-induced CDF or utilized to address the analysis of fire combinations:

1. The analytical approach is based on fire PSA analysis (Krško NPP IPEEE) [5]. Therefore, ignition frequency factors, described in the Krško NPP IPEEE will also apply in this analysis;
2. Analysis of fire in combinations with other initiating events will cover a large number of analytical cases. In this analysis spread of fire will not be further analyzed, but the fire spread analysis will be based on the findings of fire PSA analysis (Krško NPP IPEEE);
3. As in the fire PSA analysis (Krško NPP IPEEE), a large number of fire areas was screened out from further analysis because of their insignificance, it was necessary for the purposes of this analysis to optimize approach. In order to avoid large number of fires spread analyses, it was assumed that all types of fire initiating events are able to start a large fire. This is a very conservative approach. Large fire initiating events can be multiplied by a factor of the severity of a large fire according to the reference (Krško NPP IPEEE). This factor equals 0.3. This factor seems suitable for conservative treatment as due to fire in particular area all important equipment will be assumed unavailable or affected with fire phenomena. As described, this factor is therefore applicable for all fire area frequencies.
4. Manual suppression fire intervention factor equals 9.5E-01, according to the reference (Krško NPP IPEEE). This means that manual suppression will be statistically successful in only 5% of events. This factor seems reasonable for conservative analysis approach documented in this report. The factor is applicable for all fire area frequencies.
5. The first set of conservative analyses of fire combinations with other initiating events assume that all important equipment is affected in fire area under examination. If there was a specific scenario available in fire analysis (Krško NPP IPEEE), the results of this scenario were used in this report.
6. In the first screening of results from conservative analysis of fire combinations with other initiating events the quantitative screening criteria for conservative approach was used as provided. The screening criteria are based on ASME/ANS RA-Sb-2013 [41] and EPRI, 3002005287, Identification of External Hazards for Analysis in Probabilistic Risk Assessment [42].
7. In the screening process for results of the detailed analysis of survived fire areas and in Sensitivity analysis criteria of CDF<1E-07 /ry as an "acceptably low mean of core damage" (EPRI, 3002005287, Identification of External Hazards for Analysis in Probabilistic Risk Assessment) for screening will be used. For initiators originating from Level 1 PSA analyses (CDF criterion) CDF < 1E-07 /ry criterion will be used and for initiators originating from Level 2 PSA analyses (DCF - LERF criterion) CDF < 1E-08 /ry criterion will be used. This will ensure that the process of areas assessment is still conservative.
8. In the evaluation current status of the plant will be taken as input configuration, including the emergency control room (ECR), from the Safety Upgrade Program (SUP), will be assumed as available, as modification Phase 1 and Phase 2 of ECR are already implemented, and Phase 3 is partially implemented and planned to be implemented during Outage 2019. Emergency shutdown function is

at the time of writing completely implemented and fully functional.

2.1.3 Fire Phenomena Analyses: Overview of Models, Data and Consequences

2.1.3.1 Fire Hazard Analysis

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.

The other Fire Hazard Analyses (FHA of Shutdown Operational Modes, FHA for Spent Fuel decay Heat Removal Function, analysis of combination of fire and other events and FHA for the HVAC systems) were also performed with very conservative approach as described in the upper paragraph and are took into account 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 systems and equipment, necessary for safe shutdown are equipped with the HVAC systems, and malfunctions of SSCs due to thermal effects could happen only in the area where a fire occurs, but the other train of SSC with the operable HVAC system will perform its function. Additionally, smoke and corrosive gases are exhausted through the HVAC systems, designed and installed for that purpose; therefore, these indirect effects of fire were also not evaluated. The fire event also could disrupt the air circulation through the ventilation ducts, but will not affect the proper functioning of other systems outside the area affected with fire nor increase the risk of radioactive release to the environment.

Additionally, the deterministic fire hazard analysis for the SFP Heat Decay Removal function was performed according to current methodology included in FHA, in order to perform a conservative evaluation, but determining a more realistic possibility (still being conservative) of fire occurring and spreading to the adjacent areas. In support of this calculation, an evaluation of the data and tests performed by the industry was used, as shown in NUREG/CR-7197 [175], and the conclusions were evaluated considering the actual fuel load of combustible materials inside electrical cabinets and the actual duration of a fire caused by an amount of combustible material. The malfunction of the SFP Cooling system due to a fire event causes a temperature increase in the SFP, i.e. affects the SFP heat decay removal functions, as described in a separate analysis (DCM-TD-038), but the strategy for that worst case has already implemented through the validated Krško NPP procedure and additional equipment (ASF system). The SFP Heat Decay Removal function analysis is also complemented by the conclusions of the corresponding PSA analyses.

Methodology for performing analysis for each part of Fire Hazard Analysis were described in section 2.1.2.

2.1.4 Main Results of the FHA

Main results of the Fire Hazard Analysis were presented separately in the following sections.

2.1.4.1 Main results – Compliance with the Requirements in BTP-9.5-1 App. A

The BTP-9.5-1 App. A [127] addresses Fire Protection Program in order to ensure the capability to shutdown the reactor and maintain it in a safe shutdown condition and to minimize radioactive releases to the environment in the event of a fire. Fire Protection Program implements the philosophy of defense-in-depth protection against hazards of fire and its associated effects on safety-related equipment.

The primary objective of Fire Protection Program is to minimize both the probability and consequences of postulated fires. The defense-in-depth concept entails the use of administrative controls, fire protection systems and features, and safe shutdown capability to achieve the following objectives:

- prevent fire from starting
- detect rapidly, control, and extinguish promptly those fires that occur,

- protect SSC's important to safety, so that fire that is not promptly extinguished by the fire suppression activities will not prevent safe shutdown of the plant or cause radioactive release to the environment

Evaluation of requirements is performed by the item-by-item assessment of the Krško NPP status in accordance with the positions set forth in BTP APCSB 9.5-1, Appendix A [127]. Details of evaluation are presented in the Volume 1 of Fire Hazard Analysis [3]. Krško NPP is in compliance with BTP APCSB 9.5-1, Appendix A requirements.

2.1.4.2 Main results – Safe Shutdown Analysis

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.

Fire areas are summarized as follows:

1. Fire Areas free from fire damage;

   This category indicates that at least one safe shutdown equipment train serving designated function is not located in the fire area. Shutdown of the plant will be performed with available safe shutdown equipment.

2. Fire areas where safe shutdown functions are available with operational changes/manual actions

   This category indicates that both redundant train of safe shutdown equipment may be rendered inoperable by fire in this area. Required safe shutdown functions could be achieved in different ways:

   - by implementing manual actions as remove fuse to prevent inadvertent actions, disconnect power to motor operated valves and manual reposition of valves;
   - by using different instrumentation instead of affected one (i.e. local indication instead of remote), using other parameters to verify that required functions are achieved, using independent instrumentation in the Emergency Control Room;
   - performing actions from procedure FRP-3.9.100, “Operators actions in case of fire in technological part of plant” [9].

3. Fire Areas where safe shutdown function is available using alternative equipment

   Use alternative equipment instead of redundant safe shutdown equipment. Examples of alternative equipment are:

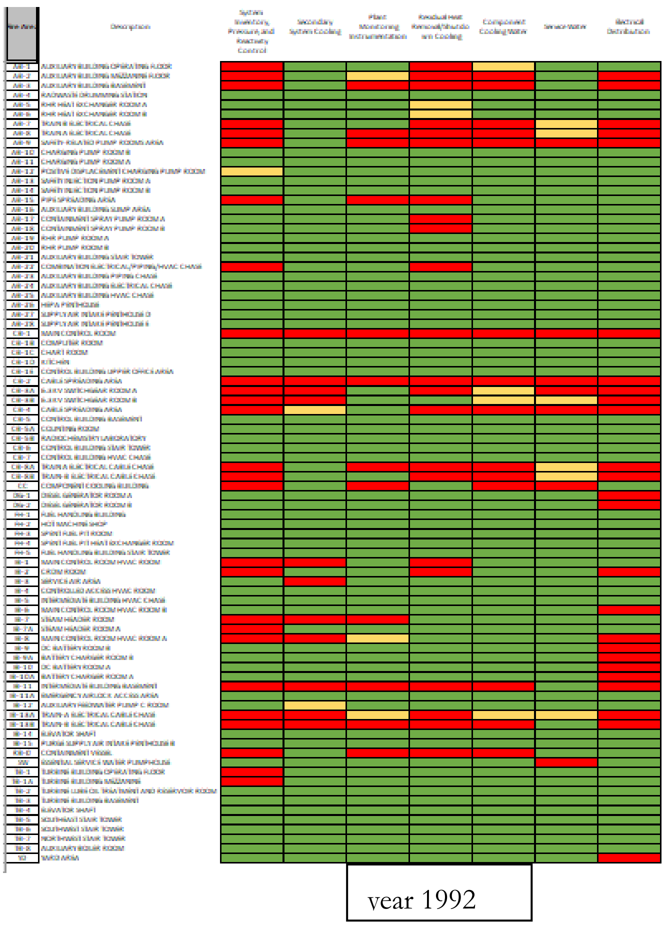
   - Alternative Auxiliary Feedwater System (AAF).
   - Alternative Residual Heat Removal System (ARHR).
   - Use Emergency diesel generator DG3 as independent power supply to alternative equipment or as substitute to DG1 or DG2.
   - Control the plant from Emergency Control Room or use ECR as an alternative way to control the plant using alternative equipment and independent instrumentation.
   - Use mobile equipment as mobile heat exchanger, mobile submersible fire protection pump, etc.

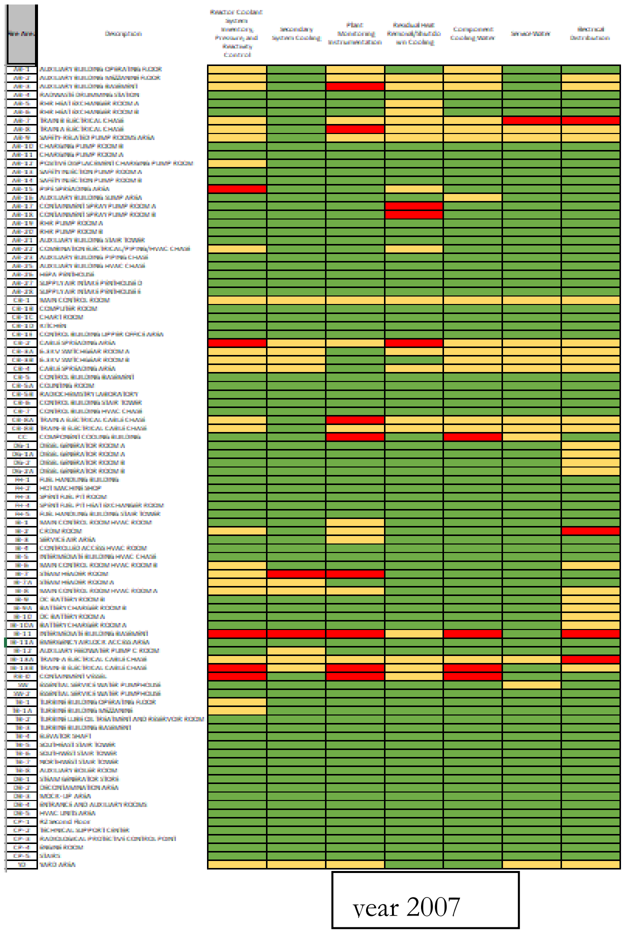
   All actions in this category will be performed in accordance with dedicated procedures e.g. FRP-3.9.100 [9], AOP-3.6.INS-3, “Abnormal Operating Procedure - Control room evacuation” [10], EOP-3.5 [153].

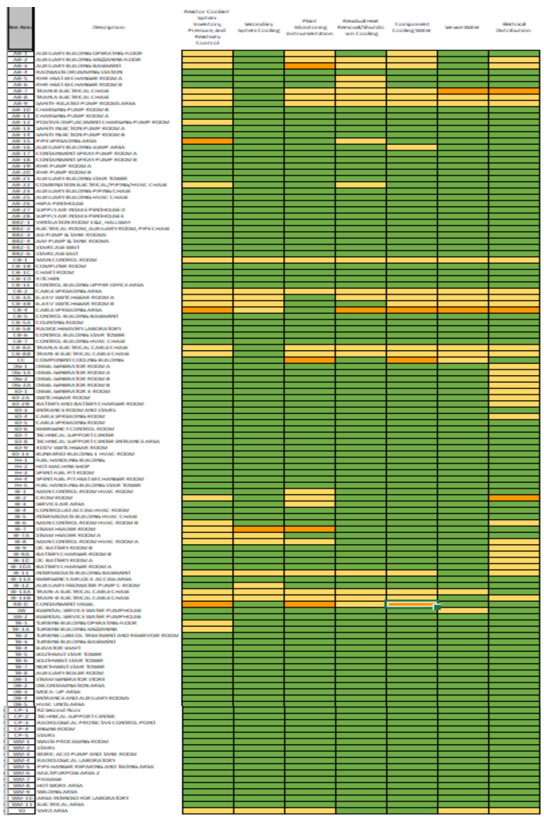
   Safe shutdown of the plant, cooling down and maintaining cold shutdown condition can be achieved in case of fire in any fire area as presented in the Volume 4 of Fire Hazard Analysis [3]. Figure 12 shows the improvements of the SSD functions in different periods, first in 1992, when first FHA analysis was performed, then in 2007 after implementation of the Fire Protection Action Plan, and lastly in 2022, after the Krško NPP's SUP was implemented.

HVAC systems as support systems for safe shutdown in case of fire is important from perspective of prevent ambient temperature increase above temperature limit for operability of safe shutdown equipment. Before 2022 (completed SUP modifications) HVAC systems, as support systems, was not addressed in the FHA. As compensation measure portable ventilation equipment was planned to use in key equipment areas. Now (after SUP modification completed) the worst case regarding HVAC system will be fire event in the Cable Spreading Area (Fire Area CB-4) which affect both trains of HVAC system, as well as other systems needed for safe shutdown the plant. In this case the most systems necessary for normal operation and for Safe Shutdown will be lost and further actions would be performed in accordance with AOP-3.6.INS-3 [10] and EEOP EECA-0.0 [162], where the alternative strategy for the Safe Plant Shutdown and Cooldown in the case of loss of both trains switchgear is described. Since the main switchgears would be lost, the power supply would be provided from DG3 in ''ISLAND'' mode of operation, which would be isolated from all other electrical distribution network on the site, and it would only supply MD3 bus loads (alternative safety systems). Since the DG3 is located in a separate building, the fire event cannot disable both buildings simultaneously. Regarding fire separation. Therefore, in Figure 12 for year 2022 all safe shutdown function will be fulfilled (no red color for any function).

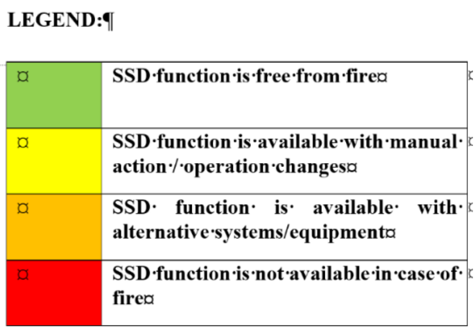
Figure 12: Safe Shutdown (SSD) Functions Evolution in Fire Areas







year 2022
after implementation of the SUP



***Note**: *for better readability, see Appendix 6.*

2.1.4.3 Main results – FHA of Shutdown Operational Modes

For fire areas, in which the fire could affect the equipment needed for the DHR, INV, SCS and ELE functions during shutdown modes, different resolution/compliance actions have been made for the following three categories:

1. Fire areas in which key safety function (KSF) equipment is completely free from fire;
2. Fire areas in which the KSF equipment is not free from fire, but possible failures can be compensated with manual operator actions (such as manual valve repositioning, turning off the valve supply power, removing some fuses, using another indication type);
3. Fire areas in which the KSF equipment is not free from fire, but manual operator actions and use of alternate equipment/method/system is required to perform KSF (e.g. ARHR, ASI).

For categories 2 and 3 dedicated operator procedures were developed, which direct compensatory operators' actions.

Detail review of the KSFs in critical non-operating or shutdown modes shows that DHR and INV functions, together with its support functions are not jeopardized in all POSs. With the construction of Emergency Control Room (ECR) as an Alternative Shutdown location and DEC systems/equipment installed (AAF, ASI, ARHR and ASFP), Krško NPP has sufficient diversification and redundancy to respond to any probable Fire event. Safety Upgrade Project implemented as a Krško NPP response to the Post Fukushima event result in highest improvement to the Plant safety. Fire analysis shows that even for the most critical locations and fire areas (e.g., MCR, cable spreading rooms), where fire could disable both trains of several safety systems, NPP Krško has solutions in place in terms of using alternative safety related equipment, which is physically and electrically separated from the main safety systems and fire areas. Some of those alternate solutions need more time to implement (e.g., establishing ARHR cooling with a mobile pump HS450, in case of disabled support systems, i.e., CC/SW), and for the POSs with reduced inventory, when time to boil can be less than 30 min, other immediate actions are also provided (before a long-term solution is ensured) to maintain the RCS inventory and temperature under the undesirable values. Such immediate actions include gravity feed of borated water from the RWST (by opening two valves), or replenishing the RCS inventory by start of ASI pump with suction from its own borated water tank and opening one motor-operated valve, both performed from the MCR (or ECR).

The main conclusion of the FHA for Shutdown Operational States is that there are no such fire areas, where fire would disable all possible methods to ensure required KSFs. The analysis shows that for every fire area, there is at least one additional solution available with which the required KSFs can be assured.

The FHA for shutdown operational modes is documented in DCM-TD-041 "Deterministic Fire Hazard Analysis of Shutdown Operational Modes" [126].

2.1.4.4 Main results – FHA for Spent Fuel Pool Decay Heat Removal Function

For the FHA of the SFP Cooling Function a conservative assumption was used that the SFP cooling system is failed, because some of the SFP cooling components are not properly separated in terms of fire protection. This assumption is very conservative, especially considering very low amounts of combustible material located in the FHB, fire detection and alarming system, fire suppression means available for manual firefighting, as well as established firefighting procedures and regularly trained firefighting crew. On the other hand, the FHA shows that even such conservative assumption would not result in loosing of the SFP inventory, because the SFP inventory cooling can be maintained despite the loss of the traditional SFP cooling by a wide variety of available make-up systems and with the SFP Alternative Cooling system. It is considered that the need for establishing the SFP Alternative cooling would be initiated in a short time, and time needed for establishing and initializing the SFP Alternative Cooling system with mobile heat exchanger is about 4 hours, as stated in AOP-3.6 REF-3, "Uncontrolled Loss of Level or Cooling in SFP" [46].

In the case that establishing the SFP Alternative cooling for any reason fails, it would be necessary to establish SFP makeup in order to compensate for the evaporation losses. Even if all the normal makeup means fail, the alternative means would be available, for SFP makeup or spraying. In the case that normal makeup cannot be established by any means, the SFP level would continue to further decrease due to evaporation losses and operators would be instructed to proceed to AESP-3.11.011, "Alternate SFP Makeup and Cooling", Attachment 2 [47]. This procedure provides instructions for SFP makeup using three different methods, depending primarily on the SFP level.

Details of analysis is presented in the document DCM-TD-038 "Fire Hazard Analysis for Spent Fuel Heat Decay Removal function" [57].

Figure 13: Mobile Spent Fuel Pit Heat Exchanger

2.1.4.5 Main results – Analysis of Combination of Fire and Other Events

For credible combination of fire and other events consequences are analyzed. For combination which could jeopardize safe shutdown of the plant, the SFP decay heat removal 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 the environment as presented in the document DCM-TD-040 "Deterministic Analysis of Combinations of Fire and Other Events" [91].

The worst case is a combination of an aircraft crash and consequential fire which could affect Spent Fuel Pool in the FHB. Fire and radioactive release mitigation is prescribed in corresponding procedures (FRP-3.9.100 [9], AESP-3.11.011 [47], DCM-TD-037 [111], SAMG-17 [62], EDMG-18.002 [163], EIP series of procedures).

As part of the action plan per B.5.b Order issues by US NRC after 11/9 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. However, the plant needs to be prepared for large fires and loss of some parts of the buildings and associated equipment. As a response, Krško NPP expanded its capability to cope with the large fires by getting new fire protection equipment - special firefighting truck (reservoir with 8500 l of water, 1500 l of foam, water pump 8000 l/min at 10 bar, high pressure water pump 300 l/min at 40 bar, 40 m hydraulic arm) shown on Figure 14, which can reach top of the containment with jet of water, and can spray water over the Spent Fuel Pool in case of SFP damage. All mobile fire protection equipment is per B.5.b stored at the site, approximately 100 m from the containment building. In addition, Krško NPP has:

- developed Extensive Damage Mitigation Guideline (EDMG) set of procedures to deal with loss of building and equipment due to direct impact and fire, and

- prepared and implemented Safety Upgrade Program (SUP) with additional capabilities to inject borated water into reactor and un-borated water into steam generators.

Figure 14: Special Firefighting Truck

2.1.4.6 Main results – FHA for Heating, Ventilation and A/C Systems

Based on the evaluation performed in the HVAC evaluation DCM-TD-039 [120], most of HVAC systems redundant trains are located in separate fire areas, their ventilation ducts are routed per separated fire areas and power sources, as well as power cables and control cables are also properly separated, therefore in case of fire in any of the fire area where the system's components are located, the fire event can affect only one train of the corresponding system, while the other train will perform its function. There are also some fire areas and the HVAC systems whose redundant trains are not properly separated; i.e. both redundant trains' equipment and power sources are located in the same fire area, and those deviations have already been identified in FHA [3] and strategies for dealing with those situations are prescribed in corresponding procedures. The worst cases are fire events in MCR and Cable Spreading Areas, which affect most HVAC systems as well as all other systems, and actions in these situations are prescribed in the corresponding procedures (AOP-3.6.INS-3 [10], EEOP EECA-0.0 [162]).

The MCR HVAC system is designed as a redundant, safety, seismically qualified system which is energized (each train) from independent safety power bus. Loss of MCR HVAC will not adversely affect MCR habitability for the coping duration of four hours, however, MCR cabinets of the Instrumentation and Process Control systems shall be timely opened to prevent excessive temperature rise. In case of fire in the MCR (CB-1 fire area) or Cable Spreading Area (CB-2 fire area, below the MCR), which can affect not only HVAC systems, but all others as well, fire protection system would activate the fire alarms, followed by the execution of steps in accordance with NE Krško procedures. If the fire is not extinguished and/or starts to spread through the whole CB-1 or CB-2 fire areas, it would be necessary to perform manual reactor trip in the MCR and evacuate MCR in accordance with AOP-3.6.INS-3 [10] procedure. After the MCR evacuation, Emergency Control Room (ECR) ensures the plant capability for the Remote Shutdown and Remote Plant Cooldown to Cold Shutdown, after the transfer of the controls from the MCR to the ECR have been performed on the transfer panels. The HVAC system that is provided for ECR, as well as for all ECR support systems, will perform their safety function, since they are independent of the HVAC system affected by fire in the MCR or Cable Spreading Area, and fire event cannot disable both locations simultaneously, i.e. this alternative shutdown location (ECR) is remote from the MCR, and simultaneous inability of both locations is not credible. Procedures are in place to provide guidelines for these actions [10].

The worst case can be conservatively considered for fire event in Cable Spreading Area (CB-4 fire area), which affects both trains of HVAC system, as well as other systems, which will be lost due to loss of the main switchgear (MD1 and MD2), located in the Switchgear Rooms - area above this Cable Spreading Area. In this case the most systems necessary for normal operation and for Safe Shutdown will be lost and further actions would be performed in accordance with AOP-3.6.INS-3 [10] and EEOP EECA-0.0 [162], where the alternative strategy for the Safe Plant Shutdown and Cooldown in the case of loss of both trains switchgear is described. Since the main switchgears would be lost, the power supply would be provided from DG3 in "ISLAND" mode of operation, which would be isolated from all other electrical distribution network on the site, and it would only supply MD3 bus loads (alternative safety systems). Since the DG3 is located in a separate building, the fire event cannot disable both buildings simultaneously.

More details of these scenarios are given in Section 3.3.2 and in a separate HVAC evaluation DCM-TD-039 [120].

2.1.4.7 FHA Results Procedures Integration

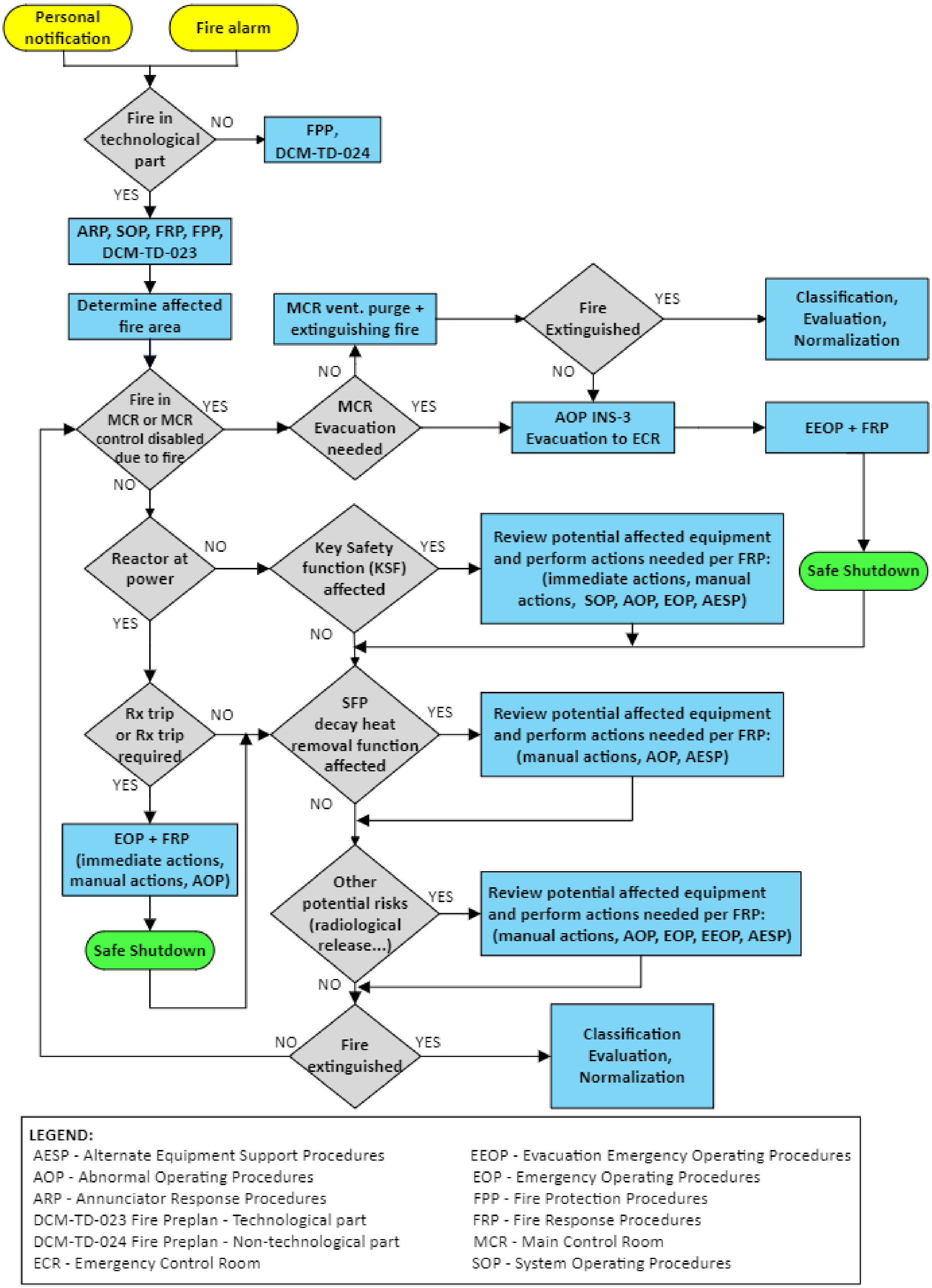
The procedures and the validation of the procedure on the simulator prove the existing systems with the combination of SUP installed additional system to ensure that fire will not jeopardize the safe operation of the plant and radioactive release in the environment will be prevented. In case of fire, the following procedure will be used to ensure safe shutdown of the plant (Figure 15).

Krško NPP has developed several operating procedures in connection with the Fire Protection (FP) system, from System Operating Procedures (SOP), which describe the operation and handling of the system during normal operation, to Alarm Response Procedures (ARP), which give the operator instructions for taking actions when an individual alarm occurs on the alarm system or on FP SIEMENS fire control station in the MCR. Operators in MCR are also equipped with procedures for the event of fire at the power plant, i.e. the Fire Protection Procedures (FPP) and Fire Response Procedures (FRP). While the FPP procedures give general instructions, directions, expectations of each stakeholder in the fire (fire finder, onsite firefighters, MCR staff, Krško fire department) and includes both the fire in the technological part of the power plant, as well as the non-technological part, the FRP procedures, on the other hand, are developed based on the FHA analyses and cover actions of operators in the fire event in the technological part of the power plant.

In the event of a fire, an alarm occurs in MCR. Operators follow the Alarm response Procedures (ARP) that provide instructions on alarm acknowledgment, provide basic background, immediate steps, and instruct operators to use follow-up procedures. In addition to the alarm, operators in MCR can also receive a direct call from the person who noticed the fire, using standard telephone system, plant paging system or portable radios. In both cases, the ARP procedures or notification via direct call direct them to procedure FPP-3.7.002 "Fire response procedure" [8], which provides instructions, organization of personnel and initial steps necessary in the event of a fire, and procedure FRP-3.9.100 "Operators actions in case of fire in technological part of plant" [9], which provides instructions on how to adjust the operation of the power, depending on the location of the fire.

The FRP-3.9.100 procedure [9] in its appendices for each fire area provides information about the equipment in this area important for the safe shutdown of the power plant, the equipment important for ensuring key safety functions during the shutdown of the power plant, the equipment for assuring the SFP decay heat removal function, and other additional important equipment in the area with different functions than listed above (radioactive releases, ventilation systems, combinations of events). In addition to the listed important equipment in each fire area in the event of a fire, appendices also provide instructions for operators to perform immediate actions and necessary manual actions, as well as instructions for the transition or parallel use of other operating procedures. The Shift Supervisor would decide and apply the instructions according to the development of the fire in the affected fire area. The appendices in the FRP procedures thus serve the operators in MCR as a warning and awareness of which equipment may be affected and how to act in the event that a fire has been developed throughout a fire area (worst-case scenario).

Figure 15: Krško NPP FHA Results Procedures Integration



The first steps of the FRP-3.9.100 procedure [9] are to determine the exact place of the fire based on the activation of alarms in MCR or the message from the person who noticed or identified the fire in the technological part of the power plant. Essential information about the fire from MCR are passed to the firefighters, the field operator of the affected area and is announced through the paging system of the power plant.

According to the priorities set in the FRP procedures, it is first checked whether the fire is in MCR. If there is a fire in MCR, it is necessary to immediately start extinguishing MCR and, by the decision of the Shift Supervisor, use breathing apparatus located just outside MCR and initiate the MCR ventilation purge. In the next step it is checked whether the evacuation of the operators is necessary due to the risk of fire. In case of evacuation, a transition is made to the Abnormal Operating Procedure AOP-3.6.INS-3 "Inability to stay or operate in MCR" [10]. Operators then perform a controlled shutdown of the plant, evacuate MCR, transfer controls from MCR to the Emergency Control Room (ECR) and take control of the plant from ECR and bring the power plant to a safe shutdown state.

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". In the case of loss of both safety trains due to fire event, the power supply would be provided from DG3 in "ISLAND" mode of operation, which would be isolated from all other electrical distribution network on the site, and it would only supply the MD3 bus loads. Since DG3 is located in a separate building, the fire event cannot disable both building simultaneously. MD3 bus in "ISLAND" mode supplies all the DEC equipment (ASI, ARH and AAF) and its instrumentation together with the ECR instrumentation and controls. The EEOP set of procedures can be then used to control that kind of event.

Figure 16: Operators Using Breathing Apparatus in Case of Toxic Atmosphere in Main Control Room (Simulator)

The next step in the procedure is to check whether the power plant is operating at power. If the power plant is operating at power, it is checked whether it is necessary to stop the operation of the reactor due to the risk of fire. This is checked with the help of procedure appendices according to the location of the fire and the development of the fire in the affected fire area. If a shutdown is required, the reactor is manually shut down after the decision of the Shift Supervisor. MCR makes transition into the EOP E-0 "REACTOR TRIP OR SAFETY INJECTION" procedure, where the power plant is safely stopped and stabilized, while the FRP-3.9.100 procedure [9] continues to be used in parallel. The FRP procedure helps the MCR operators with the list of potentially affected equipment and the instructions in the appendices to ensure the safe shutdown of the power plant. If a shutdown is not required or preferred according to the procedure appendices the operators maintain or stabilize the operation of the power plant, continue with fire extinguishing actions, and check the extinguishing success. According to the procedure appendices operators check and if necessary, implement the proposed measures and continue with the next steps of the procedure.

If the power plant is not operating at power, it is necessary to check in the FRP procedure appendices whether the fire in the affected fire area threatens the key safety functions during shutdown (DECAY HEAT REMOVAL, INVENTORY CONTROL, ELECTRICITY, SUPPORT SYSTEMS). If the answer is yes, it is necessary to check the condition of the equipment important for ensuring key safety functions during the shutdown and, depending on the development of the fire and the condition of the KSF equipment, take actions according to the instructions in the FRP procedure appendices (immediate actions, manual actions, parallel transitions to other Abnormal Operating Procedures (AOP), Emergency Operating Procedures (EOP) or Alternative Equipment Support Procedures (AESP)). In the worst-case scenario when decay heat removal (DHR) KSF is compromised, the use of an Alternative Residual Heat Removal Heat Exchanger (ARHR HEX) according to the AESP-3.11.030 procedure "ARH Pump and Heat Exchanger Alternative Cooling" [157] is used together with an Alternative Residual Heat Removal (ARHR) pump in accordance with SOP-3.2.112, Section 6.2.1 "ARH pump start with ARH HEX" [158]. In the event when inventory (INV) KSF is compromised, in the worst-case scenario the procedure would direct the operators to use Alternative Safety Injection (ASI) pump in accordance with EOP-3.5 Appendix 51 "ASI Pump Start" [159] of E-0 series of procedures.

The FRP procedure is followed by a check whether a fire in the affected fire area threatens the SFP decay heat removal function. In the event of a threat, it is necessary to check the equipment important for ensuring SFP decay heat removal function and, depending on the state of the fire, take actions according to the instructions in the procedure appendix (manual actions, parallel transitions to other Abnormal Operating Procedures (AOP), Emergency Operating Procedures (EOP) or Alternative Equipment Support Procedures (AESP)). In the worst-case scenario, if both trains of the SFP cooling system would be disabled, a mobile SFP heat exchanger for cooling the SFP according to the procedure AESP-3.11.011 "Alternative SFP Makeup and Cooling" [47] would be used.

Further, the FRP procedure checks additional equipment in the fire area, which is important due to other potential risks in the event of a fire (radioactive releases, ventilation, combination of events). In the event of a threat to the equipment, it is necessary to check the condition of additional equipment and, depending on the state of the fire, take actions according to the instructions of the procedure appendices (manual actions, parallel transitions to other Abnormal Operating Procedures (AOP), Emergency Operating Procedures (EOP), Evacuation Emergency Operating Procedures (EEOP) or Alternative Equipment Support Procedures (AESP)).

After reviewing actions and equipment for affected area according to the appendices of the procedure, the classification of the emergency event due to a fire in the technological area of the power plant is made in accordance with the procedure EIP-17.001 "Emergency Class Determination" [148]. An evaluation of the damage caused by the fire on the components and rooms of the power plant is carried out. Based on the obtained data and the evaluation of the condition, all damaged equipment is placed in a de-energized state. All resulting Technical Specifications limitations are checked and determined, and appropriate steps are taken as indicated in the actions of individual LCOs (Limiting Conditions of Operation).

In parallel to the above-described procedures, firefighters perform their actions to extinguish fire in coordination with Operations Shift Supervisor. They use Fire plans (DCM-TD-023, "Fire Plan in Krško NPP - Technological Part of the Plant" [83] for technological part of the plant, DCM-TD-024, "Fire Plan in Krško NPP – Non-technological Part of the Plant" [110] for non-technological part of the plant and DCM-TD-037, "Fire Plan in Krško NPP – Large Fires in Plant Area", [111] for large fires in plant area), which contain graphical and textual information about affected area regarding: access routes, firefighting equipment, communication systems, ventilation systems, safety hazards, sensitive equipment, locked door keys and other information related to specific fire area. Separate Fire plans are developed for each fire area in the power plant.

Throughout and during the event, the Operations Shift Supervisor checks the success of the extinguishing with the Firefighter Shift Supervisor. As long as the fire is not extinguished, the MCR staff monitors individual functions and takes actions as necessary in accordance with the FRP procedure appendices. After the fire is successfully extinguished, in agreement with the operational management of the power plant, Shift Supervisor continues with work and actions to restore the normal state of the power plant

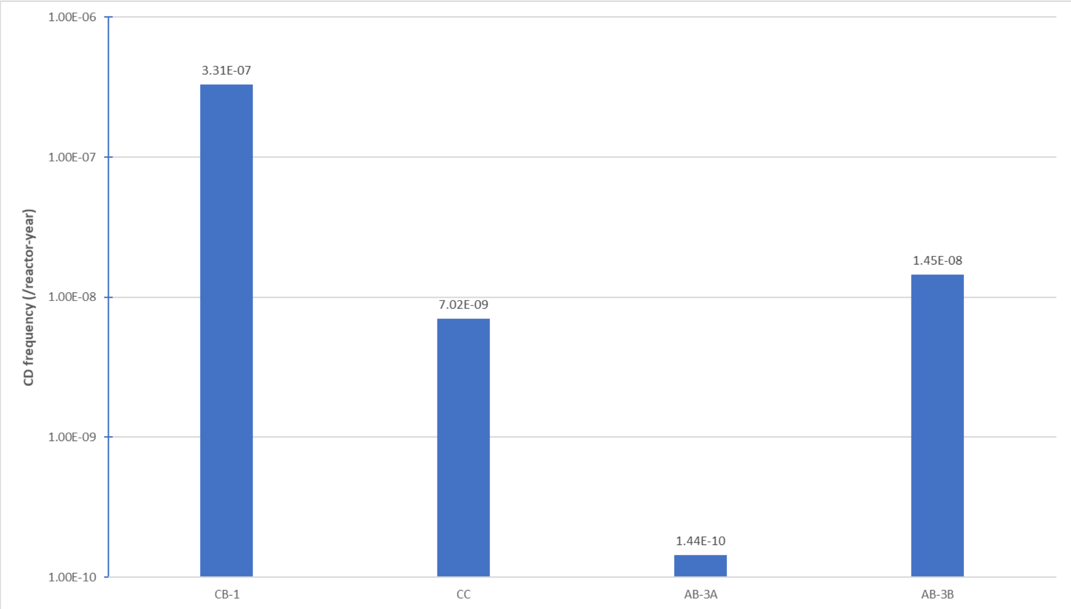
2.1.4.8 Fire Probabilistic Safety Assessment Results

As a conclusion of the work performed above and after two major safety upgrades of the plant (described in separate chapter) the four event trees remained in the PSA model. Event trees model the areas that remained after screening CDF above 1E-07/ry criteria, but due to several model updates, the current risk from fire is as provided below (Figure 17):

Fire area	Core Damage Frequency (/ry)
Control Room (CB-1)	3.31E-07
CC Building (CC)	7.02E-09
Auxiliary Building El. 100.3m (AB-3A*)	1.44E-10
Auxiliary Building El. 100.3m (AB-3B*)	1.45E-08

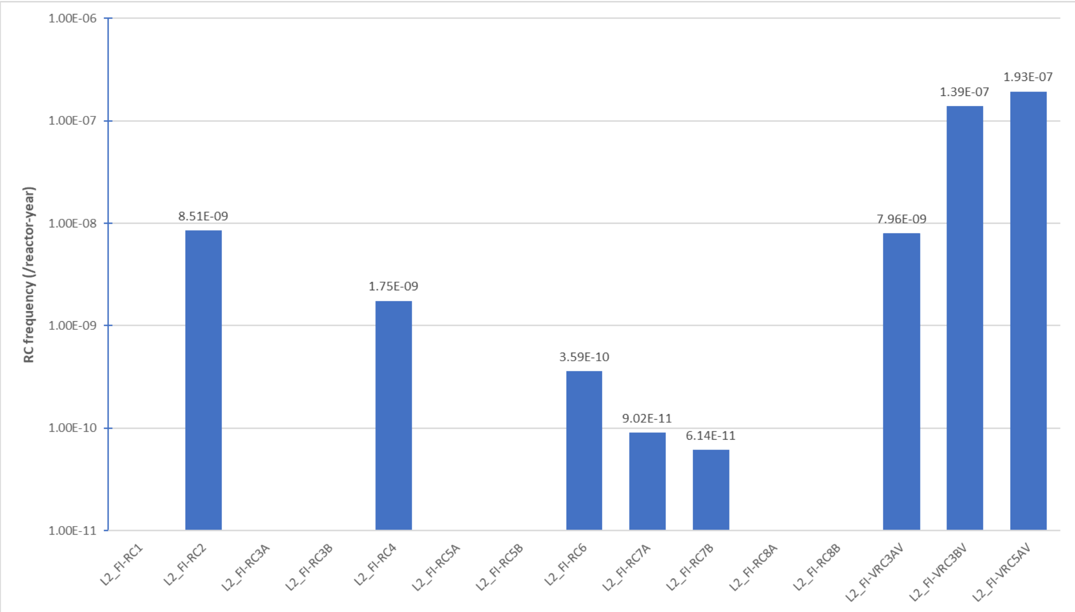
* Train A and Train B fire scenario models

Figure 17: Full Power Fire Core Damage Frequency



As a conclusion of the work performed above and after two major safety upgrades of the plant (described in separate chapter) the release categories frequencies regarding the fire analyses are as follows (Figure 18):

Figure 18: Full Power Fire Release Categories Frequencies



Release Category Definitions for Krško Level 2 PSA are as follows:

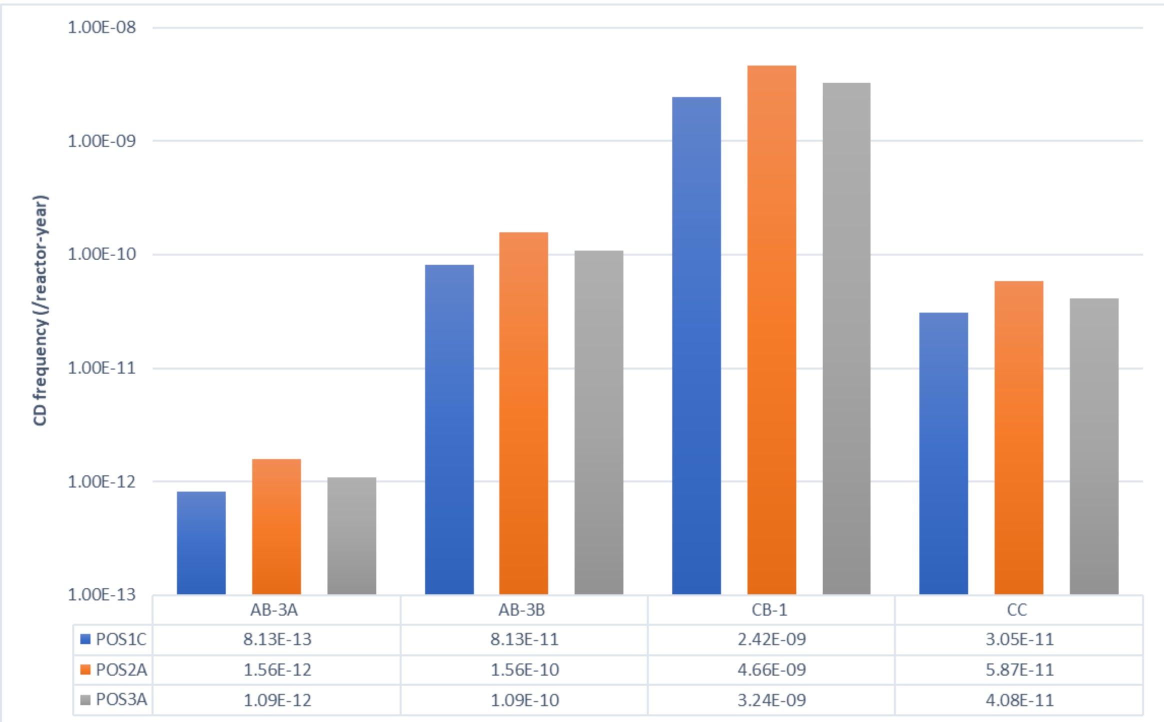
- RC1 Core recovered in-vessel, no containment failure;
- RC2 No containment failure;
- RC3A Late (time frame IV) containment failure, no MCCI;
- RC3B Late (time frame IV) containment failure, MCCI;
- RC4 Basemat penetration (no overpressure failure and no venting);
- RC5A Intermediate (time frame III) containment failure, no MCCI;
- RC5B Intermediate (time frame III) containment failure, MCCI;
- RC6 Early (time frame I or II) containment failure;
- RC7A Isolation failure, no MCCI;
- RC7B Isolation failure, MCCI;
- RC8A Bypass, scrubbed;
- RC8B Bypass, unscrubbed;
- RC3AV Late (time frame IV) containment failure, no MCCI, filtered release;
- RC3BV Late (time frame IV) containment failure, MCCI, filtered release;
- RC5AV Intermediate (time frame III) containment failure, no MCCI, filtered release;
- RC5BV Intermediate (time frame III) containment failure, MCCI, filtered release.

Note: MCCI stands for molten core-concrete interaction.

Among them, release categories' frequencies RC6, RC7A, RC7B, RC8A and RC8B cumulatively represent the Large Early Release Frequency (LERF).

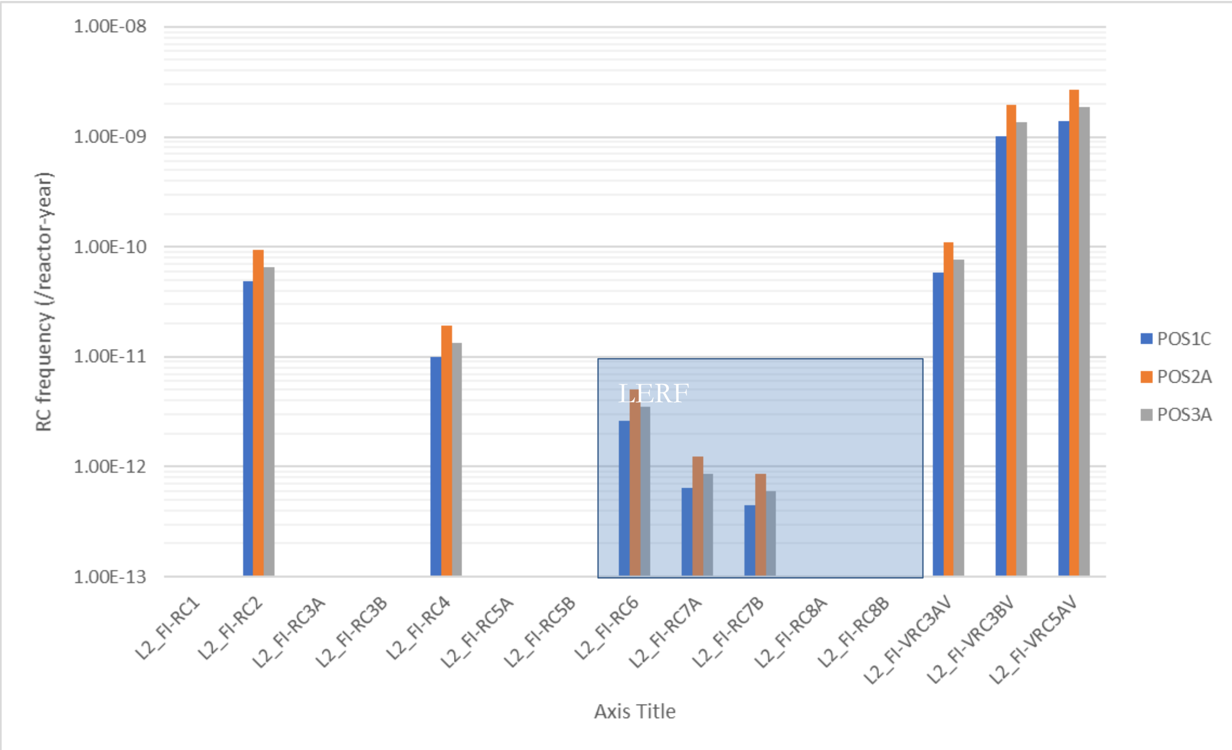
Low power operation modes core damage frequencies for fire events in above defined Plant Operating States (POS) are as follows (Figure 19), below.

Figure 19: Low Power Fire Core Damage Frequency



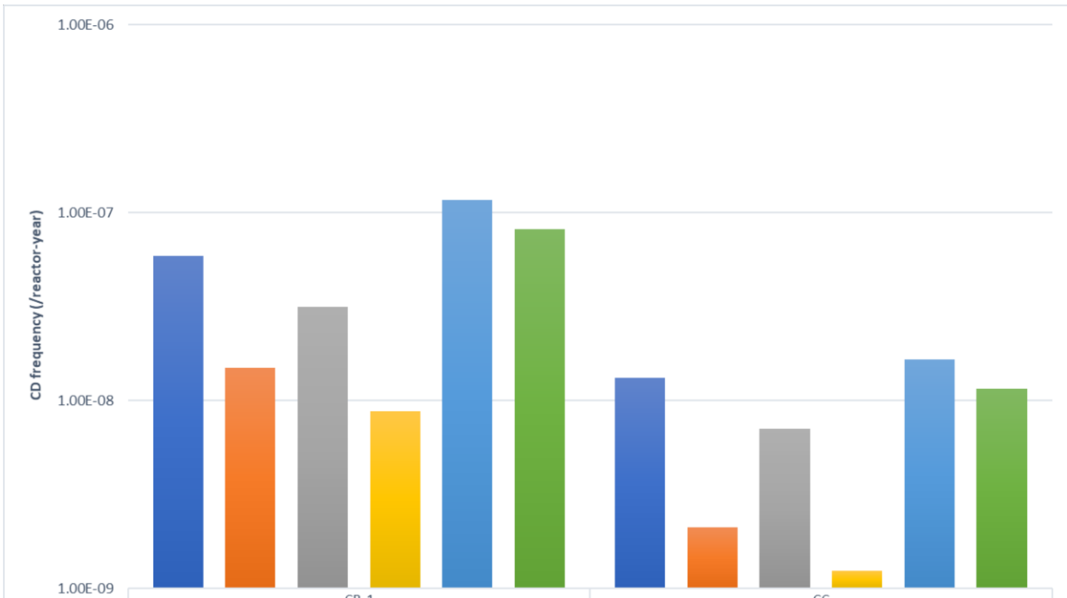
Associated low power release categories' frequencies for Level 2 fire events are presented in Figure 20 below.

Figure 20: Low Power Fire Release Categories Frequencies



Shutdown core damage frequencies for fire events in above defined plant operating states (POS) are as follows (Table 6).

Table 6: Shutdown Fire Core Damage Frequency



	CB-1	CC
POS5A	5.87E-08	1.31E-08
POS5B	1.49E-08	2.11E-09
POS5C	3.16E-08	7.08E-09
POS6A	8.77E-09	1.24E-09
POS6B	1.17E-07	1.66E-08
POS6C	8.15E-08	1.15E-08

For the loss of core cooling scenarios during shutdown the evaporation times are mostly long. Therefore, the sequences induced by the internal fires are not considered to be relevant contributors to LERF and can be mapped to late releases.

2.1.4.9 The Most Important Accident Sequencies from Fire PSA

2.1.4.9.1 Fire in Main Control Room

The control room, visitor's gallery, office and cable spreading area above the suspended ceiling are all contained within the same fire area. The cabling for control room cabinets passes directly from the cabinets through the floor to the safety-related cable spreading room below. This area is equipped with ceiling and in-cabinet smoke detectors. Portable extinguishers and breathing apparatus are also located in this area. Fire brigade and operator self-contained breathing apparatus gear are located in the turbine building hall just outside the control room entrance. Two hose stations are located in the southeast stair tower and one on the heater bay operating floor to the north for manual firefighting. The combustible loading in this area is primarily from paper, cabling, cabinets, plastics and transient combustibles.

This area contains the main control benchboard, ventilation control board, nuclear instrument racks, auxiliary relay racks, safeguards actuation panels, protection system cabinets, process instrument and control racks, and numerous other panels and racks. None of the nine control room fires in the available international experience database [168] led to abandonment of the control room, and damage has been extremely limited within the cabinet of initiation. Because of the cabinet configuration within the Krško NPP control room and based on the SNL cabinet fire tests [5], the postulated fire was assumed not to spread and damage any components outside the cabinet where the initiation occurred. At Krško NPP the cabinets have enclosed backs and tops. In the SNL cabinet fire tests, cabinets had open backs and enclosed tops. Even in this configuration fire did not spread to adjacent cabinets.

According to fire protection procedure [8], firefighters would response to fire and according to fire response procedure [9], operators would first check the need to trip the reactor. Later, during a fire, operators would continuously check if evacuation is necessary [9]. In the event that evacuation is necessary, the evacuation is performed according to the procedure for leaving the control room [10].

Evaluated fire scenario assumes abandonment of the control room due to smoke generated from a cabinet fire. Not all fires would result in abandonment of the MCR, therefore credit was given for quick extinguishment of the fire since the control room is continually manned. Control room operators have access to air packs and are trained in their use. In case of need for MCR abandonment, operator recovery of the plant from the emergency control room, was credited consistently with the NUREG-1150 fire analyses [7].

When migration to ECR is initiated, some of the controls are transferred to the ECR. The remaining control cables could, due to fire, cause spurious actuations of the remaining MCR controlled equipment. Therefore, according to the procedure for leaving the control room [10], controls of some equipment are switched over to ECR and remaining equipment is deenergized to disable the following, otherwise possible consequences of spurious actuations:

1. Loss of power supply
2. Loss of train separations
3. Loss of RCS integrity
4. Loss of containment isolation
5. Loss of other safety features

All the above-mentioned operator actions and responses of the plant shutdown and long-term cooling systems are modelled in response to a fire in the control room.

2.1.4.9.2 Fire in Auxiliary Building

Fire Area AB-3 is at grade level on the 100.3 m elevation and includes an intermediate level above the south half of the area on the 103.7 m elevation, which is the filter cask removal and cable spreading area. The ventilation system includes duct smoke detectors. Hose stations and portable fire extinguishers are located in the area for manual firefighting.

Critical equipment located in this area are some of the safety 400 V motor control centers (MCCs). Also located in the area are cabling for many components cooling (CC) valves, containment spray (CI) valves, chemical and volume control (CS) valves, safety injection (SI) valves, residual heat removal (RH) valves, ventilation and air conditioning (VA) valves, CC instrumentation, RH instrumentation, ventilation (VA) air handling units, makeup (MW) pumps (A, B), CI and RH room coolers, and 125 V DC distribution panel.

Two fire types were modelled for each scenario: one of which was a transient combustible located in proximity to the critical cable runs; and second, fixed combustible fires.

Train A Scenario: there are many potential fixed combustible fire sources in this part of the area, including:

1. Train A motor control centers
2. Hydrogen recombiner power supply
3. Waste evaporator control panel
4. Recycle evaporator control panel

Train A electrical motor control centers (MCC safety electrical distribution) powering several safety components are damaged due to fire. The first response after fire is reactor trip. Next, safety function is to establish secondary cooling and preserve the primary inventory. Additionally, design extension conditions systems (DEC) can support primary and secondary injection and recirculation.

Train B Scenario: source of fire is train B electrical motor control center (MCC safety electrical distribution) powering several safety components. The first response after fire is reactor trip. Next, safety function is to establish high pressure safety injection. After that safety function is to establish secondary cooling and preserve the primary inventory. Additionally, design extension conditions systems (DEC) can support primary and secondary injection and recirculation.

Both scenarios are separately modelled in the PSA model with initiators and responses of the plant shutdown and long-term cooling systems.

2.1.4.9.3 Fire in Component Cooling Building

Fire Area CC is a two-level structure (one at grade level and one below grade) and is divided into three fire zones. Since these fire zones are not totally isolated from one another, this building has been treated as one fire area.

This area has an area-wide smoke detector system. Portable fire extinguishers and hose stations are located on the ground floor and basement areas for manual firefighting. The combustible loading in this area is primarily from fire-resistant wood panelling, plastics, cabling, paper and 122 liters of lube oil.

The critical equipment located in the area are the component cooling (CC) pumps, component cooling/service water (CC/SW) evacuation panel, and makeup (MW) pumps. Also, cabling located in this area are for the CC valves, SW valves, CC instrumentation and SW pumps (A, B and C).

One fire scenario based on a loss of CC remained after screening. This involved fire damage to the CC pumps A and B. The first response after fire is reactor trip. Next, safety function is to establish secondary cooling, primary cooldown and preserve the primary inventory. Additionally, design extension conditions systems (DEC) can support primary and secondary injection and recirculation.

The scenario is modelled in the PSA model with initiator and responses of the plant shutdown and long-term cooling systems.

2.1.4.10 The Most Important Accident Sequencies from Spent Fuel Pool

2.1.4.10.1 Spent Fuel Uncovery Risk Assessment

A SFP fuel uncovering risk is assessed by means of the event tree. Fire event is assumed to fail the SFP cooling function in a manner that it cannot be recovered before the SFP boiling starts. In order to prevent the fuel uncovering, the SFP makeup is needed either by normal or alternative methods.

The overall contribution of internal fire hazard to the frequency of spent fuel uncover was assessed as 7.5E-09/yr, taking into account the SFP fire risk assessment and 10 plant areas where a fire can induce a total and non-recoverable loss of the SFP cooling.

2.1.4.10.2 Risk from Release of Fission Products from SFP Due to Fire Hazards ("Level 2" SFP PSA)

Spent fuel pool related scenarios induced by internal fires would lead to a loss of SFP cooling. No credible scenario was identified which would result in a loss of the SFP inventory (the loss of the SFP inventory as an initiator category was addressed and quantified separately in IIE SFP PSA [35]).

For the loss of the SFP cooling scenarios the evaporation times are very long. Therefore, the sequences induced by the internal fires and internal floods are not considered to be relevant contributors to LERF and are all mapped to late releases (any release after 4 hours is considered as late release).

2.1.4.11 Combinations of Events with Fire Events

In revision 1 of analysis [23], SNSA comments were addressed, MCR to ECR HRA for transfer of controls was evaluated, and fire spreading between the fire areas was addressed.

Previous very dominant CDF from fire in the control room was 1.08E-05 /ry. New, updated CDF for a fire in the control room with the ECR capability is 3.31E-07/ry. Even with significantly lower CDF, fire in control room is still most important contributor in fire CDF.

Krško NPP has decided to implement plant Safety Upgrade Program (SUP) to increase plant safety. It was confirmed that after SUP implementation, no mobile equipment is needed to resolve safety concerns regarding the combinations of fire with other events. However, for the Alternative RHR long-term cooling, that was implemented in SUP, one of the operation modes is planned as partially including mobile equipment.

2.1.4.12 The Most Important Accident Sequencies from Dry Storage

Results of risk from dry storage is presented in Chapter 2.4.

2.1.4.13 Contribution of Fire Events to Overall PSA Results

In the tables (Table 7, Table 8 and Table 9) and Figure 21 below, the contribution of the fire events to the overall PSA results is presented.

Comparison of the results among POS is difficult (Table 7) because different assumptions and different level of conservatism are applied to each POS. Similarly, the difference between power PSA results and shutdown PSA results are difficult and needs to be taken with care. One should note the objectives of PSA are much wider than looking only to the quantified values of core damage frequency.

The results show that Krško NPP POS with closed reactor head (POS5A and POS5C) are related with dominant contribution from internal initiators.

The CCW system is identified as an important system in POS5B and POS6B, although the core damage frequencies are low, but the most of the important minimal cut sets are related with it.

All states and especially those with open reactor coolant system rely significantly on the operator actions. The human reliability analysis plays a dominant role in the low power in shutdown states. This is shown by the results of the analysis.

Table 7: 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%

The fire CDF in shutdown states (POS5 and POS6) is considered overestimated. According to the planned PSA update, shutdown states will be also updated. Additionally, information from fire hazard analysis for shutdown states will be considered.

For spent fuel (Table 8), the dominant risk is assigned to seismic risk and operator actions. As fire would affect heat removal function and due to a large amount of cooling water, all effects evolve rather slow. Therefore, risk due to fire is very low compared to total spent fuel uncover frequency.

Table 8: 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%

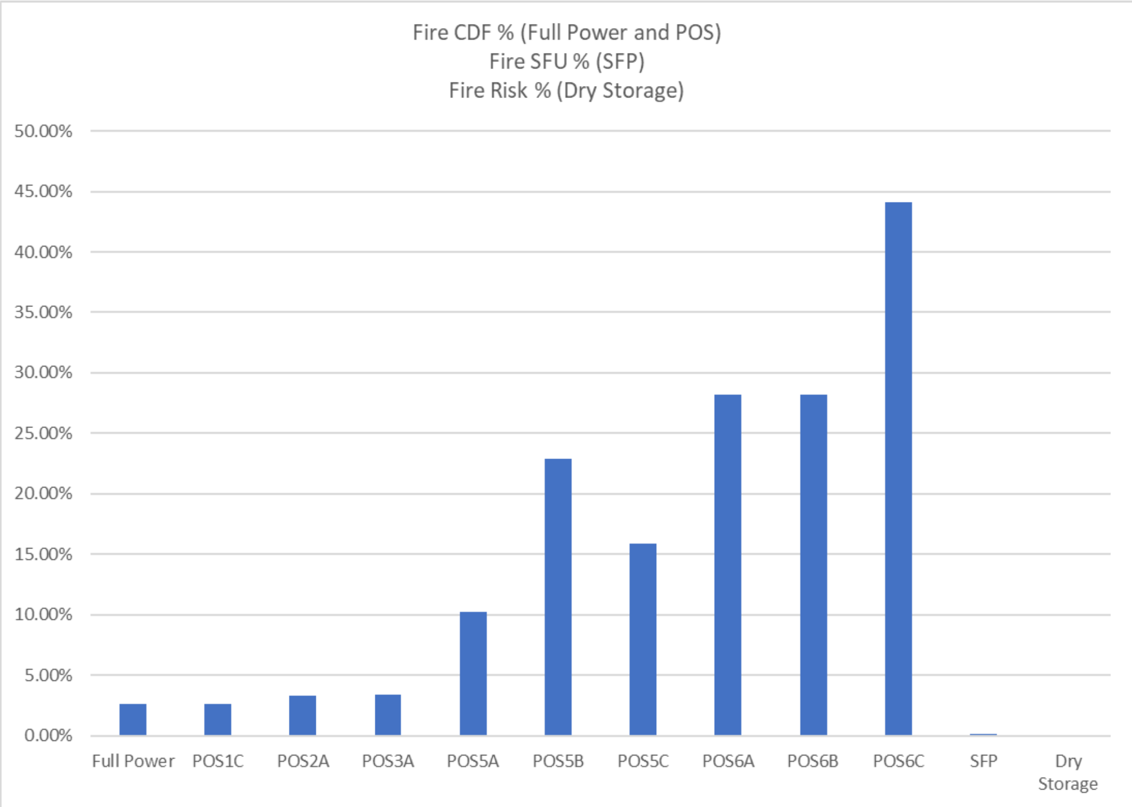
* SFU: Spent Fuel Uncovery

Dry storage risk from fire is bounded by fire from aircraft accident. Risk, assigned solely to fire origin is analysed as negligible (Table 9).

Table 9: 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%

Figure 21: Contribution of Fire Events to Overall PSA Results



2.1.5 Periodic review and management of changes

Review and Update of FHA Analyses

In accordance with Slovenian regulations "Pravilnik o dejavnikih sevalne in jedrske varnosti - JV5" [21], Fire Hazard Analysis should be updated after every major change or at least every two years.

Update of the FHA Analysis integrates all changes which influence Fire Protection Program (organizational changes, administrative changes, new firefighting equipment, modifications). Evaluation of modification impacts to FHA is performed in accordance with procedure ESP-2.624 "Design Impact Evaluation" [131].

A review of implications for Fire Protection Program is carried out for the following changes (modifications) to the plant, including design changes:

- modifications that affect any fire protection equipment (sprinklers, fire hose, hydrants, fire detectors);
- modifications that increase the probability for fire initiation or propagation;
- modifications that affect emergency lighting;
- modification that affect communication equipment;
- modifications that could adversely affect safe shutdown of the plant in case of fire;
- modifications that improve fire protection;
- modifications that could jeopardize manual firefighting efforts;
- modification that could affect access or escape routes;
- modifications that changes cable penetrations: leading to fire or smoke spreading barrier changes;
- modification that increase combustible loading;
- any other modification that could adversely affect the performance of the fire protection features.

Regular Review and Update of PSA Analyses

Krško NPP developed its Fire Probabilistic Safety Analysis (PSA) together with the rest of its PSA already in the 1990's. The Fire PSA was developed based on at the time valid standards and international practice. Since the Krško NPP PSA is a living process, the Fire PSA was updated occasionally to consider major upgrades in the plant (e.g. Fire Protection Action Plan improvements, Installation of Emergency Control Room). However, the Krško NPP Fire PSA was not updated to take into account the development of standards and practice in this area.

To mitigate the fire risk, presented with the Fire PSA results, Fire Protection Action Plan (FPAP) [12] was initiated in the '90s. Within this program, plant fire safety was crucially increased by plant fire protection upgrade. Consequently, fire PSA analyses were updated to reflect plant changes [13].

In 2013, the Safety Upgrade Program (SUP) started at Krško NPP with installation of passive autocatalytic recombiners and passive containment filtered vent system. Later, the dedicated primary and secondary DEC cooling trains were added to the plant, embedded in the bunker building. Dedicated diesel generator is available for the DEC systems also embedded in separate bunkered building together with the Emergency Control Room (ECR). Additionally, alternative means for spent fuel cooling were added. Consequently, also upgrade of PSA analyses and model will be performed. To prepare the foundation for fire PSA update, Krško NPP and SNSA initiated the fire PSA expert mission that was coordinated by the IAEA agency with reputable fire PSA experts. In 2020, the review was documented in the review report [11], that highlighted areas of potential improvement for upgrading the Krško NPP Fire PSA. As the plant was also preparing for the third PSR review, it has been agreed with SNSA that the results of this review will be considered as part of the PSR3 review and the update of the fire PSA will be carried out in the PSR3 action plan that is currently prepared and the first actions are already in implementation.

Periodic Safety Review

The Periodic Safety Review (PSR) is a systematic safety reassessment, which has attained international recognition as a primary means to assess the cumulative effects of plant aging and plant modifications, operating experience, technical developments and siting aspects. In the current, internationally accepted, safety philosophy PSRs are comprehensive reviews aimed at the verification that an operating NPP remains safe when judged against current safety objectives and practices and that adequate arrangements are in place to maintain an acceptable level of safety. The fire analyses are reviewed in the Hazard Analyses review and Safety Analyses review safety factors.

Krško NPP (NEK) undertook the 1st PSR following approximately twenty years of plant operation, starting in 2001 [14]. As a result, it was found that Krško NPP could safely operate, as a minimum up to the completion of the next Periodic Safety Review.

The 2nd NEK PSR project started in 2010. The scope of the 2nd Krško NPP PSR was defined in the program document [15] in terms of safety factors. The 15 PSR safety factors have been selected. The outcome of the review was a list of safety issues for every relevant safety factor documented in thematical safety factor reports.

Currently, the 3rd NEK PSR is in progress, initiated in 2020. The scope of the 3rd Krško NPP PSR was defined in the program document [16] in terms of safety factors: SSG-25 [17] (Safety Factors in a Periodic Safety Review) and SNSA's practical guidelines (Praktične Smernice, Vsebina in obseg občasnega varnostnega pregleda sevalnega ali jedrskega objekta, PS 1.01, Izdaja 2, 2020) [18]. The outcome of the review is a list of safety issues for every relevant safety factor documented in thematical safety factor reports.

As presented in the previous chapter, one of the actions from the PSR3 is also fire PSA update, that has two main origins in:

- plant upgrade program; and
- development of standards and practice after the Krško NPP fire PSA implementation.

2.1.5.1 Overview of actions

Fire Protection Action Plan (FPAP)

The Fire Protection Action Plan [12] prioritized proposed fire protection modifications contained in the Nuclear Power Plant Krško Fire Hazards Analysis–Safe Shutdown Separation Analysis, the International Commission for an Independent Safety Assessment Analysis of Core Damage Frequency Due to Fire at the Krško Nuclear Power Plant [19] and the IPERS reports [20] using a risk-based approach which provided a timely reduction of the probabilistically significant contributors to fire-induced core damage frequency.

It was found that implementation of Appendix R [43] separation guidelines led to approximately one order of magnitude reduction in fire-induced core damage frequency at the United States light water reactors. While Appendix R implementation has been found to substantially reduce fire risk on a plant-wide basis, most plant fire areas at Krško NPP have sufficient redundant methods of safe shutdown (i.e., critical safety-related equipment located in other plant areas). Therefore, Appendix R compliance is required in limited plant areas if the only goal is to accomplish low fire risk.

The prioritization method ranked proposed modifications for a fire area into the following three categories:

1. Category 1 – core damage frequency > 1.00E-6/ry and the proposed modification(s) meets the cost benefit ratio criteria of < U.S. $1,000/person-rem reduction to implement;
2. Category 2 – core damage frequency > 1.00E-6/ry and the proposed modification(s) exceeds the cost benefit ratio criteria of < U.S. $1,000/person-rem reduction to implement;
3. Category 3 – core damage frequency < 1.00E-6/ry.

A core damage frequency contribution of 1.00E-6/ry from a functional accident sequence (a combination of an initiating event together with functional failures resulting in core damage) meets the US NRC reporting criteria for Individual Plant Examination of External Events analyses. Functional accident sequences with frequencies less than 1.00E-6/ry were deemed to be insignificant contributors to risk. The cost benefit ratio of US $1,000/person-rem is the US NRC regulatory value used in back-fit rule calculations and also is employed for evaluating generic and unresolved safety issues:

1. For Category 1, the modifications are highly recommended to be implemented as soon as funding and resources are available;
2. For Category 2, the modifications should be scheduled following completion of Category 1 modifications;
3. For Category 3, the modifications are not significant contributors to fire-induced core damage frequency and should be considered for exemption from implementation.

The Fire Protection Action Plan has made full use of the Level 1 and Level 2 Fire PSA analyses. A partial Level 3 analysis has been performed to obtain risk estimates for the Category 2 fire areas (since no Category 1 fire areas were found at Krško NPP). A costing analysis has been performed utilizing methods similar to what had been employed in the US NRC Generic Issue 57 resolution study.

National Legislation

Several Slovenian regulations prescribe how a nuclear facility should be managed and also prescribe elements of safety. These regulations also include requirements on the use, quality and extent of safety analyses.

Krško NPP meets the requirements of the Slovenian legislation (ref. [21], [22] and others), and therefore Krško NPP has PSA models for all relevant events and all operating states of the power plant. Krško NPP has a PSA model for the SFP and an analysis for the spent fuel dry storage.

In addition, an update of the PSA model for spent fuel in terms of external events is currently underway, as Krško NPP managed to obtain a fragility study for the spent fuel pool and PSA modelling of the results is underway. Fire PSA analyses for the SFP are also documented in the same report. At the same time as the seismic model is updated, the PSA analyses for all events are also updated with the latest status of the Krško NPP Safety Upgrade Program (SUP).

In accordance with the legislation, the Krško NPP also has a Level 2 PSA model for all suitable and reasonable conditions [22] of the power plant.

International Legislation and Standards

Several standards and guides prescribe elements of safety. Krško NPP follows the US ANSI/ANS standards, EPRI guides, US NRC Regulatory Guides, WENRA documents and reference levels, and IAEA documents and guides.

Krško NPP's Safety Upgrade Program (SUP)

Krško NPP's Safety Upgrade Program overview is presented in Chapter 1.1.1.1.

2.1.5.2 Implementation Status of Modification/Changes

2.1.5.2.1 Important FP Modifications Implemented since 1991 to 2021

Safe shutdown analysis first performed in 1991, in accordance with 10 CFR 50 App. R [43] resulted in several discrepancies. It was recognized that several fire areas did not fulfill App. R requirements to protect at least one train of equipment needed to shutdown the plant in case of fire.

Krško NPP developed the resolution of these findings and discrepancies that have been discussed and proposed in "NE Krško Fire Protection Action Plan" (Revision 2, April 1998) [12], and performed plant modifications that resolved the issues. A group of modifications have been implemented (fire areas: CB-1 (MCR), AB-9, SW and CB-3A), screened by their importance to CDF (>10E-6) – Category 2 fire areas. The additional re-evaluation has been performed after these implemented modifications within the NEK ESD/TR-23/09 "NE Krško Fire Protection Plan Update" [13] assessment document.

Modifications for most critical fire areas (the ones which most significantly reduced fire CDF) were performed between 1998-2021 and are as follows:

- Main Control Room (Fire Area CB-1) modification

  In case of fire in the Main Control Room (MCR), substantial safe shutdown equipment could be jeopardized. The modification was performed to ensure independent way to bring the plant to hot shutdown mode from local evacuation panels. Double fusing (isolation) of circuit paths was performed for critical components necessary for plant operation during hot standby and cold shutdown to ensure plant control from evacuation panels during MCR evacuation. Also, wide range RCS temperature (TE-413), and control of secondary pressure with PORV PCV-655A were added to the one of the evacuation panels to ensure operational control (verification of natural circulation and pressure control) of RCS. Additionally, the RCS pressure indication (PI406B) and SG1 level indication (LI518A) were added to the evacuation panels. This modification provided the capability to bring the plant in the cold shutdown mode from the evacuation panels.

- Auxiliary Building el. 94 (Fire Area AB-9) modification

  To provide one train of safe shutdown equipment free from fire in case of fire in the fire area AB-9, one train of redundant cables was wrapped with one-hour fire rating barrier and fixed automatic fire suppression system was installed in the area.

Figure 22: Wrapped Cables in Auxiliary Building

- Service Water Pumps Room (Fire Area SW) modification

  The potential for damage to SW pump A in case of fire was minimized since its cables were protected with one-hour cable wraps and a wet pipe sprinkler system in fire zone SW-1 was installed. In addition, a heat shield was installed between SW pump A and C.

Figure 23: Fire Barrier between Service Water Pumps

- Switchgear room Train A (Fire Area CB-3A) modification

  In this fire area eight cables of redundant safe shutdown train equipment were rerouted outside the area.

Based on those modifications, fire PSA analyses [5] and FPAP program [12], [13] were updated to reflect the new status of those areas in the fire analyses.

2.1.5.2.2 Safety Upgrade Program (SUP)

Additional important set of modifications in general, but also with regards to fire safety, were included within the Krško NPP's Safety Upgrade Program (SUP) described in chapter 1.1.2, which was implemented between 2013-2022. The following SUP modifications contributed the most to the enhancement of the Krško NPP fire safety:

- Diesel generator 3 (completed in 2012)

  New diesel generator DG3 was installed in the new bunkered building 1 (BB1). Diesel generator DG3 serves as an alternate AC source to the plant in case of a total loss of on-site or off-site electrical power or as a substitute to the existing plant emergency diesel generators DG1 or DG2. Additionally, to provide adequate separation, train A cables from DG3 to emergency bus MD1 were wrapped in 3-hour barrier in one of the fire areas (IB-11).

  With the SUP implementation, DG3 got a new function in managing of DEC and/or beyond-design accidents, the so-called "ISLAND" mode. In "ISLAND" mode of operation, DG3 would be isolated from all other electrical distribution networks on the site, and it would only supply MD3 bus loads. Since DG3 is located in a separate building, a fire event cannot disable both buildings simultaneously. MD3 bus in "ISLAND" mode supplies all DEC equipment with its instrumentation and control (ASI, ARH and AAF) together with ECR instrumentation and control.

Figure 24: Bunkered Building and Emergency Diesel Generator 3

- Emergency Control Room (completed in 2018)

  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.

  ECR ensures remote/alternate shutdown of the plant, with controls and indications capable of operation independent of the MCR and/or cable spreading area in the Control Building. Switching of necessary controls from MCR operation to ECR operation is done by switches on Transfer Panels, located in switchgear rooms in the Control Building el.107.62. Necessary indications for alternate plant shutdown are provided by independent redundant instrumentation.

- Spent Fuel Pool (SFP) Alternative Cooling System (completed in 2020)

SFP alternative cooling system is designed and structured in accordance with (DEC) requirements specific for the Krško NPP. SFP alternate cooling design function is to:

- Enable alternative cooling of spent fuel by use of Mobile Heat Exchanger (MHX);
- Enable alternative cooling of spent fuel by use of spray system;
- Enable depressurization of the Fuel Handling Building (FHB).

The SFP alternative cooling system with MHX is designed to remove decay heat (capacity of 8.4 MW) from the SFP and can be used for cooling SFP in the case of loss of cooling (SFP pump or SFP-related piping or SFP-related CCW system failure) if SFP integrity has not been jeopardized. The SFP alternative cooling system with MHX is designed as a stand-alone system and it can be operated complete independent of other systems, including the existing SFP Cooling system located in the FHB.

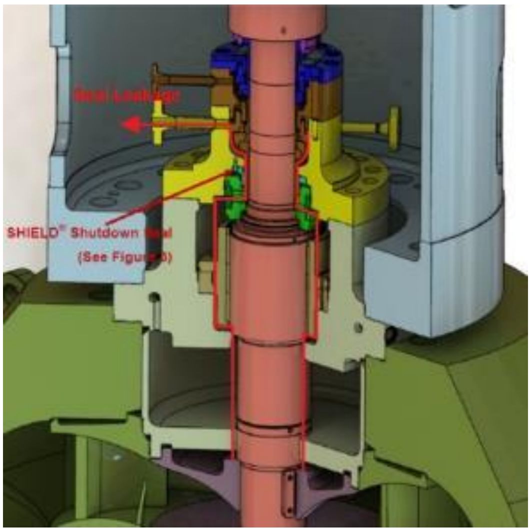
The SFP Spray system can be used in case of an accident where the SFP is drained or partially drained. With the spray system a clad temperature lower than 400 °C for spent fuel elements can be maintained. The SFP spray header consists of piping and permanently installed 12 spray nozzles. The SFP spray header installed along the north and south SFP walls, elevation 115.55, is fixed along the edge of the SFP wall.

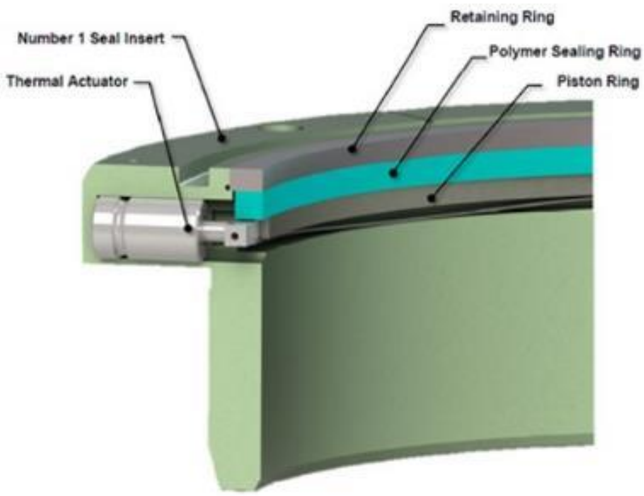
FHB Depressurization system provides protection of the FHB against overpressure and maintain its physical integrity. Pressure increase in the FHB could occur in case of evaporation of SFP water.

- Installation of High Temperature Seals (HTS) on both Reactor Coolant Pumps (completed in 2021)

The original No.1 Reactor Coolant Pump seals were sensitive to high water temperature, such that within several minutes of losing all seal cooling, the seal may depart from nominal conditions and approach leak rates in excess of 20 gpm (5.5 m^3/hr). The new installed HTS is a passive, mechanical shaft sealing system that is actuated by elevated fluid temperatures on the low-pressure side of the No. 1 Reactor Coolant Pumps seal. Once this seal is actuated, it limits the Reactor Coolant Pump shaft leakage to less than 1 gpm (0.27 m^3/hr) per pump. The replacement of these seals is especially important for fire scenarios, which would lead to loss of Reactor Coolant Pumps seal cooling (fire in CC, SW)

Figure 25: High Temperature Reactor Coolant Pump's Seal





- Alternative Auxiliary Feedwater System (AAF) (completed in 2022)

The purpose of Alternative Auxiliary Feedwater system (AAF) is to provide water injection into steam generators in case of an inoperable Auxiliary Feedwater System as a result of a DEC event. The AAF system consists of high-pressure pump, piping, valves and a dedicated water reservoir. The new AAF system functions independently of the primary Auxiliary Feedwater system. The AAF system is physically located in the Bunkered Building 2 which is constructed to withstand aircraft impact, extreme seismic events and extreme weather. In addition to the dedicated AAF water reservoir in the BB2 building, a non-safety-related, seismic category I underground well was installed to provide makeup water to the AAF and ASI systems. The DG 3 provides power to BB2 critical loads via 6.3 kV switchgear MD3.

Figure 26: Bunkered Building 2 with AAF and ASI Pumps and Tanks

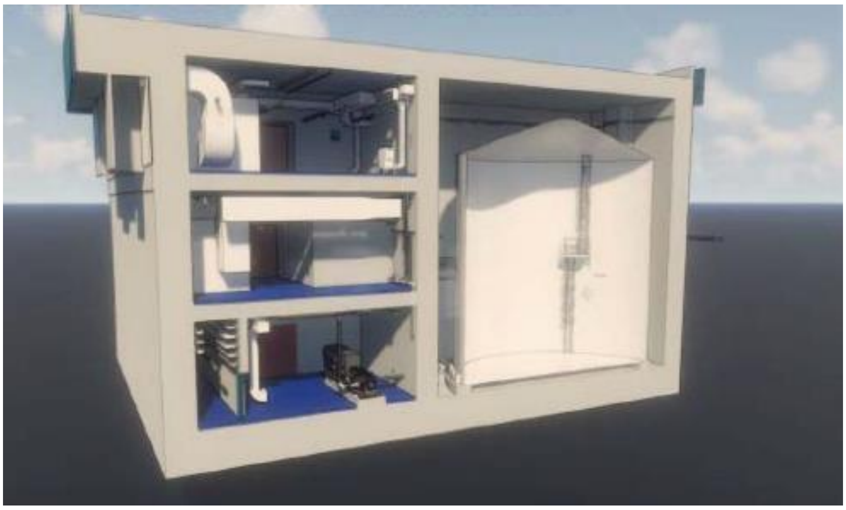


Figure 27: Alternative Auxiliary Feedwater Pump (AAF)

- Alternative Residual Heat Removal System (ARHR) (completed in 2022)

The primary function of the ARHR system is to remove decay heat from the core and the RCS under DEC conditions. The system consists of permanently installed components (pump, heat exchanger, MOV's, HOVs, instrumentation and interconnection piping inside existing buildings. The ARHR motor cooler is cooled either by Component Cooling (CC) system flow or Sava River water flow while ARHR HEX secondary side is cooled only by Sava River water supplied by a mobile pump located in the yard close to Sava River. ARHR will be placed in operation when existing RHR systems, components are not available due to earthquake, fire or flooding or other severe accident. The ARHR pump and ARHR heat exchanger are designed for the same design basis as the existing RHR pump and RHR heat exchanger. The ARHR system can be used to support or replace the normal RHR system. In case of DEC event causing the unavailability of the RHR pumps only ((i.e. intact RHR system piping and cooling chain CC – SWS – UHS available), the ARHR pump can be used as a backup to any one of the RHR pumps. Following DEC event which would cause inoperability of RHR system, the ARHR is able to replace the existing RHR system.

Figure 28: Alternative Residual Heat Removal (ARHR) Pump and HEX

Figure 29: External Connection Point for ARHR System Cooling Water

- Alternative Safety Injection System (ASI) (completed in 2022)

  The purpose of the ASI system is to provide borated water from a dedicated tank into RCS in the case of inoperable Safety Injection (SI) system as a result of the DEC event. The ASI system consists of high-pressure pump, piping, valves, instrumentation and borated water tank. The new ASI system functions independently of the primary SI system. The ASI system is physically located in the Bunkered Building 2 which is constructed to withstand aircraft impact, extreme seismic events and extreme weather. In addition to the ASI tank located in the BB2 building, a non-safety-related, Seismic Category I underground well was installed to provide makeup water to the AAF and ASI systems. The DG 3 provides power to the BB2 critical loads via 6.3 kV switchgear MD3.

  Control and power supply for the ASI system are located in the BB1 building, but also separated from the main technological part. Motor-operated valve 108801 is the only active component that is not located in either the BB1 or BB2 building. Valve 108801 is located in IB100 (the main technological part) but physically separated from primary SI system components.

Figure 30: Alternative Safety Injection (ASI) Pump and Borated Water Tank in Bunkered Building 2

2.1.5.2.3 Other Important FP Modifications Implemented since 1991 to 2022

Besides the above two main improvement programs (FPAP and SUP) the following improvements were implemented, which all had great impact on fire safety:

Improvements performed from 1991 to 2001

- Fire Detection systems have been significantly expanded and modernized. All areas were covered with fire detectors including all cabinets in the MCR and evacuation panels (existing before implementation of the ECR). All detectors are addressable. Graphical view of each detector location is provided in MCR and fire brigade room.
- All fire protection doors were replaced with the qualified 3 hour and 1.5-hour doors.
- Additional emergency lighting with integral battery pack rated at 8-hour was installed to additionally illuminate areas where manual actions need to be performed in case of fire.
- Complete new wireless communication system was installed in the technological part of the plant covering all areas and rooms.
- Two fire areas were additionally equipped with the automatic water sprinkler system (to accommodate the 10 CFR 50 Appendix R requirements).
- Complete underground distribution piping for the Fire Protection system was replaced with the plastic piping (1.500 meters of piping, 35 valves, 20 hydrants).
- The MCR room ceiling plates were replaced with the non-combustible material.
- New firefighting paths were installed over the MCR ceiling with 3 different access paths (ladders).
- New position (Fire Protection Program Engineer) was established within the Krško NPP operation. The function and responsibilities of this position have been defined in accordance with Appendix R (Licensed SRO operator).
- Additional man resources were trained and added to the Firefighting Department.
- Advance training has been conducted for the local operators regarding the firefighting.
- Additional external man resources from the Krško NPP professional Firefighting Brigade have been organized and contracted as a support for the Krško NPP Fighting Department.
- Explosion analysis was developed (Elaborat eksplozijske ogroženosti [164]).
- New procedure FPP-3.7.006 "FP permit" [95] was developed. This procedure identifies the conditions under which a FP Permit is required and the criteria for preparing and using FP Permit. Any work that either involve hot work, affecting FP equipment or fire barrier, or flammable liquid decanting, require

a FP Permit.

Figure 31: Replacement of Underground Fire Protection System Piping

Figure 32: Replacement of MCR Ceiling with Fire Resistant Material

Improvement after World Trade Center attack (2001)

- Special firefighting truck (reservoir with 8500 l of water, 1500 l of foam, water pump 8000 l/min at 10 bar, high pressure water pump 300 l/min at 40 bar, 40 m hydraulic arm). The truck is capable of spraying over the SFP. Moreover, with hydraulic arm spraying water it can reach the top of the containment building.

Figure 33: Firefighting Truck with Hydraulic Arm

Improvements performed after Fukushima accident:

- Portable hydraulic driven submersible pump with floating device (flow: 4000 l/min at 2.5 bar; featuring access to any open water source at distances of up to 60 meters horizontally and 30 meters vertically);
- Mobile diesel hydraulic power pack pump with floating device (flow: 11000 l/min at 12 bar; featuring access to any open water source at a distances of up to 60 meters horizontally and 30 meters vertically; container type);
- Firefighting truck (reservoir with 4000 l of water, 1500 l of foam, 1000 kg powder);
- Container with 1700 m 8" hoses;
- Truck for containers carriage;
- Two movable high-pressure pumps (flow: 500 l/min at 32 bar);
- Two movable firefighting pumps (flow: 2000 l/min at 3 bar);
- Two electric submersible pumps (flow: 1170 l/min at 0.5 bar);
- A new building for all movable firefighting equipment was constructed (at a distance of more than 100 m from buildings containing safety-related equipment, safe against seismic and flood event);
- Fuel for 3 days of operation of firefighting equipment;
- 50 sets self-contained breathing apparatus and 300 bottles.

Figure 34: Pumping Station with Floating Pump

Improvements from 2012-2014

- New procedure FPP-3.7.018, "Performance of fire drills" [115] (Instructions how to perform fire drill) Procedure define planning, performing, objective, goals, evaluation and improvements;
- Procedure FPP-3.7.006 "Fire permit" [95] was expanded with requirements for working in the explosion areas and occupying intervention areas;
- Fire pre-plans were developed for non-technological part of the plant (35 plans);
- In each reactor coolant pump cubicle a color video camera was installed for on-line video surveillance of reactor coolant pumps;
- Manual actuation of each reactor coolant water pumps fire extinguishing system was made possible from the MCR;
- 12 fixed extinguishing water systems were replaced with a new ones;
- Fire Detection System was broadened to all areas in the non-technological part of the plant;
- One movable firefighting pump (flow: 2000 l/min at 3 bar);
- One electric submersible pump (flow: 1170 l/min at 0.5 bar);

Improvements from 2016-2018

- Oil collection system for reactor coolant pumps were installed to prevent the spreading of oil inside the containment;
- Fire pre-plans were developed for large fires DCM-TD-037 "Fire Plan in Krško NPP – Large Fires in Plant Area", [111];
- 5 fixed extinguishing water systems were replaced with a new ones.
- Portable hydraulic driven submersible pump with a floating device (flow: 4000 l/min at 2.5 bar; featuring access to any open water source at distances of up to 60 meters horizontally and 30 meters vertically);
- Movable firefighting pumps (flow: 2000 l/min at 3 bar).

Improvements from 2018-2020

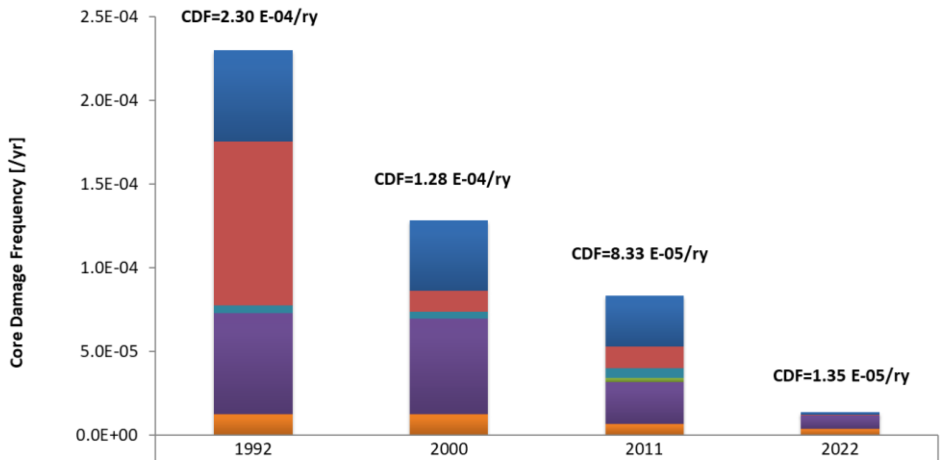
- The new dynamic, curtain-type fire dampers were installed to separate safe shutdown equipment trains A and B (ventilation systems for Battery rooms, and Switchgear rooms);
- 14 control panels for fixed fire extinguishing systems were replaced with a new ones;

- 4 fixed fire extinguishing water systems were replaced with a new ones;
- Fire Detection System was installed in the movable generators and transformer of the AE system;
- 12 isolation gate valves of the FP system were replaced with resilient type valves which have better sealing capability;
- Thermovision camera for firefighting intervention.

Figure 35: New Control Panel for Fixed Fire Extinguishing System

2.1.5.2.4 Results of Continuous Plant Improvement Process on Nuclear Safety Including Fire Safety

Figure 36: History of Krško NPP CDF



	1992	2000	2011	2022
Internal Initiating Events	5.44E-05	4.20E-05	3.05E-05	1.60E-06
Internal Fires	9.78E-05	1.25E-05	1.28E-05	3.53E-07
Internal Flooding	4.62E-06	4.53E-06	5.88E-06	8.94E-09
High Energy Line Breaks			2.53E-06	2.73E-08
Seismic Events	6.03E-05	5.67E-05	2.51E-05	7.67E-06
Other External Events	1.26E-05	1.26E-05	6.50E-06	3.83E-06

All of the above mentioned improvements are clearly seen in the Figure 36 as all of those enhancements had impact on the fire safety of the Krško NPP. Not all of those improvements were credited in the Krško Fire PSA, but the largest improvements programs, such as FPAP and SUP, are clearly distinguished as major reduction of the fire risk in Krško NPP's overall PSA. CDF from Internal Fires as a cause has decreased from 9.78E-5/ry in 1992 to 3.53E-7/ry in 2022 which represents 0,4% of CDF value in 1992 (more than two decades). As could be observed, internal fires CDF was reduced from initial 9.78E-05/ry from year 1992 to 3.53E-07/ry in the year 2022, what represents the reduction of internal fires CDF to 0.4% of initial internal fires CDF value.

2.1.6 Licensee's Experience of Fire Safety Analyses

2.1.6.1 Overview of Strengths and Weaknesses Identified

As the identification of strengths and weaknesses the perspective can be focused on the plant design itself and the fire analyses evaluating the risk of the plant design.

Strengths of the Plant Design

As already provided above, it was found that implementation of 10 CFR 50 Appendix R [43] separation guidelines led to approximately one order of magnitude reduction in fire-induced core damage frequency at the United States light water reactors. While Appendix R [43] implementation has been found to substantially reduce fire risk on a plant-wide basis, most plant fire areas at Krško NPP have sufficient redundant methods of safe shutdown (i.e., critical safety-related equipment located in other plant areas). Therefore, Appendix R compliance is required in limited plant areas if the only goal is to accomplish a low fire risk. In other words, not all plant areas are strictly in compliance with the Appendix R. Plant was built in accordance to at that time state-of-the-art standards. This was confirmed with the performance of the Appendix R analysis, which showed that most of the important plant areas, where safety systems are located (including relevant cable routing) was done in a way to adequately separate safety system trains.

As a consequence of fire protection action plan (ref. [12] and [13]), proposed risk-based plant modifications were implemented as described in chapters above.

Design of Krško NPP does not meet full compliance with the Appendix R requirements (20 feet separation between trains etc.) especially in some common (both train components are within the same rooms/areas) like Component Cooling or Essential Service Building, common cable spreading room or as a most vulnerable Main Control Room. Fire response procedure for the fire in those areas were comprehensive to give instructions to establish all safety functions mostly by a number of manual actions including some special system configuration. One of the goals for the recently implemented Safety Upgrade Program (SUP) were to provide alternative systems to ensure the capability for all the safety functions even if the fire started in a such common areas and consequentially the equipment from both trains can be affected.

After the implementation of SUP the capabilities for the alternative strategies to meet safety objectives are provided in the sense of some kind of third Safety train in BB1 and BB2 which is independent from the originally installed ECCS system component. In the case of need for the MCR evacuation the full control over the Safety Systems can be established from the Emergency (alternative) Control Room (ECR) and in the case of Loos of power and original ECCS the island mode of operation (in fact in cooldown) from the BB1 building is possible.

As a response to Fukushima accident, Krško NPP upgraded safety with availability of mobile equipment and with the Safety Upgrade Program. Within the program, additional emergency control room was constructed to shut down and cool the plant from alternative location in case of evacuation from main control room. This safety upgrade was very beneficial from the fire risk, as fire in MCR was a dominant sequence. It is still the most important fire sequence, but not over dominant, due to availability of the new Emergency Control Room.

Additionally, the Safety Upgrade Program provided a separated safety train (DEC equipment) for primary and secondary cooling and for spent fuel cooling in the dislocated bunkered building. This is implemented in the Krško NPP PSA model, but not in the fire part of the model, as complete update of the fire PSA is on the way, performing through the third periodical safety review action plan.

Important strength is continuous improvement (including fire prevention and detection and firefighting readiness) that is described and can be observed in the chapters above.

Weaknesses of the Plant Design

As mentioned above, not all plant fire areas were strictly in compliance with the Appendix R requirements. This plant weakness was partially mitigated with the implementation of the fire protection action plan modifications, which removed plant weaknesses with the highest risk impact, 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 building, 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.

Strengths of the Safety Analyses

At the time the fire analyses (FHA and PSA) were carried out, they were advanced and in line with the (at the time) latest findings on fire protection and analyses area. Thus, these analyses were able to support fire protection action plan and define the most efficient fire risk reduction modifications.

These analyses were regularly reviewed and updated to account for the plant modifications that were carried out. PSA analyses were broadened to include low power and shutdown modes, as well as SFP. Therefore, these analyses also helped to identify possible enhancements and direct the design of the post-Fukushima improvements (e.g. SUP, including installation of ECR), which further enhanced fire safety and reduced potential risk presented by fire hazards.

In addition to that, analyses of combination of all events with fires were also carried out, which show that the power plant is safe even for cases of combinations of events.

Weaknesses of the Safety Analyses

The original Krško NPP FHA was limited to 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 of the SFP, as well as HVAC systems, 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.

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.

Development of fire PSA methodology resulted in many supporting guides (ref. [24], [25], [26], [27], [28]) that are available for fire PSA update. Therefore, before the fire PSA update, the review of the current fire PSA model and analyses were performed [11], which is the base for the update in the PSR3 action plan.

2.1.6.2 Lessons Learned from Events, Reviews, Fire Safety Related Missions, etc.

Special Safety Review (EU stress tests)

In the framework of the EU stress tests conducted by the European Commission following the Fukushima accident, Krško NPP has performed improvements in the scope of SUP [55], as described in Section 2.1.5.2.

OSART mission 2003

Warehouse of oils and gases in the non-technological part of the plant contain large quantities of combustible material; some barrels are corroded and deformed; some collection traps containing oil and water are not protected with Fire Detection System.

Krško NPP Response: Large quantity of combustible materials was substantially decreased; degraded barrels were replaced with new ones; warehouse roof wase expanded to prevent rain or snow to the warehouse.

Independent review mission 2007

Area for Improvement (AFI): Discrepancy in proper protection of safety systems from fire:

- Temporary storage places in area AB el.111 are located near cables of safety-related equipment. Also, areas were not equipped with fire detection and extinguishing systems.

  Krško NPP Response: All temporary storages are removed from the area; the Fire Detection System is installed in all rooms of technological part of plant.

- Fire barrier plates between cable trays of safety and non-safety systems have cracks between plates.

  Krško NPP response: All fire barrier plates between cable trays are corrected to have overlapping between plates.

- Areas with safety-related equipment AB el.82, el.89 and el.100 have not installed Fire Detection System.

  Krško NPP response: Fire Detection System is installed in all areas of the technological part of the plant.

Independent review mission 2011

Recommendation: Replace electric stove in the MCR kitchen with induction type; upgrade suppression systems for extinguishing reactor coolant pumps with actuation from MCR.

Krško NPP Response: The electric stove in MCR was replaced with induction type; the modification was performed to provide actuation of the suppression system for reactor coolant pumps from MCR.

Independent review mission 2014

Performance Deficiency: Fire drill standards and expectations are not clearly defined:

- Planning of fire drills did not have explicit goals; the purpose of fire drill not always recognized; acceptance criteria was not clearly defined; recognized discrepancies in the fire drill did not always result in the issuance of Corrective Action Program request (CAP).

  Krško NPP Response: Procedure for fire drills FPP-3.7.018 "Performance of fire drills" [115] was revised to clearly define the required issues.

OSART mission 2017

Deficiencies: Krško NPP does not have Fire Preplans for managing big fires (airplane crash); there is no control of transient combustibles in temporary modification process; mobile diesel generators do not have installed Fire Detection System.

Krško NPP Response: Krško NPP developed new Fire Preplans for big fires DCM-TD-037 "Fire Plan in Krško NPP – Large Fires in Plant Area", [111]; temporary modification process was upgraded with control of transient combustibles; mobile diesel generators were equipped with the Fire Detection System.

Independent review mission 2019 – No AFI's on fire protection area.

IPERS (INTERNATIONAL PEER REVIEW SERVICE) 1998

Review Mission for Krško NPP, Fire PSA, 15-19 June 1998 [20] was performed on fire PSA analyses [4]. The IPERS comments generally concern methodology, assumptions, and scope of the Level 1 Fire IPEEE. All comments were addressed and re-quantification of the Level 1 Fire IPEEE was performed to provide the result of these comments for so reviewed fire PSA analysis [5].

The First Krško Periodic Safety Review 2003

The review of non-seismic hazard analysis also covering the PSA external events non seismic was covered in the PSR1 review documented in PSR-NEK-2.6B report [48]. No issue findings from fire PSA analyses were recognized.

The Second Periodic Safety Review of Krško NPP 2013

Similar to other NPPs in Europe, the licensing requirement for Krško NPP is to undertake a comprehensive Periodic Safety Review (PSR) every 10 years. The First PSR was initiated in 2001 and completed in 2003. The Second PSR was initiated in 2010, with the plant freeze date on 31 December 2010. [49].

On 11 March 2011, an accident involving damage to the cores of 3 reactors with massive offsite release of radioactivity occurred at Fukushima in Japan. This event had a profound impact on the nuclear safety all over the world. The effect was particularly felt in Europe, where a comprehensive "Stress test" was undertaken to assess the margins European plants have, when subject to external impacts that are beyond their design basis.

In its initial response to Fukushima accident, Krško NPP initiated immediate modifications (803- NA-L and 804-EE-L, mainly procuring and enabling connection of mobile equipment). Along with all of the NPPs in Europe, Krško NPP undertook a comprehensive assessment in accordance with the ENSREG specification. The Krško NPP's report (SSR) as a part of the Slovenian national report was reviewed at the EU level.

Following the review of the report and considering the status of the margins identified, and responding to the SNSA's request, Krško NPP developed a comprehensive "Safety Upgrade Program" (SUP). The program envisages a multi-year activity addressing a variety of safety improvements that are considered relevant.

Because of practical reasons related to the implementation, the freeze date of the 2nd PSR remained 31 December 2010, and therefore could not address both the analysis and the safety improvements that were implemented or have been planned. Consequently, the safety issues and findings of the PSR might have been identified in the areas that are already addressed or will be addressed following the initiation of the SUP. To enable realistic planning of the reposition of the findings of the 2nd PSR, Addenda to PSR2 review [50] was prepared with an independent evaluation to identify the safety issues that are either already resolved or expected to be resolved with the completion of the SUP. Freeze date for the Krško NPP Special Safety Review and Krško NPP Safety Upgrade Program Impact Assessment was 30 June 2012.

No issue findings from fire PSA analyses were recognized.

IAEA Expert mission on Fire PSA and the Third Periodic Safety Review of Krško NPP 2020

In 2020, the expert mission was coordinated by the International Atomic Energy Agency (IAEA) with the objective to discuss the current Fire PSA of Krško NPP and to discuss the details of the latest standards and good practices associated with the fire PSA.

Krško NPP developed its fire probabilistic safety analysis (PSA) together with the rest of its PSA already in the 1990's. The fire PSA was developed based on at the time valid standards and international practice. Since the Krško NPP's PSA is a living process, the Fire PSA was updated occasionally to consider major upgrades in the plant (e.g. Fire Hazard Analysis Update, Fire Protection Action Plan improvements, Installation of Emergency Control Room). However, the Krško NPP fire PSA was not yet updated to take into account the development of standards and practice in this area.

The mission highlighted areas of potential improvement for upgrading the Krško NPP's Fire PSA to meet the requirements of later PSA standards. The review findings were documented in the IAEA report to Slovenian Nuclear Safety Administration (SNSA) [52] authority. It was agreed with SNSA that the review recommendations would be treated as a PSR3 review for the fire PSA analyses, and that recommendations will be implemented and performed in the frame of the Krško NPP PSR3 action plan.

2.1.7 Regulator's Assessment and Conclusions on Fire Safety Analyses

Fire safety analyses are covered under the Fire Protection program TD-6. The fire safety analyses demonstrate fire safety in the Krško NPP. Fire safety analyses are prepared according to Slovenian regulation (National Fire Safety Code, Rule on Radiation and Nuclear Safety Factors [101]) and American regulation (10 CFR50 Appendix R [43], BTP APCSB 9.5-1, Appendix A [127]) in the field of fire protection in nuclear power plants. Fire safety analysis covers deterministic fire safety analyses such as the Fire Hazard Analysis (FHA) as well as the probabilistic fire risk analysis (Fire PSA). The deterministic part of the fire hazard analysis covers individual fires, as well as their spread in all locations where there is constant or temporarily installed combustible material, in all operating states of the power plant, including shutdown states. The probabilistic safety analysis of the fire hazard is a part of the probabilistic safety analysis of the first level. This analysis verifies the appropriateness of the arrangement and fire protection measures and determines the risks caused by fires in the Krško NPP.

2.1.8 Overview of a Strengths and Weaknesses Identified by the Regulator

In scope of TPR II, the licensee performed a self-assessment report regarding fire safety SA-2022-03 "Team self-evaluation of the areas of fire protection and fire preparedness". The purpose of the report was to identify gaps/noncompliance between fulfilment of requirements from TPR II Technical specification and Krško NPP's documents and analysis.

Main strengths:

- the Krško NPP installed additional safety systems with the safety upgrade program (SUP) and consequently improved fire safety;
- the Krško NPP regularly updates fire safety systems. Several fire projects and modifications were carried out;
- the Krško NPP regularly corrects/ discovers irregularities. Non-compliances are solved with new and revised procedures, revised Fire safety analysis and several FP modifications are implemented;
- in the scope of the Fire Protection Program (TD-6, [96]) the Explosion risk analysis and EX procedures were prepared, and more EX modifications were implemented.

Main weaknesses:

- Circuit analysis was not performed in accordance with the NEI 00-01 guideline [180]. SSA shall consider multiple spurious operation (MSO);
- FP systems are not seismically designed as required by RG 1.189 [181]. It is necessary to review the current status of FP systems and to strengthen them accordingly. Generic studies were performed under NUREG-1211, "Regulatory Analysis for Resolution of Unresolved Safety Issue A-46, Seismic Qualification of Equipment in Operating Plants" [184], which indicated that enough margin exists in design of piping system, even though the system is not seismically designed. The approach made use of earthquake experience data supplemented by test results to verify the seismic capability of selected equipment. On NPP Krsko Individual Plant Examination (IPE) project was carried out, which also included an examination of the seismic resistance of non-safety piping systems. The evaluation concluded that very high resistance of Krpško NPP's systems, structures and components to seismic loads exists.
- Separated safety train (DEC equipment) for primary and secondary cooling and for spent fuel cooling in the dislocated bunkered building is implemented in the Krško NPP PSA model, but not in the fire part of the model, as complete update of the fire PSA is on the way, performing through the third periodical safety review action plan.

2.1.8.1 Lessons Learned from Inspection and Assessment as Part of the Regulatory Oversight

The SNSA obtains information about the status of fire safety analyses in three ways:

- Review and assessment of the modifications (a lot of modifications directly or indirectly change the contents of fire safety analyses);
- Regular reporting of the Krško NPP;
- Thematic inspections performed by SNSA.

The Krško NPP shall report annually and quarterly to the SNSA. A part of these reports is dedicated to the reporting about fire safety. The most important is a summary of activities performed within fire protection program, fire events and operational experiences regarding fire safety.

The SNSA performs regular thematic inspections in order to access the status of fire safety analysis.

Insigts and findings from recent inspections are the following:

- SNSA proposed to improve the seismic resistance of the FP System. The problem was addressed in PSR2 "Consider combination event in FHA";
- More fire foreign operating experience were considered (NRC IN 2013-06, IAEA IRS 8343, IAEA IRS 8426, NRC IN 2014-10 "Potential Circuit Failure-Induced Secondary Fires or Equipment Damage");
- Missing fire barriers between SR and NSR cable trays were identify in the cable spreading area El.111.89, CB-2 fire area;
- the document "Fire protection action plan update" (NEK ESD-TR-23/2009) discusses the findings from the FHA analysis and prioritizes them into three categories (cost-benefit analysis). They implemented the recommendations of the second category.
- the compliance with the Krško NPP's documents and analysis with U.S. regulation (NUREG-0800 [182], RG 1.189 [181]) were reviewed;
- the compliance with the Krško NPP's documents and requirements from IAEA document SSG-64 "Protection against Internal Hazards in the Design of NPP's" [139] was checked;
- In 2021 there was one fire event "Smoldering of discarded headsets due to overheating of the plastic parts of the headsets when welding the pipeline in the turbine building" in the Krško NPP.

All findings from recent inspections were solved or properly addressed by Krško NPP.

2.1.8.2 Conclusions Drawn on the Adequacy of the Licensee's Fire Safety Analyses

Fire safety analyses are in compliance with Slovenian regulation (National Fire Safety Code [101], Rule on Radiation and Nuclear Safety Factors [21]) and American regulation (10 CFR 50 Appendix R [43], BTP APCSB 9.5-1, Appendix A [127]).

A general SNSA opinion is that Fire safety analyses (FHA and Fire PSA) is quite well developed, but it is important to resolve all open weaknesses and discrepancies.

2.2 Research Reactors

Not applicable.

2.3 Fuel Cycle Facilities

Not applicable.

2.4 Dedicated Spent Fuel Storage Facilities

2.4.1 The Fire Safety Objectives

MPC is the confinement boundary for the storage of spent fuel assemblies in a HI-STORM FW system. As a fully welded stainless steel enclosure, MPC is backfilled with helium and designed for thermosiphon capability for internal circulation of the helium as cooling media. The HI-STORM FW XL domed lid, together with the HI-STORM FW XL cask body forming the whole overpack, provides physical protection to the spent nuclear fuel assemblies and radiological shielding for the environment.

MPCs are stored in the HI-STORM FW Version XL overpack, designed to withstand large impulsive or impactive loads, including also the seismic events. The HI-STORM FW system is designed to protect the stored spent nuclear fuel assemblies, including the protection from all credible design basis accident events.

The storage of fuel assemblies in the HI-STORM FW System is analyzed for site specific conditions to verify the safety of the spent fuel assemblies, and compliance with given requirements including the protection of the fuel for the design accident conditions. Site specific analyses include evaluations of the site boundary dose rates, casks thermal and structural parameters and include all naturally occurring hazards that are presented in the Krško NPP's USAR, Chapter 21 [1].

The measures applying to defend and to protect against natural and other hazards, including protection against fire was included in the SFDS project design. The fire hazard analysis related to SFDS was performed and documented as a separate plant specific document HI-2177799 "Evaluation of Plant Hazards at Krško Nuclear Power Plant" [65], which presents the review of potential Krško NPP specific hazards as explosion, fire, fall, missile, flood, and transient hazards that could affect spent fuel storage operations at the ISFSI and/or ISFSI cask transport operations along the ISFSI haul path. That analysis was performed for each postulated hazard and it consists of a review of the applicable physical and chemical properties of the materials involved.

Based on performing evaluation and analysis, all fire safety measures are incorporated in the Krško NPP SFDS design, as follows:

- the potential spread of fire to adjacent structures and land is restricted by the use of fire-resistant materials,
- evacuation exits from the facility are provided,
- water for fire suppression is provided through the existing hydrant network and the FP pumps;
- the existing emergency access routes provide access for firefighting.

Although the DSB structure is designed to mitigate environmental effects on the HI-STORM FW system during normal operation (long-term storage), the DSB structure is not required for the HI-STORM FW system to perform its design safety functions - safely store the nuclear spent fuel assemblies. The function of the DSB structure is to provide a sheltered environment with potential to reduce the impact of certain external design basis hazards, and to minimize the dose at the plant boundary. Two fire areas are defined in the SFDS, which are equipped with Fire Detection System to provide indication in MCR, and at the Fireman brigade office on the Fire Protection Station.

The structure of the DSB also reduces energy of the potential missiles, and may prevent them from impacting the overpacks directly. During a fire or explosion event outside the DSB structure, the walls of DSB provide a physical barrier from the hazards, limiting the effects of a fire or explosion on overpack system. Site hazards, such as air-borne missiles, fire, and explosions, are evaluated against the overpacks without the DSB structure per report HI-2177799, "Evaluation of Plant Hazards at Krško Nuclear Power Plant" [65] in a conservative way.

2.4.2 Scope, Assumptions and Methodologies Applied to Perform the Fire Hazard Analysis

The detailed fire hazard analysis for ISFS was performed in separate technical reports such as HI-2177799 "Evaluation of Plant Hazards at Krško Nuclear power Plant" [65], HI-2177837 "Thermal Evaluation of Dry Storage Building at Krško" [68], HI-2177921 "Aircraft Crash Analyses of Krško HI-STORM FW with Domed Lid" [67], and HI-2177928 "Thermal Evaluation of HI-STORM FW Inside Dry Storage Building at Krško" [150], which also include the description of methodology and assumptions used in the process of the assessment.

The engineering evaluation performed for each postulated hazard consists of a review of the applicable physical and chemical properties of the materials involved. Each hazard is evaluated for fire potential on the basis of its fire hazard rating.

A number of fire hazards which might affect the casks during travel on the haul path and storage in DSB have been identified in HI-2177799 [65] report. Before performing calculations to evaluate the effects of these hazards, an engineering evaluation was performed to determine the actual hazard potential for fire posed by each case. If the fire potential for an individual hazard is negligible, no subsequent calculations of fire effects are required. If the fire potential for an individual hazard is deemed credible, appropriate controls or limitations have been set to mitigate the possibility of exceeding the allowable heat input of the cask.

The report HI-2177837 [68] evaluates and analyses the postulated VCT motor fuel fire inside the DSB as one of the hazards, while the HI-2177928 [150] report evaluates and analyses the MPC and HI-STORM FW XL cask beyond design basis aircraft crash fire accident.

All postulated fire events evaluated within these reports are compared against thermal evaluations performed for design basis fire events. The design basis fire events evaluate a cask-engulfing fire and demonstrate that the peak cladding and cask component temperatures remain within the HI-STORM FW FSAR defined limits for the heat input to the cask. By demonstrating that the heat input generated by any hazard at Krško NPP is bounded by the design basis event heat input, it can be concluded that no hazard will increase the peak cladding or cask components temperatures above the design basis limit.

It is noted that using design basis fire events as the acceptance criteria for fire hazards ensures that a large margin is maintained against the HI-STORM FW FSAR defined component temperature limits.

Additionally, there are no combustible or explosive materials associated with the HI-STORM FW XL system, and no combustible materials are stored within the DSB. However, a hypothetical fire accident has been analyzed in HI-2188103 report [142] as a bounding condition for HI-STORM FW XL system, related to a transport vehicle fuel tank fire engulfing the loaded HI-STORM FW XL overpack or transfer cask during their handling. The performed analysis shows that overpack fire accident does not affect the safe operation of the HI-STORM FW XL system.

Under DEC conditions, a large commercial aircraft is assumed to crash into dry storage building. The hypothetical fire event due to ignition of the aircraft fuel from such an impact is evaluated as BDBA. Following the aircraft impact, the dry storage building is assumed to collapse and the casks tip over. This impulse impact for HI-STORM FW XL of aircraft accidents is analysed in HI-2177921 "Aircraft Crash Analyses of Krško HI-STORM FW with Domed Lid" [67] report. Under such a horizontal orientation (casks tips over), the natural convection in the HI-STORM FW XL annulus and the helium circulation inside MPC will be impeded, adversely affecting the heat transfer characteristics of the system. The temperature and MPC confinement boundary pressures are presented in deterministic assessment report HI-2177928 "Thermal Evaluation of HI-STORM FW Inside Dry Storage Building at Krško" [150]. The following conclusions are drawn from these evaluations:

- The MPC confinement boundary component temperatures are within their limits
- The MPC cavity pressure is within the acceptance criteria
- The MPC fuel basket is structurally adequate under the fire event following aircraft crash accident (BDBA)

A sensitivity study was also performed to evaluate the impact of a higher temperature fire following the aircraft crash accident and the conclusion is that the maximum temperatures of the MPC components are not highly sensitive to the fire conditions, as documented in HI-2177928 report [150].

2.4.3 Prevention and Protection Measures to be Adopted as Result of the Fire Hazard Analysis

The FHA calculation performed for each identified hazard have showed that the only fire hazard, of which heat would cause exceedance of acceptable limits, is a fire of fuel oil tank for the plant Steam Auxiliary system. All other evaluated fire hazards produce maximum heat inputs within acceptable limits.

In the meantime, the modification was performed replacing the above ground fuel oil diesel tank with the underground fuel oil storage/tank, to satisfy the needed requirement to remove the old tank prior to transferring loaded MPCs to the DSB. Likewise, administrative requirements have been put in place for the diesel delivery trucks to the new fuel oil loading area to maintain a distance of 110 feet away from the stored casks in the DSB, or to maintain a shorter distance of 49 feet away with the means in place to extinguish the possible fire within 26 minutes. Thus, all fire hazards (except the described fuel oil tank loading, which is restricted with administrative requirements) can be concluded, as they will not adversely affect loaded casks during transport or stored at the DSB, at any time.

The procedures have been implemented to prevent transient hazards in the vicinity of the hauling path and DSB during cask transportation on the hauling path. Additional measures have been implemented to ensure that transient hazards maintain a safe distance from DSB at all times while casks are in storage.

Upon detection of a fire adjacent to a loaded transfer cask (HI-TRAC VW) or HI-STORM FW XL overpack, the Krško NPP firefighting personnel shall take the appropriate immediate actions necessary to extinguish the fire, and take appropriate radiological precautions, particularly with the HI-TRAC VW transfer cask. Following the termination of the fire, a visual and radiological inspection of the equipment shall be performed.

As appropriate, temporary shielding around the HI-TRAC VW transfer cask shall be installed. Specific attention shall be taken during the inspection of the water jacket of the HI-TRAC VW transfer cask. If damage to the HI-TRAC VW transfer cask is limited to the loss of water in the water jacket due to the pressure increase, the water may be replaced. If damage to the HI-TRAC VW transfer cask is extensive and/or radiological conditions require (based on dose rate measurements), the HI-TRAC VW transfer cask shall be unloaded, prior to repair. If damage to the HI-STORM FW XL storage overpack as the result of a fire event is widespread and/or as radiological conditions require (based on dose rate measurements), MPC shall be removed from the HI-STORM FW XL overpack. The HI-STORM FW XL overpack may be returned to service after appropriate restoration (reapplication of coatings etc.) if there is no significant increase in the measured dose rates (i.e., the shielding effectiveness of the overpack is confirmed) and if the visual inspection is satisfactory.

2.4.4 Event Combinations to be Considered

The Dry Storage Building (DSB) is designed to withstand any of normal, emergency or the DEC condition. Natural hazards are considered as an integral part of the safety design and seismic fragility analysis for cask stability and seismic fragility analysis of the SFDS building were also performed. Initiating events, which includes dropping of the cask during transfer operations, as well as external events during onsite storage (such as earthquakes, floods, high winds, lightning strikes, accidental aircraft crashes, snow load and pipeline explosions), potential cask failures from mechanical and thermal loads, including thermal loads caused by mis-loading events, are addressed in a separate technical Krško NPP report [69].

The DSB is analyzed for potential effects of combined external hazards [69] that mainly result from natural phenomena or possible explosion. The HI-STORM FW XL containing MPC loaded with spent nuclear fuel and the ISFSI/DSB pad will be able to withstand possible hazards caused by the occurrence of natural phenomena. The effects of external hazards on the HI-STORM FW system can result from individual external hazards or the combination of multiple external hazards. The 'FW' in HI-STORM FW system stands for Flood and Wind, indicating that the HI-STORM FW system is specifically designed to consider the adverse effects of "Floods and Wind".

There are many possible combinations of external hazards, however, the three most severe combinations of the external hazards and their effects on the HI-STORM FW system and ISFSI at Krško NPP nuclear station are outlined as:

- Snowfall and Strong Wind;
- Earthquake and Flood;
- Fire and Explosion.

While the first two combinations are not of fire related aspect interests, the Fire and Explosion combination is of prime interest from the SFDS facility fire hazard aspects. The HI-STORM FW XL is a composite structure, with outer shell and lid constructed from thick carbon steel, with a thick concrete filling between inside the outer shell for shielding. The ISFSI/DSB pad concrete, and the DSB at the Krško NPP is comprised of non-flammable, concrete and metallic walls. As so, the fire could not cause damage to the DSB or HI-STORM FW XL structures, constructed from non-flammable materials. In the case of an explosion, it is difficult to penetrate the concrete walls on all four sides of the DSB. The aircraft impact and possible fire in the DSB will not have a significant effect because of the thick walls of the DSB, as well as the sturdy, robust construction of the HI-STORM FW XL (thick carbon steel shell and lid with concrete) cask. It is very difficult for the aircraft to penetrate and cause damage to spent nuclear fuel cladding, stored inside the huge mass of the HI-STORM FW XL and the MPC confinement. Since MPC and HI-STORM FW XL are constructed from non-inflammable materials, the probability of fire is negligible, and the availability of any system for heat removal is not required, as the cooling system is of a passive design. The HI-STORM FW system and ISFSI at Krško NPP will therefore not be so damaged by the combined effects of fire and explosion, that the primary functionality of the system will be affected.

Additionally, a separate analysis provides the seismic/structural evaluation of the HI-STORM FW XL storage cask due to a potential SFDS facility building collapse accident at the Krško NPP, documented in the HI-2167350 "Seismic/Structural Analysis of the Anchored HI-STORM FW XL Under a Beyond Design Basis Accident Earthquake Condition" [151][144] report. The postulated building roof collapse accident could be caused by a beyond-design-basis (BDB) seismic event or a BDB aircraft crash accident, which has been evaluated separately in HI-2177948 "Analysis of HI-STORM FW XL for the Krško Dry Storage Building Roof Collapse Accident" [144] report. That calculation considers the combined effect from a crashing aircraft and the roof structure and concluded that the postulated DSB collapse accident will not result in any unacceptable consequences to the loaded HI-STORM FW XL storage casks at the Krško dry storage facility.

Both individual and combined effects of hazards are analyzed in separate documents as described, and results are included in HI-STORM FW system design.

2.4.5 How the Performance Levels are Achieved Through the Adopted Design and Layout

The introduction of nuclear spent fuel dry storage technology represents a safer way of storing SF under the same environmental and radiation conditions as are prescribed in the existing operating license, and as the cooling system is passive, no device/system or energy source is needed for cooling and operation for assurance of intended safety function. Additionally, both radiation safety and the robustness of the system are improved. In addition to the passive cooling method, better radiation safety and robustness of dry SF storage has also other benefits, above all due to better protection against intentional and unintentional negative influences or human acts. At the same time, the accumulated Spent Fuel Decay Heat and amount of radioactive highly irradiated spent fuel will be removed from the plant SFP, reducing the requirements for active cooling of residual heat stored at Krško SFP.

The HI-STORM FW XL storage system is analyzed against the design basis accident events for site specific accidents in scope of a separate report HI-2177799, "Evaluation of Plant Hazards at Krško Nuclear Power Plant" [65], which demonstrates the HI-STORM FW XL systems' capability to protect the spent fuel under the site's credible explosive, fire, missile, flooding, and lightning strike events, and demonstrates the HI-STORM FW XL system is designed to withstand these assortments of design basis accident conditions within the design's acceptable limits presented in HI-STORM FW XL FSAR [143].

2.4.6 Assessment of Radiological Impact Following a Fire Event, as Postulated in the Safety Analysis of the Installation, in Relation to the Safety and Radiological Objectives

As already descried in previous sections, the SFDS is analyzed and designed against all possible fire hazards [65]. The HI-STORM FW XL overpack loaded with the MPC casks is protected against any design-basis accident, and leakage from the confinement boundary is not credible. Assumed limiting beyond design-basis accident (BDBA) scenario of large commercial airplane crash with subsequent fire, was separately analysed in reports HI-2177928, Thermal Evaluation of HI-STORM FW Inside Dry Storage Building at Krško" [150] and HI-2177921 "Aircraft Crash Analyses of Krško HI-STORM FW with Domed Lid" [67]. The structural analysis states while it is expected some of the casks involved in the crash accident will eventually tip over and hit the ground, the anchored HI-STORM FW XL casks at Krško can survive the postulated accident with no breach of the MPC enclosure confinement boundary, as documented in the report HI-2177814 "Krško SFDS Site Boundary and Outside Wall Dose Calculations"[151].

In the scope of the DSB design, the assessment of the potential radiological consequences of an the MPC cask leakage as a result of a beyond design basis accident at Krško NPP was also performed [145]. The hypothetical breach of the MPC casks is evaluated considering several conservative assumptions.

During loading, unloading, and transfer operations, shielding from gamma radiation is provided by the stainless steel structure and the fuel basket of the MPC and the steel, lead, and water in the HI-TRAC VW transfer cask. For storage, the gamma shielding is provided by MPC, and the steel and concrete (composite "Metcon" structure) of the overpack. Shielding from neutron radiation is provided by the concrete of the overpack during storage and by the water gap of the HI-TRAC VW transfer cask during loading, unloading, and transfer operations.

The complete loss of the HI-TRAC VW transfer cask neutron shield along with the water jacket shell is assumed in the shielding analysis for the post-accident analysis of the loaded HI-TRAC VW transfer cask and bounds the determined fire accident consequences. The loaded HI-TRAC VW transfer cask following a fire accident meets the accident dose rate requirement of 10 CFR 72.106. The high temperatures experienced by the HI-STORM FW XL overpack concrete are limited to the outermost layer and remain below the short-term temperature limit. The loaded HI-STORM FW XL overpack following a fire accident meets the accident dose rate requirement of 10 CFR 72.106. The analysis of the fire accident shows that the MPC Confinement Boundary is not compromised and therefore, there is no overall reduction in neutron shielding capabilities and no release of airborne radioactive materials. Since there are no specific regulatory acceptance criteria for a beyond design-basis accident for a spent fuel storage cask, the main acceptance criteria were that the maximum Krško NPP DBA Total Effective Dose Equivalent (TEDE) at the site boundary will not be exceeded (it will be 2.5 % of maximum annual dose at the Krško NPP fence), as justified in HI-2177814 [152] report.

Additionally, for the purpose of radiation shielding, the DSB inlet duct walls and side walls are constructed with panels of sandwiched shielding plastic (High Density Polyethylene, HDPE) between steel sheets. Since HDPE is highly flammable, the heat produced by the combustion of these panels augments the heat produced by combustion of the aircraft fuel. To account for this, the calculation is done to evaluate the heat from HDPE burning in comparison to the aircraft fuel heat in report HI-2177928 [150]. The results show that the HDPE heat is negligible in comparison to the fuel heat even with the conservative assumptions listed above, and therefore, considering the margins-to-limit available, the impact of the combustion of the shielding panels are negligible.

It should be noted that the HI-STORM FW overpack loaded with MPCs is protected against any design basis accident, and leakage from the confinement boundary is not credible [143].

2.4.7 Dry Storage Fire Probabilistic Safety Assessment

As a result of Probabilistic Safety Screening Assessment, the cumulative risk is provided. The analysis is in whole provided in NUREG-1864 [160].

NUREG-1864 is US NRC based pilot Probabilistic Safety (Risk) Assessment for very similar Holtec HI-STORM 100 SFDS system. It is a comprehensive study that calculates the individual probability of a prompt fatality within 1.6 km and a latent cancer fatality within 16 km radius around SFDS. Study provides results due to internal initiating events and applicable hazards. Study from NUREG-1864 was used for Krško NPP with plant specific initiating events. In the study, the frequencies of all initiating events which could affect the subject cask at the subject site were estimated. Then, the responses of MPC and fuel to the mechanical and thermal loads induced by the initiating events were determined. Third, the consequences of a release of radioactive material to the environment was calculated in terms of the individual probability of a latent cancer fatality (no prompt fatalities were predicted). Finally, these results are combined to estimate the risk to the public in terms of the annual probability of a latent cancer fatality. The study results were used also for Krško NPP SFDS with adaptation of Krško NPP specific initiating events in Overview of Initiating Events and PSA Screening Evaluation of Spent Fuel Dry Storage [37].

2.4.7.1 Dry Storage Fire Probabilistic Safety Assessment Assumptions and Methodologies

In the analysis, methodologies presented in following chapters were used.

2.4.7.1.1 The Pilot Probabilistic Risk Assessment of a Dry Cask Storage System at a Nuclear Power Plant, NUREG-1864

The cask system consists of a Multi-Purpose Canister (MPC) that confines the fuel, a transfer overpack that shields workers from radiation while the cask is being prepared for storage, and a storage overpack that shields people from radiation and mechanically protects MPC during storage. The study covers various phases of the dry cask storage process, from loading fuel from the spent fuel pool, preparing the cask for storage and transferring it outside the reactor building, moving the cask from the reactor building to the storage pad, and storing the cask.

The study (NUREG-1864 [160]) develops and assesses a comprehensive list of initiating events, including dropping the cask during handling and external events during onsite storage (such as earthquakes, floods, high winds, lightning strikes, accidental aircraft crashes, and pipeline explosions). Potential cask failures from mechanical and thermal loads are modelled.

The study estimates the annual risk for one cask in terms of the individual probability of a prompt fatality within 1.6 km (1 mile) and a latent cancer fatality within 16 km (10 miles) of the site.

2.4.7.1.2 Final Safety Analysis Report on the HI-STORM FW MPC Storage System, HI-2177798

Chapter 12 of HI-2177798 FSAR [143] - Accident Analysis, presents the evaluation of the HI-STORM FW System for the effects of off-normal and postulated accident conditions; and other scenarios that warrant safety analysis (such as the MPC reflood during fuel unloading operations), pursuant to the guidelines in NUREG-1536. The design basis off-normal and postulated accident events, including those based on non-mechanistic postulation as well as those caused by natural phenomena, are identified. For each postulated event, the event cause, means of detection, consequences, and corrective actions are discussed and evaluated. For other miscellaneous events (i.e. those not categorized as either design basis off-normal or accident condition events), a similar outline for safety analysis is followed. As applicable, the evaluation of consequences includes the impact on the structural, thermal, shielding, criticality, confinement, and radiation protection performance of the HI-STORM FW System due to each postulated event.

2.4.7.1.3 Key Analytical Assumptions

The HI-STORM FW system is designed to protect the stored fuel assemblies. This includes protection from all credible design basis accident events against the system.

An initiating event is a disturbance in the normal operation of the dry cask storage system, which could potentially lead to a release of radioactive material to the environment. Those initiating events that could not affect the subject plant, the transfer/storage cask(s), or MPC were eliminated from further consideration. For the remaining initiating events, estimates of frequencies, probability of the MPC failure, and consequences were developed. Initiating events are provided for activities during the handling, transfer, and storage phases, respectively.

Also, relevant DEC A, DEC B and BDBA NPP Krško PSA initiators, that have the potential to jeopardize the fuel stored in HI-STORM FW system and warehouse building are provided.

Initiating event frequencies are listed, based on applicable design basis conditions, DEC and BDBA potential accidents. The list is based on available generic documents, as are:

1. NUREG-1864 [160], where the set of initiating events is based on: NUREG-2300 and Holtec HI-STORM Topical Safety Analysis Report HI-9591312 (like Krško NPP FSAR, HI-2177798) that is based on NUREG-1536 and NRC Regulatory Guide 3.61;
2. Krško NPP Analyses of Potential Safety Improvements [58], where DEC accident set is based on IAEA SSR-2/1 document and Krško NPP IPE evaluation;
3. WENRA WGWD Postulated Initiating Events document [173], that is principally based on IAEA NS-

R-5.

2.4.7.2 Initiating Events for Dry Storage

As dry storage is passive cooling facility, there are no relevant sources of fires, capable to endanger the stored fuel assemblies. Design-based initiating events are as follows:

- Handling Accident
- Non-Mechanistic Tip-Over (Other hazards like seismic)
- Fire
- Partial Blockage of MPC Basket Flow Holes
- Tornado
- Flood
- Earthquake
- Fuel Rod Rupture
- Confinement Boundary Leakage
- Explosion
- Lightning
- Burial Under Debris
- 100% Blockage of Air Inlets
- Extreme Environmental Temperature

Therefore, the relevant bounding fire scenario analysis is covered within Design Extended Conditions (DEC) and Beyond-Design-Basis Accident (BDBA) analyses for dry storage:

- DEC Seismic Fragility Analyses
- DEC & BDBA Dry Storage Building Intake/HI-STORM FW Flow Blockage
- DEC Flood Analysis
- DEC Snow Load
- DEC High Environmental Temperatures
- DEC Aircraft Crash Analysis
- BDBA Combination of External Events Hazards
- BDBA Cliff-edge Effect

Aircraft crash represents the large-scale bounding fire scenario for dry storage.

2.4.7.3 Bounding Fire Scenario for Dry Storage

Aircraft Crash and Fire scenario can be considered as a DEC A scenario, as there is a successful radionuclide retention within all including directly impacted storage casks for mission time of 7 days. Upper bound risk for radionuclide releases is calculated as 8.87E-15/yr [37]. Additionally, impact from fires due to aircraft fuel was evaluated. No additional risk was recognized.

Therefore, fire is not considered to be relevant contributor to risk.

In the DEC A scenarios, Aircraft Crash also represents the bounding accident for the following types of combinations of relevant accidents:

- Fire and explosion

- Seismic event with fire

2.4.8 The Main Results of the FHA with Regard to the Safety Objectives

The fire hazard analysis for Dry Storage Facility was provided as a separate document [65] and it demonstrates the cask system has the capability to protect the fuel under the site's credible explosive, fire, missile, flooding, and lightning strike events. The DSB is also a totally passive facility where no active system is needed to support the heat removal from the stored fuel.

The main result for the Krško NPP Independent Spent Fuel Storage Installation/Dry Storage Building shows that there is enough safety margin, robustness and redundancy incorporated in the design of facilities and their support systems. All fire safety precautions and measures (fire detection, low combustible load, equivalent fire severity, the separation between fire areas, administrative measures, etc.) reduce the probability of a fire event. The previously described FHA also shows that radiological impact following a fire event, as postulated in the safety analysis of the installation, in relation to the safety and radiological objectives cannot cause significant or important doze release, even if considering the combination of multiple events. This facility therefore does not present an unacceptable risk to the public and the environment.

2.4.9 Licensee's Experience of Fire Safety Analyses

The fire safety analysis for Krško SFDS facility are based on the HI-2177798, HI-STORM FW FSAR for Krško« [143], HI-2177799, Evaluation of Plant Hazards at Krsko Nuclear Power Plant [65], HI-2177921, Aircraft Crash Analyses of Krsko HI-STORM FW with Domed Lid [67], HI-2177928, Thermal Evaluation of HI-STORM FW Inside Dry Storage Building at Krsko [150], and HI-2146214, Safety Analysis Report on the HI-STAR 190 Package [183] analysis documents. These analysis are based on the vendor origin regulatory requirements (i.e. U.S. NRC - american technology developed by Holtec International), and specifics of the Krško NPP SFDS design of protection DSB building, where the HI-STORM FW spent fuel casks are kept protected from the environment.

2.4.9.1 Overview of strengths and weaknesses identified

The SFDS is a new nuclear installation. The SFDS facility obtained the construction license in December 2020, and the final approval of the project/modification in accordance with ZVISJV-1 was issued in October 2022. Based on the fact, there is no identified strengths and weaknesses at the moment.

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

Since the SFDS is a new nuclear installation, as mentioned above, at the moment there is no events, reviews, fire safety related missions, etc. for this facility.

2.4.10 Regulator's Assessment and Conclusions on Fire Safety Analyses

The SFDS is a new nuclear installation. The SFDS facility obtained the construction license in December 2020. The final approval of the project/modification in accordance with ZVISJV-1 was issued in October 2022.

The fire safety analyses demonstrate fire safety in the Spent Fuel Dry Storage (SFDS). Fire safety analyses for SFDS were currently in draft version and will be implemented in new revisions of fire safety analyses, as part of the regular revision after the project closure. Fire Protection program for SFDS does not exist. Fire safety analyses cover deterministic fire safety analyses such as the Fire Hazard Analysis (FHA) as well as the Probabilistic Fire Risk Analysis (Fire PSA).

The general SNSA opinion is that the Fire Hazard Analyses (FHA) for SFDS are well developed.

2.4.10.1 Overview of a Strengths and Weaknesses Identified by the Regulator

Main strengths:

- Both the deterministic and probabilistic part of fire safety analyses were carried out for the SFDS, as part of the regular revision of the Krško NPP programs and procedures, after the implementation of the modifications.

Main weaknesses:

- N/A

2.4.10.2 Lessons Learned from Inspection and Assessment as Part of the Regulatory Oversight

Several inspections were performed between construction and licensing of the SFDS. No important fire issues were identified regarding fire safety.

2.4.10.3 Conclusion on the adequacy of the licensee's fire safety analyses

Fire safety analyses regarding the SFDS are in compliance with Slovenian regulation (National Fire Safety Code [101], Rule on Radiation and Nuclear Safety Factors [21]) and U.S. regulation.

The general SNSA opinion is that the Fire Hazard Analyses (FHA) for SFDS is quite well developed, but the above-mentioned weaknesses should be resolved.

2.5 Waste Storage Facilities on Nuclear Installations Sites

2.5.1 The Fire Safety Objectives

Krško NPP is evaluated with regard to fire protection to determine that the total Fire Protection Program provides reasonable assurance that a fire will not cause an undue risk to the health and safety of the public, will not prevent the performance of the necessary safe shutdown functions, and will not significantly increase the risk of radioactive release to the environment. The fire protection is based on applicable NFPA standard, i.e. defense-in-depth concept. As stated in WENRA [136], fire safety for facilities is primarily related to prevention of radioactive releases from waste involved in a fire rather than to protect SSCs from fire effects.

The facilities are equipped with automatic fire detection and automatic/manual fire suppression features for extinguishing of fires that may occur. The HVAC and radiation monitoring systems are provided in all waste storage facilities to maintain required environmental condition, negative pressure inside the building and to prevent the radioactive release to the environment. Additionally, procedural controls are introduced to limit accumulations of combustible materials and related hazards (ADP-1.1.105 [61]) and to control the radionuclide composition and specific activity.

The Decontamination Building is a standalone building, while the other radwaste storage facilities (RWSF and WMB) are separated from the other buildings, where the safe shutdown equipment/systems are placed, with sufficient fire resistances barriers. In case of fire or in case of combinations of events in the waste storage facilities, the fire will not spread to the adjacent areas, and there will not be uncontrolled discharge of the radioactive materials to the environment. These facilities have very high level of buildings' fire resistance, and are divided into fire sectors [3], equipped with efficient automatic fire detection and extinguishing equipment, which enable fast and reliable detection of any fire at the earliest stage and reliable and fast extinguishing. In the fire event, fire can affect only one fire sector in the affected building.

2.5.2 Scope, Assumptions and Methodologies Applied to Perform the Fire Hazard Analysis

Waste is stored within the Krško NPP perimeter fence in the radioactive waste storage facilities and described in Chapter 11 of USAR [1]. The stored waste meets special storage criteria that comply with the Rules on Radioactive Waste and Spent Fuel Management (Official Gazette of RS No. 125/21 [80]). These

Rules regulate the classification of radioactive waste according to radioactivity level and type, radioactive waste and spent fuel management, the scope of reporting on radioactive waste and spent fuel generation, and the manner and scope of keeping central records on radioactive waste and spent fuel generation, and keeping records on stored and disposed radioactive waste and spent fuel. There is a basis in place for the storage and decay-storage capacity of low- and intermediate-level radioactive waste that the annual maximum permissible dose equivalent of radiation from the entire nuclear power plant complex may not exceed 0.2 mSv at the Krško NPP fence.

2.5.2.1 Radwaste Storage Facility

The Radwaste Storage Facility (RWSF) is a concrete structure, constructed of three hour rated barriers and designed for storage of Low and Intermediate Level Radwaste (LILW) from primary plant structures in the sealed steel containers. RWSF is surrounded by the Auxiliary Building and Waste Manipulating Building and divided into several rooms inside the building, which form unique fire area YD-22. This area is part of the common fire area YD, which encompasses the general outdoor area of the site, surrounding the principal plant structures. This building does not have any penetrations to the Auxiliary Building, and there are only fire rated doors to WMB and entrance from the yard. The waste from the other plant's areas is transferred through WMB, via corridor provided, and in accordance with the Krško NPP procedure PRZ-7.309, "Interni transporti radioaktivnih materialov in kontaminirane opreme" [89].

The Radwaste Storage Facility is equipped with the HVAC system, which maintains continuous negative pressure inside RWSF relative to the surrounding atmospheric pressure, maintaining ambient temperature and humidity in pre-determined value, and establishing radiation monitoring and preventing releases of airborne contaminants to the environment. The ventilation system is designed in accordance with NFPA 90A [81], and is capable of being isolated in case of fire to prevent spreading of fire and release of radioactive material to the environment.

The packages of waste, stored in RWSF are prepared and managed in accordance with valid Krško NPP procedures COP-6.302, "Preparation of Radioactive Waste for Temporary Storage" [74] and COP-6.303, "Temporary Storage of LILW Packages" [75], and those packages are in accordance with applicable regulatory rules and in accordance with waste acceptance criteria for storage, based on requirements from the national regulation JV7, "Rules on radioactive waste and spent fuel management" [80] and [88]. Quantitative or qualitative criteria are specified in USAR [1], section 11.5.6 and Table 11.5-9 "Waste acceptance criteria for storage in RWSF building". These acceptance criteria include, among other, control of surface rate and dose rate at referent points, surface contamination, chemical stability, control of ignitability, and control of flammability of the stored packages.

The JV7 Rules [80] also regulate the classification of radioactive waste according to radioactivity level and type, radioactive waste and spent fuel management, the scope of reporting on radioactive waste and spent fuel generation, and the manner and scope of keeping central records on radioactive waste and spent fuel generation, as well as requirements for keeping records on stored and disposed radioactive waste and spent fuel. The radioactive waste, after having been compacted or solidified, and depending on the purpose, is packed into different containers: 208 l steel barrels, 200 l stainless steel barrels or 150 l stainless steel barrels with biological protection. The barrels and pressings are then placed into Tube Type Containers. The compressible dry solid waste is stored in 208 l drums and approximately 70% of that waste is combustible waste, but it does not contribute to the combustible material since it is stored in stainless steel drums. In case of possible damage of drums, during transport and storage, when there is a possibility that the combustible material is no longer protected by the drums, a separate procedure was introduced, which determines the handling of such drums COP-6.304 "Management of Drums in case of Damage" [76]. Additionally, Krško NPP uses an external service for the incineration of combustible waste and the melting of radioactive metallic waste material and receives back the treated waste, in order to minimize and relieve storage capacity. The product residues from incineration are filled into 100-liter drums, which are then concreted into 208-liter drums, and stored in RWSF. Therefore, the combustible materials amount stored in drums in RWSF is unchanged in recent decades.

The RWSF building, as well as the corresponding HVAC system is provided with intelligent smoke detectors in each of the RWSF building supply air duct, and a common RWSF building discharge vent duct connected to the common plant stack (Plant Vent System), with fire and smoke dampers. The RWSF building ventilation system is capable to isolate the RWSF building in case of fire, postulated accident event or post accidentally. Additionally, heat detectors are provided inside the HVAC filter plenums for fire detection, which annunciate an alarm on the Main Control Room Fire Protection Panel upon detection of a fire. In case of fire, regardless of the small possibility of such an event due to the negligible amount of combustible material, the Fire Detection System will annunciate MCR and the RWSF building will be automatically isolated by closing the fire and smoke dampers, and all necessary actions will be performed in accordance with applicable procedure FPP-3.7.002 "Fire Response Procedure" [8] and DCM-TD- 023 "Fire Plan in Krško NPP – technological part of plant"[83].

The combustible materials are enclosed in sealed metal drums; hence there are no exposed combustibles to initiate or sustain combustion. Strict application of plant procedures, careful characterization of waste before packaging, management and closing of storage packages provide an additional barrier in preventing the outbreak of an internal fire. Additionally, in accordance with waste acceptance criteria for storage, mentioned above, the possible ignitability is eliminated by treatment technology before the storage, and the quantities of flammable materials are limited.

The105nalyseste materials are stored in packages in accordance with waste acceptance criteria for storage (USAR, Table 11.5-9), which require that the amount of flammable materials is low. Additionally, there are no other combustible material in RWSF, the fire detection system and extinguished equipment are provided, and the intervening combustible load is controlled through Krško NPP administrative procedure [61]. Taking into account all the above, the occurrences of fire in RWSF does not present the hazard, and there is no possibility that fire will affect the principal adjacent plant structures (WMB and AB) or safety-related equipment located in those structures. The substantial reinforced concrete construction of the plant structures, combined with the separation distances to the nearest significant hazards, provides reasonable assurance that the challenge to the structural integrity of the principal plant structures will be adequately met. Additionally, since the dose contribution of the RWSF building adjacent to other sources from the plant, does not exceed 0.2 mSv/year at the site boundary, specific beta/gamma contamination on the surface of the package does not exceed 400 Bq/100cm^2, and specific alpha contamination on the surface of the package does not exceed 40 Bq/100cm^2 [1], it can be concluded that the increase in radioactive discharge into the environment, as a consequence of the fire in RWS, is negligible.

2.5.2.2 Decontamination Building

Decontamination Building (DB) is a reinforced concrete structure designated for the storage of the two old steam generators, as well as for the storage of associated, non-compactable low and intermediate level waste produced during the replacement of the steam generators. The dimensions of the outer walls and of the roof slab are governed by radiological shielding requirements, according to the relevant codes. The DB shielding is designed to maintain the dose requirement of less than 0.25 mSv/yr whole body in accordance with 10 CFR 50, Appendix I [92] and 40 CFR 190 [93].

The DB105nalyped with the HVAC system, which maintains the contaminated spaces under negative pressure relative to the clean surrounding spaces, maintains the temperature within design limits, and filters the exhaust air prior to discharge to the atmosphere. The exhaust ventilation duct is equipped with a radiation monitor, and a continuous sample from DB is drawn through a particulate and iodine filter that are analyzed in accordance with the Krško NPP procedures.

DB is a standalone building, divided in five fire areas (DB-1 to DB-5), and they are enclosed by reinforced concrete fire barriers, and equipped with fire-rated doors. The total combustible loads in DB contribute to combined fire severity of 1 minute in DB-1 fire area (where the old steam generators are located), of 2 minutes in DB-2 fire area (Decontamination area), of 8 minutes in DB-3 fire area (Mock-up area), of 10 minutes in DB-4 fire area (entrance and auxiliary rooms) and of 7 minutes in DB-5 fire area (HVAC unit area), i.e. approximately 30 minutes in the whole building. The Fire Detection System and suppression equipment are provided in all fire areas, except DB-1 area where the old steam generators are placed and total combustible load is negligible, as stated above. The dry chemical and carbon dioxide fire extinguishers are provided for manual firefighting and a hose cabinet is located in the corridor of the fire areas.

The corresponding ventilation system is designed in accordance with NFPA 90A standard [81], and it is equipped with smoke detectors, fire dampers where the HVAC ducts penetrate fire rated barriers and radiation monitors. The continuous sample from DB is drawn through a particulate and iodine filter, and analyzed in accordance with the Krško NPP procedures. The ventilation maintains negative pressure in the rooms which are potentially contaminated to prevent release of radioactivity into the environment. The

HVAC system will be automatically switched to isolation mode of operation in case of fire signal from the fire control panel, or when any fire damper is closed, or when the radiation detector reports an excessive amount of radiation, or due to any malfunction of the equipment, which is important for maintaining negative pressure in the rooms.

In case of a fire, the Fire Detection System annunciates the Main Control Room, the Emergency Control room as well as the Fire station in the Fire Brigade House, and DB will be automatically isolated by closing the fire and smoke dampers, as part of the HVAC system operation in the isolation mode, and all necessary actions will be performed in accordance with applicable fire response procedures FPP-3.7.002 [8] and DCM-TD-023 [83]. Despite the fact that the fire area DB-1 is not covered with the Fire Detection System or suppression equipment, there is no possibility for the fire and fire spreading to the adjacent fire areas in the building, since the total combustible load in this fire area is low (equivalent severity time is 1 minute) and there is no intervening combustible material [3]

The power sources and power cables for equipment, including control panels are provided from the switchgear, located in the same building, so there are no interfaces to other buildings, systems and components related to the safe shutdown function.

Taking into account the data related to combustible material, the fire protection system and suppression equipment installed in DB, characteristics of fire barriers in DB and the HVAC system, it can be concluded that any fire in DB will be detected and extinguished before the fire spreads to the adjacent fire area in DB, causing any damage to the DB equipment, or causing the release of radioactive material into the environment.

2.5.2.3 Waste Manipulating Building

The Waste Manipulation Building 1 (WMB) is a single concrete building and it is placed in the corner between the existing RWSF, Auxiliary Building (AB) and the service road (WMB is shifted from AB for distance of 1.40 m). WMB is designed in accordance with the latest standards related to fire protection [77], in a way that fire spreading to the adjacent building is incorporated in the design by application of 3 hours rated walls and by rated fire doors to the other building (RWSF). The Fire Safety Study [77] was performed prior to the WMB construction, therefore this building is designed and constructed to fulfill all relevant standards' requirements. The dimensions of the outer walls and of the roof slab are governed by radiological shielding requirements, according to the relevant codes, as summarized in the WMB Dose Rate Study [86]. The WMB shielding is designed to maintain dose requirement of less than 3 μSv/hr on the outside of WMB and the annual effective dose from external radiation at the Krško NPP perimeter fence of 0.2 mSv shall not exceed due to the dose from WMB.

WMB is separated into eleven fire areas (from WM-1 to WM-11) which are enclosed by reinforced concrete fire barriers (three-hour fire rating for outer walls and 90- and 180-minutes fire ratings for internal walls) and fire rated doors. The total combustible materials in each fire area are evaluated in FHA [3], and the equivalent combined fire severity in these fire areas is from one to twenty-nine minutes (in the electrical area), which is less than the resistance of fire barriers (walls). Rated fire dampers are installed where the HVAC ducts penetrate rated fire barriers and penetrations of rated fire barriers are sealed with non-combustible materials, in accordance with applicable NFPA 90A standard [81].

WMB was designed for the purpose of conditioning Low and Intermediate Level Waste (LILW) before it is sent for processing (incineration, melting), for the final handover and packaging in special canisters for final takeover and storage, all in accordance with the latest standards related to fire protection, in accordance with NEKNAD-5P1001B ŠPV, "Študija požarne varnosti – Prostor za manipulacijo" [77]. The building has been designed to ensure radiological protection of the surrounding area and the environment, as well as provide adequate working conditions in the building itself (thickness of walls, closed ventilation filter system and implementation of a closed floor drainage system).

WMB is equipped with HVAC system, which is partially incorporated in the RWSF HVAC system, described in Section 2.5.2.1. These two HVAC system have a common exhaust line which is directed to the Plant Vent System, where the radiation monitoring is provided, and fire dampers are installed wherever the exhaust ventilation duct penetrate fire barriers between these two buildings. Additionally, WMB HVAC system has own air supply system, i.e. air-handling unit, located also in the RWSF building. Fire dampers are installed where ventilation ducts penetrate walls between WMB and RWSF. In case of fire, the installed smoke detector will annunciate an alarm in the MCR and on the Main Control Room Fire Protection Panel, and the WMB will be automatically isolated by closing the fire and smoke dampers, and all necessary actions will be performed in accordance with applicable procedure FPP-3.7.002 "Fire Protection Procedure" [8] and DCM-TD-023, "Fire Plan in Krško NPP–- Technological Part of the Plant" [83].

WMB is equipped with floor drains and in the event of a fire, it is possible to keep the waste water created in the fire or different hydraulic oil in the floor drainage reservoir, to prevent liquid discharges from the facility into the surrounding area. Emissions from the buildin"s ventilation system will be routed 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.

Fire Detection System is installed in each fire area, as well as in the HVAC system; and manual fire alarm stations are located in the vicinity of the entries to the fire area WM-1. Detectors and manual fire alarm stations annunciate an alarm in MCR, in ECR, as well as on the Fire Station in the Fire Brigade House. The dry chemical and carbon dioxide fire extinguishers are provided within fire areas for manual firefighting, as well as hose cabinets within the building.

In case of fire, the Fire Detection System will annunciate MCR, and the WMB facility will be automatically isolated by closing the fire and smoke dampers, and all necessary actions will be performed in accordance with applicable fire protection procedures [8] and [83].

There are no high specific fire loads in the WMB facility, as mentioned above and evaluated in FHA [3]. Increased fire hazards are only present during the activities in the welding area and hot workshops (fire areas WM-8 and WM-9), but all activities in these areas, as well as in the entire Krško NPP, take place through the process of a work order, in accordance with the applicable administrative procedure ADP-1.1.122 [94], which also includes a fire permit in accordance with the procedure FPP-3.7.006 [95]. The walls to the adjacent building are 3 hours fire rated in accordance with the NFPA 101 and the NFPA 803 requirements. The causes of fire in the building can be only related to activities in the welding area or hot workshop and installation fire due to overload (electrical rooms). The flammable materials and gas required for welding are not stored in those fire areas. Evacuation from WMB, including emergency lightning, is designed in accordance with the NFPA requirements [85].

Taking into account the data related to combustible material, the Fire Detection System and suppression equipment installed in WMB, characteristics of fire barriers and all procedures to be applied, it can be concluded that any fire in WMB will be detected and extinguished before the fire spreads to the adjacent fire areas, causing any damage to the WMB equipment, or causing the release of radioactive material into the environment.

2.5.3 Prevention and Protection Measures to be Adopted as Result of the Fire Hazard Analysis

In the scope of the Fire Protection Program [96], the necessary defense-in-depth principles are introduced, as follows: maintaining the combustible material as low as possible; the combustible and intervening combustible materials are controlled in accordance with the Krško NPP administrative procedure [61], the adequate fire barriers for the existing combustible loads are provided and controlled, control of fire barriers and penetrations through those barriers are performed in accordance with the procedure OSP-3.4.590, "Visual Inspection of Fire Barriers" [97], control of the fire-rated doors is also established and it is performed through the procedure OSP-3.4.181 "Inspection of Fire Doors" [98]. Additionally, the radwaste storage facilities, as well as other Krško NPP fire areas, are equipped with Fire Detection System (intelligent smoke detectors and temperature monitoring for the plenums, where it is applicable) and fire suppression equipment; the fire signaling is provided on different locations in the Krško NPP (independent from each other) to provide audible and visual alarm, and to display alarm graphical location together with more extensive event message [3]. A set of procedures is also in place for dealing with the event of fire [8] and [83]. The alarms are annunciated in MCR as well as on Fire Station in Fire Brigade House upon detection of fire, and actions are prescribed in corresponding fire protection procedures [8] and [83]. Generally, it can be considered that any fire event will be detected and extinguished before it can cause damage in these building and start to spread into the adjacent areas.

Instructions for the potential fire event in these facilities are described in the Fire response procedure as well as for other areas in the technological part on Krško NPP with corresponding manual actions in case of fire, added to the fire response procedure [9], as described in Section 3.2.2.

2.5.4 Event Combinations to be Considered

The separate analysis DCM-TD-040. "Krško NPP Analysis of Combination of Fire and Other Postulated Initiating Events" [91] was performed, which demonstrates that the threats from fire and other hazards which could happen simultaneously are either prevented or removed and able to be coped with. That analysis has screened out the radwaste storage facilities, based on the absence of safe shutdown equipment in these areas and due to fire rated barriers (regularly inspected in accordance with applicable operating surveillance procedure OSP-3.4.590 [97]) that prevent spreading of fire to the adjacent areas, which contain safe shutdown equipment.

Below are briefly discussed credible combinations of events and their possible impact on spreading of releases from the waste storage facilities:

a) Plant Internal Event and waste storage facilities (RWSF, DB and WMB) fire event

   There are no internal events which could impact the fire safety robustness of the radwaste storage facilities in Krško NPP. Even in the case of loss of off–- or/and – on-site power (LOOP or SBO event) this would not increase the possibility or enlarge the potential radioactive releases to the environment. In case of the LOOP (and SBO as well) all three HVAC systems for the radwaste storage facilities will be stopped and the ventilation ducts will close. The loss of power in fact decreases the probability of the fire within these areas, as the electrical spikes, as the potential ignition source, are eliminated. In addition, the Central Detection Fire system is powered from its own independent battery, providing operation of the system for at least 24 hours.

b) External fire and waste storage facilities (RWSF, DB and WMB) fire

   Due to the fire rated barriers (fire rated walls, doors, penetrations) a potential external fire cannot spread into the waste storage facilities (RWFS, DB and WMB). However, the external fire could temporarily disrupt the entrance of the Fire Brigade to the buildings if needed. Nevertheless, low combustible loading in all of these buildings could not cause a longer fire event and the fire would be extinguished (by itself or manually with fire suppression equipment) without any damage to the equipment inside the building and without any releases to the environment.

c) Seismic and Fire Events

   All the Krško NPP waste storage facilities (RWSF, DB and WMB) are seismically designed and will maintain their designated function even in the case of more severe seismical event. Passive nature of systems/activities in all of these buildings (there is normally no activity or process running in these buildings) will ensure that even in the case of a seismic event, the probability for the fire in the radwaste facilities is low. Simultaneously, fire would be mitigated with the installed fire protection systems. In case of the Fire Protection System malfunction due to seismic event, manual firefighting and robust fire barriers are credited.

d) Flooding and Fire Events

   The waste storage facilities (RWSF, DB and WMB) are protected against the introduction of the water into the buildings in case of flood, since the NPP Krško is protected from floods of 0.01% frequency (10000-year flood), by the construction of the left Sava dike and plant design (embankments were constructed along the Sava, upstream and downstream of the power plant). Dikes were designed and constructed without penetrations and are appropriately sealed. The right bank of the Sava was preserved in its natural state, thus ensuring an extreme flood would spill over onto the right-side floodplain along the Sava. In addition to the design basis flood (DBF), the power plant is also protected against probable maximum floods (PMF) with appropriately designed intermediate structures placed between the Sava and the external devices, and the protective embankment against water intrusion into the area. Therefore, for such a low probability event, there is no probability that the fire event in the buildings could be increased, neither the independent simultaneous fire in the building during the flooding could increase the consequence of the fire. The accessibility of the Fire Brigade member to the Facilities in such a case will also not be affected.

Additionally, the Waste Manipulating Building (WMB) is protected against the intrusion of the water in case of the event of a probable maximum flood (PMF) following an earthquake above 0.3 g with flood protection barriers in accordance with MD-24, "Flood Protection Program" [99]. The protection is provided by a system of water barriers, which will be installed in in accordance with applicable emergency procedure EIP-17.080, "Installation of Flood Protection In Krško NPP" [100]. Flood sealing is ensured by the exterior walls, and the intrusion of water through the door is prevented by removable flood barriers.

Therefore, the combination of flood and fire in these buildings would not increase the consequences of the fire, neither increase possibility for radioactive releases.

2.5.5 How the Performance Levels are Achieved through the Adopted Design and Layout

Passive nature of the buildings and almost no activities which would include fire hazardous operation in these buildings, very little and controlled amount of combustible material, robust design and construction of the building, appropriate fire barriers, continuous fire detection, as well as continuous presence of well-trained professional Fire Brigade on the site, ensure the minimum likelihood of fires in these buildings and assure that the consequences of potential fires would not jeopardize the safe shutdown of the plant or radioactive releases into the environment. The consequences of fire event would not increase even in case of the combination of a fire and other plausible event (see chapter 2.5.4), regardless if the fire event in the radwaste storage facilities is caused by other plant event or initiated simultaneously with some other plant internal or external event.

As stated in the previous sections, the Decontamination Building is a standalone building, while the other radwaste storage facilities (RWSF and WMB) are separated from the other buildings, where the safe shutdown equipment/systems are placed, with sufficient fire resistances barriers. In case of fire, or in case of combinations of events in the waste storage facilities, the fire will not spread to the adjacent building and will not jeopardize the equipment and systems needed for Safe Shutdown and there will be no uncontrolled discharge of radioactive material into the environment.

2.5.6 Assessment of Radiological Impacts following a Fire Event, as Postulated in the Safety Analysis of the Installation, in relation to the Safety and Radiological Objectives

The Krško NPP waste storage facilities and their corresponding HVAC systems' designs and construction were governed by radiological shielding requirements and in accordance with all applicable standards to prevent radioactive release into the environment.

The stored radwaste meets special storage criteria that comply with the Rules on Radioactive Waste and Spent Fuel Management (Official Gazette of RS No. 125/21 [80]), where is the basis in place for the storage and decay-storage capacity of low- and intermediate-level radioactive waste that the annual maximum permissible dose equivalent of radiation from the entire nuclear power plant complex may not exceed 0.2 mSv at the Krško NPP fence.

The dimensions of the outer walls and of the roof slab of radwaste storage facilities in Krško NPP are governed by radiological shielding requirements according to the relevant codes, enabling traffic and passengers' movements around the buildings without any restrictions. The Decontamination Building shielding is designed to maintain the dose requirement of less than 0.25 mSv/yr whole body in accordance with 10 CFR 50, Appendix I [92] and 40 CFR 190 [93]. The WMB outer wall and roof slab design was also designed to maintain dose requirement of less than 0.2 mSv/year on the plant boundary and 3µSv/h on the outer wall, according to the relevant codes. [86].

These buildings are also equipped with HVAC systems, which provide a constant amount of fresh air in personnel spaces at the rate required by the ASHRAE standard [90], maintaining airflow direction from the clean to contaminated spaces, and providing that exhaust air from contaminated spaces are filtered through the HEPA filters prior to exhausting to the atmosphere. There are also radiation monitors provided on the exhaust ventilation ducts, which provide indications and alarms in case of excessive amount of radiation. The continuous samples from these buildings drawn through a particulate and iodine filters are analyzed in accordance with Krško NPP procedures SOP-3.2.708 "Radiation Monitoring System (RM)" [87].

After the radiation detector indicates out of normal level of radiation, alarm in the MCB is annunciated, followed by the usage of Abnormal Operating Procedure AOP-3.6 R&C-1, "Radiation Monitoring System High Activity", [63]. As already described in section 2.5.2, in case when radiation detectors report an excessive level of radiation, HVAC systems will be automatically shifted into isolation mode of operation, to prevent release of radioactivity into the environment. Taking into account that radwaste storage facilities are designed to maintain prescribed dose requirements, the increased radioactive materials release during normal operation is not possible.

In the unlikely event of a fire (see section 2.5.2) in these buildings, the fire will be quickly detected by Fire Detection System available in all fire areas. Upon detection of smoke, the detectors will annunciate an alarm on the Main Control Room Fire Protection Panel, at the Fireman brigade office and in ECR. Operators shall recognize this fire event by the fire alarm and start to implement appropriate procedures (the Fire Brigade is constantly available on site); considering the minimum amount of combustible material in these buildings, the fire will be extinguished before it can cause damage to the fire barriers or other components and spread to the adjacent fire areas. Additionally, the corresponding HVAC systems for radwaste storage facilities are equipped with fire dampers, which will automatically isolate the buildings in case of a detected fire and will as such prevent any possible radioactive releases to the environment.

2.5.7 The Main Results of the FHA with Regard to the Safety Objectives

Design and location of all three Krško NPP radwaste storage facilities (RWSF, DB and WMB), installed fire protection system (detection system and suppression equipment), plant strict fire protection policy (control over the transient combustibles, fire brigade supervision during the implementation of the activities with the heat source) as well as permanently present well-trained Fire Brigade at Krško NPP site, ensure that the probability of a fire event in the Krško NPP radwaste storage facilities is very low, and the potential fire consequences would not cause any damage to the equipment or the radiological release to the environment. Additionally, these facilities are properly separated from other buildings at Krško NPP (Decontamination Building is a standalone structure without any connections with the other buildings) where the safe shutdown equipment/systems are placed, with sufficient fire resistance barriers. In case of a fire event in these facilities, it will not jeopardize the safe shutdown systems/equipment, since there are not enough combustible loads to support spreading of fire to the adjacent fire areas/buildings, and the fire detection and suppression systems are provided.

Even if all the above measures would fail and releases from these buildings would occur, it is important to understand that the quantities of real source terms in these building are so low (as described in section 2.5.2), that they could not cause the raise of radioactivity on the site to the level needed for the activation of an emergency event in accordance with Emergency Planning Procedure EIP-17.001 [148].

2.5.8 Licensee's experience of fire safety analyses

Deterministic assessment is provided in the chapters above. Regarding the amount of radionuclide material and very low probability of fire spread to the safety and important areas, these areas are not modelled within fire PSA analyses.

2.5.8.1 Overview of strengths and weaknesses identified

Following strengths are recognized:

- Fire will be quickly detected by Fire Detection System available in all fire areas (except in DB-1 fire area);
- Minimum amount of combustible material in these buildings (the procedural controls are performed in the waste storage facilities to limit accumulations of combustible materials and related hazards in accordance with Krško NPP administrative prociedure ADP-1.1.105 [61]);

- HVAC systems for radwaste storage facilities are equipped with fire dampers, which will automatically isolate the buildings in case of a detected fire and will as such prevent any possible radioactive releases to the environment;
- The packages of waste, stored in RWSF are prepared and managed in accordance with waste acceptance criteria for storage, based on requirements from the national regulation JV7, "Rules on radioactive waste and spent fuel management" [80] and regulation Z3 "Regulation on the Mode of Collection, Accounting, Processing, Storing, Final Disposal and Release of Radioactive Waste into the Environment" [88].
- The quantities of source terms in these building are so low, that they could not cause the raise of radioactivity on the site to the level needed for the activation of an emergency event in accordance with Emergency Planning Procedure EIP-17.001 [148].

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

The Krško NPP operating experience program is based on ADP-1.0.020 "Corrective Action Program" [108]. All internal events are noted, processed and analysed per this program and corrective actions prescribed and tracked. External events that are delivered to Krško NPP via international organisations are also processed in the scope of the Corrective Action Program.

In accordance with observations and findings of various events, reviewe and missions, the following improvements were performed in recent 10 years, related to waste storage facilities:

- Fire plans for WMB were prepared;
- Fire Hazard Analysis [3] was revised to include waste storage facilities (DB, RWSF and WMB);

In 2009, the authorized inspection of active fire protection systems was carried out, related to the implemented modification on the RWSF HVAC system. Active fire protection, fire dampers and smoke dampers were tested, and some deviation were found. These inspection findings were eliminated and after re-inspection and testing it was found that the system meets the acceptance criteria from a fire safety point of view, for which the relevant certificates were issued.

2.5.9 Regulator's Assessment and Conclusions on Fire Safety Analyses

Fire safety analyses are covered under the Fire Protection program (TD-6). The fire safety analyses demonstrate fire safety in the Waste Storage Facilities (WSF). Waste storage facilities are divided between three buildings: Decontaminaton Building (DB), Waste Manipulating Building (WMB) and Radwaste Storage Facility (RSWF). Fire safety analyses are prepared in accordance with Slovenian regulation (Fire Protection Act, Rule on Radiation and Nuclear Safety Factors) and American regulation (10 CFR 50 Appendix R [43], BTP APCSB 9.5-1, Appendix A [127]) in the field of fire protection. In case of WSF the probabilistic safety analysis is not performed.

In scope of TPR II, the licensee performed a self-assessment report regarding fire safety SA-2022-03 "Team self-evaluation of the areas of fire protection and fire preparedness". The purpose of the report was to identify gaps/noncompliance between fulfilment of requirements from TPR II Technical specification and the Krško NPP's documents and analyses.

2.5.10 Overview of a Strengths and Weaknesses Identified by the Regulator

Main strengths:

- Fire safety, particularly in WSB, is at a quite high level.

Main weaknesses:

- there are no separate FHA for WSF buildings, particularly for RWSF (YD-22); nevertheless, it is written in TD-6 (Fire Protection Program) that the fire risk in RWSF is quite high (level 4) (Krško NPP will consider RWSF as a separate fire area in the next revision of fire safety analysis – FHA);

- fire detection system is missing in fire area DB-1 (old steam generators warehouse with a negligible combustible load).

2.5.10.1 Lessons Learned from Inspection and Assessment as Part of the Regulatory Oversight

The SNSA obtains information about the status of fire safety analyses in the following ways:

- Review and assessment of the modifications (a lot of modifications directly or indirectly change the contents of fire safety analyses);
- Regular reporting of the Krško NPP;
- Thematic inspections performed by SNSA.

The Krško NPP shall report annually and quarterly to the SNSA. A part of these reports is dedicated to the reporting about fire safety. The most important is a summary of activities performed within fire protection program, fire events and operational experiences regarding fire safety.

Insigts and findings from recent inspections are the following:

- SNSA identified that in general NPP's FHA the RWSF (Yard-22) building is not divided into fire zones or fire cells.
- NEK considers RWSF as a separate fire area (RWS) in the newly prepared revision of fire safety analysis – FHA, currently under review.

2.5.10.2 Conclusion on the adequacy of the license''s fire safety analyses

Fire safety analyses are in compliance with Slovenian regulation (Fire Protection Act, Rule on Radiation and Nuclear Safety Factors) and American regulation (10 CFR50 Appendix R, BTP APCSB 9.5-1, Appendix A). The SNSA opinion is that the Fire safety analyses for WSF are generally good. However, the particular FHA that address the relevant buildings are obviously missing, especially for RWSF that has relatively high risk of fire according to the Fire Protection Program.

3 Fire Protection Concept and Its Implementation

Fire Protection Program (TD-6) [96] describes how the fire safety activities are organized at Krško NPP. It was established based on a defence-in-depth principle. The defense-in-depth principle was focused on achieving an adequate balance in:

- preventing fires from starting;
- quickly detecting and extinguish promptly those fires that do occur to limit consequences;
- provide protection for structures, systems and components, needed for safe shutdown so that a single fire in the plant that is not promptly extinguished will not prevent the safe shutdown of the plant. This protection is achieved by establishing a comprehensive set of designated and alternative systems and procedures that provide instructions to fulfill the main goal of achieving Safe Shutdown and preventing release of the radioactivity during the potential fire event.

The principles of achieving each level of defence in depth are described in the following sub-chapters.

The Fire Protection Program establishes the responsibilities, authorities, methods for implementation of the Fire Protection Program and includes:

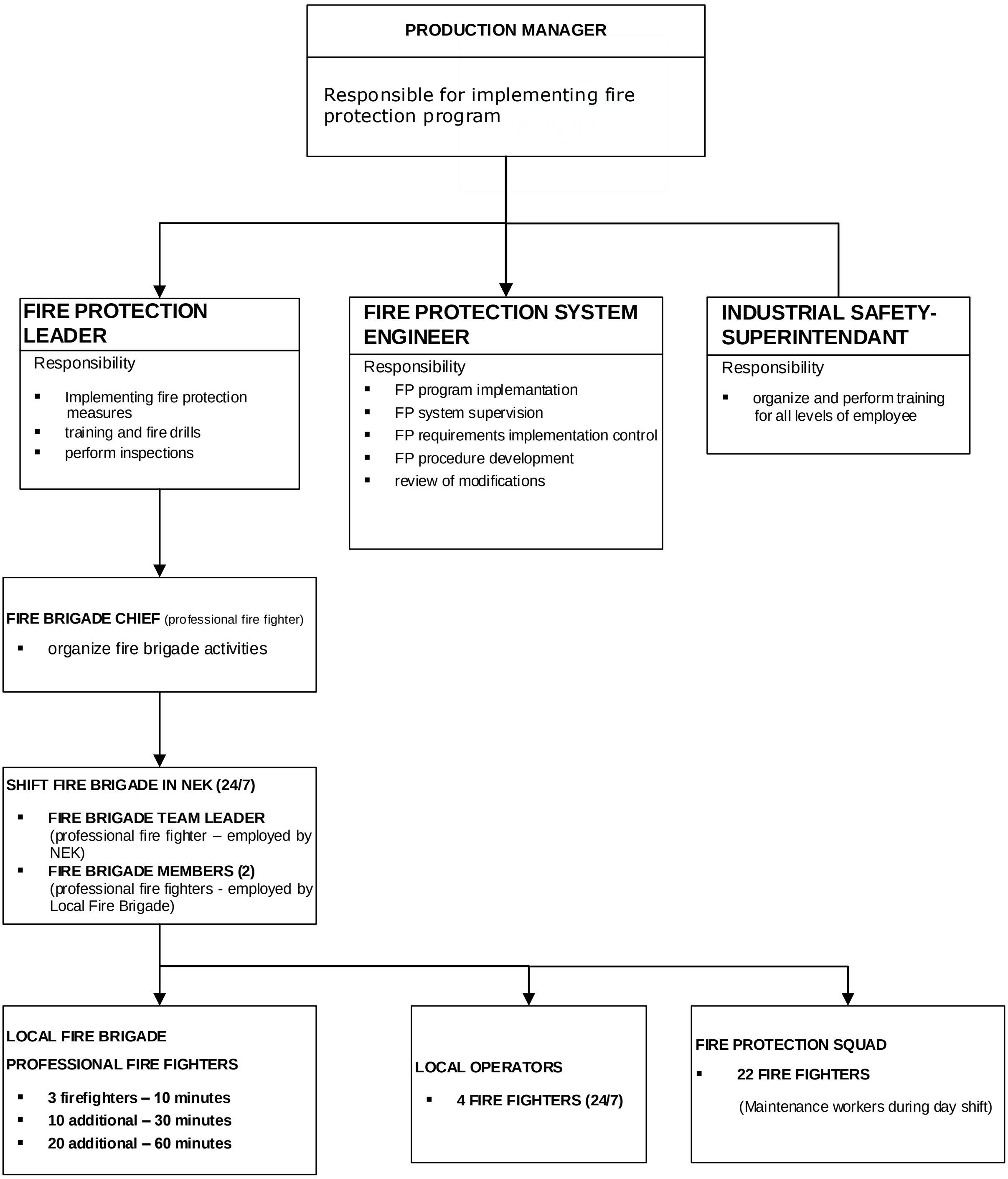
- Organizational responsibilities;
- Testing and operability requirements of fire protection equipment;
- Preventive measures;
- Actions in case of fire for various groups including firefighters, operators and other plant staff;
- Fire Brigade member and general employee training program requirements;

- Fire Brigade drill requirements.

Fire Protection Program requirements are in accordance with national and US regulations and standards (National Fire Safety Code [101], National Firefighter Organization Code [102], Rules on Radiation and Nuclear Safety Factors [21], Rules on providing safety at radiation or nuclear facilities [22], 10CFR50 App. R, BTP 9.5-1 App. A, NFPA). Organisational structure of Fire Protection in Krško NPP is shown in Figure 37.

Fire protection concept and its implementation is common for the whole Krško NPP's site, including dedicated spent fuel storage facilities and waste storage facilities. The latter two, DSFS and WSF, are therefore included in the description of the NPP situation.

Figure 37: Organizational Chart



3.1 Fire Prevention

3.1.1 Design Considerations and Preventions Means

Part of fire prevention measures in Krško NPP is achieved with design SSCs. Where practical, non-combustible material was used to prevent occurrence of fire and consequential loss of safety functions. Technical specifications which are followed at modification processes require use of fire-retarding and non-propagating material for cable insulation and also non-combustible material for thermal insulation of piping, tanks, ducts and other equipment.

Apart from being included in plant structural design, fire prevention is of a high concern at performing operation, maintenance and modification activities at the plant. Several processes (as stated in 3.1.2) were established to minimise the amount of fire loads present at the plant and also to minimise ignition sources during operation and plant activities.

3.1.2 Overview of Arrangements for Management and Control of Fire Load and Ignition Sources

Fixed fire loads are controlled in Fire Hazard Analysis and margins are set for each fire area. Criteria for setting those margins are resistance of fire barriers in a fire area. Plant modifications are controlled per procedure ESP-2.602 "Plant Design Modification" [103], which includes control of fire barriers, fire protection equipment impact and revision of Fire Hazard Analysis [3].

Additional (transient) fire loads are controlled within a process per ADP-1.1.105 "Controlled disposal and storage of material" [61], which considers allowable fire load margins for each fire zone. Thus, control is established not to exceed combined (fixed and transient) quantity of flammable material in a room. Rules are prescribed that define acceptable micro location for transient loads (e.g. no loads in ex-zones, no loads in cable rooms, no loads in waste storage rooms, combustible loads shall be reduced to a minimum).

Beside the ADP-1.1.105 process, each introduction of burnable material into technological part of the plant is also controlled per procedure FPP-3.7.004 "Control of burnable material" [104], which demands the following:

- transient combustibles should be protected from ignition sources;
- use of wood should be minimized;
- remove all waste, debris, oil spills, flammable liquids, gases, oxygen cylinders, or other combustibles resulting from work activity;
- combustible packing containers shall be removed from safety-related areas immediately following the unpacking;
- oil-soaked or paint-covered rags, cloths, waste shall be deposited in approved metallic container;
- only use flammable solvents when absolutely necessary. Ensure adequate ventilation is provided in the area and no ignition sources are within 10 m;
- flammable materials, liquids or gasses shall be stored in accordance with procedure ADP-1.1.105 "Controlled disposal and storage of material";

Handling of flammable liquids and gases is controlled per FPP-3.7.007, "Handling of flammable liquids and gases" procedure [105]:

- flammable liquids should be handled only in areas where there are no open flames or other ignition sources;
- while handling flammable liquids, ventilation should be implemented to prevent the accumulation of flammable vapours;
- all spills involving flammable liquids must be disposed of quickly and safely;

- while flammable liquids are not being used, they should remain in their covered containers;
- containers of flammable liquids must be labelled with information about the content;
- quantity of flammables to be entered into controlled areas shall be limited to daily use;
- adequate ventilation shall be supplied to areas where potential spontaneous explosive ignition of flammable gases can occur;
- compressed gas cylinders shall be kept away from heat sources;
- cylinders shall be stored upright and secured by suitable chains, ropes, etc.

Housekeeping is another means of fire prevention process. Several activities are conducted to keep plant in good, clean condition. These include daily rounds performed by field operators and firefighters and also planned periodic observations of buildings by plant leaders and weekly cleaning of rooms, which are led and performed by managers. Thus, standards and expectations are communicated from management to field workers.

Housekeeping requirements (Procedure ADP-1.1.158, "Plant Housekeeping, Cleanliness Control and Material Condition Inspections" [106]):

- all stairways, walks, fire escapes shall be kept clear of obstruction;
- spills of any type (oils, grease, water, etc.) must be cleaned up as soon as possible;
- smoking is not allowed inside controlled area;
- work areas shall be cleaned following a job and, if necessary, periodically while the work is in progress or prior to shift change;
- oil-soaked or paint-covered rags, cloths, waste shall be deposited in approved metal containers.

Ignition sources that could result from installed equipment, are controlled by design of that equipment and process of parameter monitoring (e.g. lubrication oil pressure, bearing temperatures, hydrogen pressure). Predictive maintenance procedure PDM-4.200 "Thermographical control in Krško NPP" [107] provides process for Infra red examination of potential ignition /overheating sources.

"Transient" ignition sources are related to activities (maintenance, modifications, testing) performed on site. Each activity, that could produce ignition sources, is controlled with "Hot work permit" process. Depending on fire vulnerability at location, measures of firewatch are defined and controlled per procedure FPP-3.7.006 "Fire Permit" [95].

This procedure among other identifies the conditions under which a Hot Work Permit is required and the criteria for preparing and using the Hot Work Permit. Any work involving open flames, welding, grinding, or temperatures that would exceed the heat of ignition of materials in contact with that work, requires a Hot Work Permit.

3.1.3 Licensee's Experience of the Implementation of the Fire Prevention

One of the indicators of the successful implementation of fire prevention is a number of fires and minor fire events per year. The last fire at Krško NPP was experienced in year 2000, when spontaneous ignition of radwaste has occurred in a drum, located in the RWS. However there have been 15 minor fire events in recent 10 years (e.g. burst of a light bulb causing a fire alarm, malfunction of a heating device causing its paint to smoke, smoldering of a headset due to heat during welding operations). The number of fires and minor fire events per year is shown in Figure 38 and described in Table 10. Slightly higher numbers of minor fire events in recent years are a consequence of more sensitive reporting approach. Events like the examples mentioned above were not always reported in the past.

Figure 38: Number of Fires and Minor Fire Events per Year

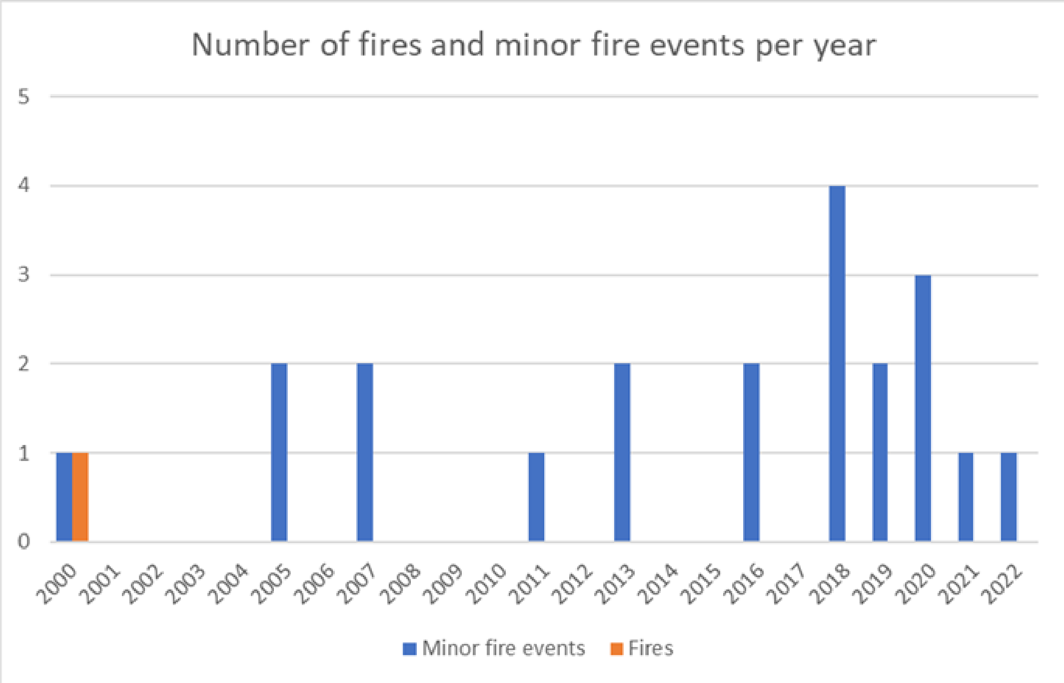


Table 10: Description of Fires and Minor Fire Events per Year

Year	Description of fire
2000	Smoldering of radiation protection sheets during hotwork
2005	Smoldering of FME protection sheet during hotwork
2005	Mechanical damage of power cable caused shortcut and smoke
2007	Smoldering of protective respirator during hotwork
2007	Smoldering of welding machine cable during hotwork
2011	Burnout of light ballast in office light
2013	SmokeIg from laundry drying machine due to overheating of fibres
2013	Smoke in turbine building caused by chemical reaction during repair of foundations
2016	Burnout of portable room heater in an office
2016	Burn of harness inside a truck during lifting operations.
2018	Burnout of light ballast in office light (2x)
2018	Overheating of room heater in River Dam House due to fan malfunction.
2018	Burnout of power supply cousing smoke in a cabinet in MCR
2019	Smoldering of portable light during hotwork.
2019	Smoldering brush and cables of welding robot during hotwork.

Year	Description of fire
2020	Overheating of bearing housing on ventilation unit due to bearing malfunction.
2020	Overheating of room heater in River Dam House due to fan malfunction. (2x)
2021	Smoldering of headset that was placed on hot surface during hot work.
2022	Smoke and smell comming from computer monitor in the MCR.

3.1.3.1 Overview of Strengths and Weaknesses

Control of fire load which is dealt with in ADP-1.1.105 [61] describes the introduction of flammable material into rooms of the technological part of the plant and also into some "important-to-safety" areas at non-technological part, e.g. Spare parts store, Operations support center and Mobile equipment storage.

A safety behaviour of employees has been established to recognise and report any not suitably left equipment, that might have missed the process of control of transient load.

Potential ignition/overheating sources are examined by the use of thermal imaging camera within predictive maintenance process.

Outsourced professional firefighters gain experience in relatively frequent interventions outside the plant and are at the same time familiar with plant buildings, systems and processes.

Fire permit process is not used solely for hot works but for many situations that involve fire protection issues, e.g., inoperability of the fire detection system Fire Detection System, inoperability of the fire extinguishing system, inaccessibility of the fire route, breach of a fire barrier, works in explosion zone, etc.

As a response to NEI 12-06 "Diverse and Flexible Coping Strategies (Flex) Implementation Guide" [161], scenarios of Beyond Design Bases events were analysed, connection points were installed, and a large fleet of mobile equipment was provided to mitigate the consequences of severe accidents. Some equipment is dedicated specifically to combat fire:

- Large Fire Truck with hydraulic arm, which can deliver 36 m^3/h of water to height of 40 meters and can thus spray water to top of containment building or deliver water to the Spent Fuel Pool;
- Three fire pumps (110 m^3/h, 8 bar) on trailers with additional equipment (electric submersible pumps, 5 kW mobile electric generators, piping, tools);
- Fire truck with 4000 liters of water, 1000 kg of fire extinguishing powder, 1000 liters of fire foam, low pressure pump (21 m^3/h, 8 bar), high pressure pump (24 m^3/h, 40bar) and other equipment;
- Fire command vehicle with documentation, communication and basic firefighting equipment;
- Two pumping stations HS60 (24 m^3/h, 2,5 bar), which can pump water from 18 meters deep sources e.g. the Sava River;
- Large pumping station HS450 (660 m^3/h, 12 bar) which can pump water from 18 meters deep sources e.g. Sava River;
- Container with 2.200 meters of 8 inch hoses to deliver water to various consumers.

Besides that, other mobile equipment was provided which can fulfil crucial safety functions in case of beyond design-basis accident. Scenarios and procedures were developed and connection points prepared for the following equipment:

- High pressure mobile pump (30 m^3/h, 30 bar) to provide secondary cooldown by filling water to steam generators;
- High pressure mobile pump (14,4 m^3/h, 137 bar) to provide injection into the primary reactor system;
- Two mobile air compressors for compressed air supply to safety pneumatic equipment;

- Three 150 kW mobile electric generators;
- 1.000 kW mobile electric generator;
- 2.000 kW mobile electric generator with transformer;
- Mobile heat exchanger for alternative cooling of the Spent Fuel Pool;
- Mobile strainer for cleaning the river water when used to provide alternative cooling;
- 4,5 ton tractor for moving mobile equipment to the plant area;
- Trailer with container of 980 liters to supply mobile equipment with diesel fuel.

Figure 39: Fire Truck with Hydraulic Arm

Figure 40: Tractor with 150 kW Diesel Generator

Figure 41: Mobile 1.000 kW Diesel Generator

Figure 42: Mobile Equipment Storage

3.1.3.2 Lessons Learned from Events, Reviews, Fire Safety-Related Missions, etc.

The Krško NPP operating experience program is based on ADP-1.0.020 “Corrective Action Program” [108]. All internal events are noted, processed and analysed per this program and corrective actions prescribed and tracked.

External events that are delivered to Krško NPP via international organisations are also processed in the scope of the Corrective Action Program.

In accordance with observations and findings of various missions, the following improvements were performed in recent 10 years:

- A calibrated instrument is installed for testing mobile pump;

- Combustible material control was expanded to all parts of the plant, not only rooms with safety equipment;
- Performance indicator was established to indicate occurrences of Fire Protection System water leaks;
- Fire plans for newly built WMB were prepared;
- Evacuation plans for non-technological part of the plant were put into plant documentation system;
- Fire Protection Program TD-6 [96] was revised to reflect organisational changes;
- Fire Hazard Analysis [3] was revised to include newly built WMB;
- Fire drill scenarios are to concern not only fire load and probability of fire in a room but also the importance of (safety) equipment that is installed in a room;
- Procedure of entering into reactor containment during power operation was prepared in fire plans to help firefighters respond quickly;
- A detailed instruction for calculating fire load was added to procedure ADP-1.1.105 "Controlled disposal and storage of material" [61];
- Some parts of non-technological part of the plant were defined as important for safe operation and control of burnable material was established in those areas;
- Periodic control of transient fire load was established;
- A form of designating burnable material in storage areas was defined;
- Education/training was defined for a person who controls burnable material at the plant;
- Control of burnable material intake was added to temporary modification control process;
- Fire plans were developed for large fires at the Krško NPP area;
- Separate fire plans were developed for every fire sector containing safety equipment;
- Mobile diesel generators were equipped with fire extinguishers and Fire Detection System;
- Duration of Hot Work Permit was limited to a maximum of 24 hours;
- Fire watch after Hot Work is finished was prolonged to at least 30 minutes;
- Air tightness was checked for areas with FM200 extinguishing system with door-fan test;
- Power supply for transformer automatic extinguishing system was improved by replacing control cabinets;
- Mobile equipment for alternate fulfilment of nuclear safety functions (not only related to firefighting) was provided. Beside that there is also a list of mobile Fire protection equipment that contains:

Large pumping station HS450 (11.000 l/min) with 2 kilometers of hoses, two medium pumping stations HS60 (4.000 l/min), three pumps FOX 3 (1.600 l/min), 6 submersible electric pumps, Fire truck with water tank, pumps and equipment, Large-scale fire truck with aerial water monitor.

3.1.3.3 Overview of Actions and Implementation Status

Krško NPP improvements in the field of Fire Protection Area since the year 1991 (the issuance of the first Krško NPP FHA) are numerous. Important physical modifications, significant Fire Protection Program enhancements, organisational changes and new procedures have been prepared and implemented.

The Krško NPP Fire Protection Action Plan (FPAP, [12]) has been prepared on the basis of Krško NPP FHA. Recommendations from FHA were screened and prioritized on the basis of the Risk-based approach. The recommendations for physical changes have been classified in accordance with the equipment location in the particular fire area. Particular fire area has been prioritised on the basis of impact to the common CDF, caused by internal fire. The modifications were classified on the basis of their importance (from the PSA perspective). Modifications which have a major impact on the PSA CDF risk have been implemented.

That consequentially reduced the fire-based CDF for almost factor 10.

The following improvements were performed:

- New position (Fire Protection Engineer) was established within the Krško NPP operation department. A Reactor Operator or Senior Reactor Operator license is demanded for this position. The function and responsibilities of this position have been defined in accordance with 10CFR50 App R [43];
- Additional man resources were trained and added to the Firefighting Department
- Advanced training has been conducted for the local operators regarding the firefighting
- Additional external man resources from public professional Firefighting Brigade have been organized and contracted as a support for the Krško NPP Firefighting Department
- Surveillance procedures have been written for periodic testing of Fire detection, protection and extinguishing systems. (OSP-3.4.181, [98])
- Firefighting plan for each Fire Area in the technological part of the plant was developed and distributed as a support for the more successful potential firefighting including a lot of useful information about particular location. Firefighting plans were also developed for the non-technological part of the plant and for large fires at the Krško NPP area
- The process was developed for control over transient combustible material including control over local storage places
- The evacuation paths have been evaluated and special marking was enhanced for these paths
- Ex zones were marked and incorporated in the plant layout drawings
- Work Order process was improved regarding the control over the activities involving heat development processes
- New set of operation procedures was developed to cover the operation of the plant in case of fire and consequential safe shutdown to Hot standby, Hot shutdown and Cold shutdown. The procedures were validated on the simulator and partially during the normal plant shutdown
- Changes were done to the existing components, cable, cable trays in accordance with the Appendix R separation criteria (wrapping, rerouting, rewiring, protection walls, isolating of safe shutdown equipment control circuits, additional controls and indicators required for the hot and cold shutdown installed on the Shutdown panels etc.)
- Existing Fire Detection Systems have been significantly expanded and modernized (All MCR cabinets were wired with the addressable fire detectors; new intelligent programmable Fire detection Central was installed; serial link connection from the FP Central to the Krško NPP Process Information System (PIS) was established; new software has been developed for the upgrading of the possibilities for the early detection of fires. All Krško NPP Fire Areas and corresponded detector status are shown on screen)
- All fire protection doors were replaced with the qualified 3 hour or 1.5-hour doors
- Additional emergency lighting with integral battery pack rated at 8-hour min. was installed
- Complete new wireless communication system was installed in the technological part of the plant covering all areas and rooms
- Two fire areas were additionally equipped with the automatic water sprinkler system
- Complete underground piping for the Fire Protection water extinguishing distributing system was replaced with a plastic pipe
- The MCR room ceiling plates were replaced with the non-combustible material
- New firefighting paths were installed over the Main Control Room ceiling with 3 different access paths (ladders)

- The warehouse of liquid combustible material was upgraded to reduce the potential hazard and potential impact on the plant operation (the warehouse is located outside the technological part of the plant)
- New position "Fire protection technician" was established and additional two professional firefighters employed to facilitate testing and support of firefighting activities
- In each reactor coolant pump cubicle, a color video camera was installed for on line video surveillance of reactor coolant pumps
- Manual actuation of each reactor coolant water pumps fire extinguishing system was made possible from the Main Control Room
- Fixed extinguishing water systems were replaced with a new one
- Fire Detection System was broadened to all areas in the non-technological part of the plant
- Control panels for fixed fire extinguishing systems were replaced with a new one
- Fire Detection System was installed in the mobile generators and transformer of the AE system
- 12 isolation gate valves of the FP system was replaced with the resilient type valves which have better sealing capabilities
- Electric fire pump control panel and pressure maintenance jockey pump control panel were replaced with new ones
- Wrapping of control and power cables to enable fire separation of redundant safety systems
- Emergency Control Room was built to provide safe shutdown capability in case of inhabitability of the Main Control Room due to fire or other reasons
- Additional Fire alarm control panel was installed in the Emergency control room (in addition to panels in the Main Control Room and at Fire brigade office)
- Fire separation of safety switch gear rooms and battery rooms was improved by modification of ventilation systems by adding fire dampers and wrapping ventilation ducts with fire-resistant insulation
- Upgrade of automatic suppression system in the auxiliary building cable room. Installation of additional branch with sprinklers
- Installation of automatic speed regulator for diesel driven fire protection pump
- Replacement of automatic fire suppression system in the computer center ($CO_2 \rightarrow$ FM200)
- Replacement of Fire Detection System in the radiation waste storage building
- Replacement of the reactor coolant pump motor with the integrated oil collection system
- Installation of temperature control in the FP tank and replacement of the level control
- Implementation of new procedure for control and permission for breaching fire barriers and for works which cause fire protection system inoperable
- Development of a computerized hot work permit
- Access points to the Sava River for mobile fire protection pumps
- Connection to the hydrant system for alternate supply of water

Currently open items, that are yet to be implemented at Fire protection systems are:

- Replacement of 4 automatic extinguishing systems that are becoming obsolete;
- Refurbishment of electric and diesel Fire protection pumps to improve performance.

3.1.4 Regulator's Assessment of the Fire Prevention

The Krško NPP has a well-established Fire Protection Program based on a defence-in-depth principle. It is in accordance with national regulations and standards regarding the fire safety (National Fire Safety Code [101], National Firefighter Organization Code [102]) as well as the regulation on nuclear and radiation safety (Rules on radiation and nuclear safety factors, Rules on providing safety at radiation or nuclear facilities). It is also in compliance with the foreign (US) regulation, e.g. with US NRC 10CFR50 App. R [43], BTP 9.5-1 App. A [127], NFPA.

3.1.4.1 Overview of Strengths and Weaknesses in the Fire Prevention

The following strengths and weaknesses were observed by the SNSA:

Strengths:

- important strength is continuous improvement (including fire prevention and detection and firefighting readiness).
- the plant weakness was partially mitigated with the implementation of the fire protection action plan modifications, which removed plant weaknesses with the highest risk impact, while other weaknesses were compensated with appropriate administrative procedures (control of combustible material, firefighting readiness, etc.).

Weaknesses:

- N/A

3.1.4.2 Lessons Learned from Inspections and Assessment on the Fire Prevention as Part of its Regulatory Oversight

The regulatory body carries out inspections of facilities and activities to verify that the authorized party is in compliance with safety requirements and the conditions specified in the authorization. The most important topics discussed at inspections are:

- surveillance testing of fire systems (fire pumps, fire detectors and sprinkler systems, hydrant network),
- potential (near miss) fires or fire events and fire system alarms,
- the problem of malfunction or failure of FP systems
- review of current open problems on fire protection systems and components
- review of major changes (modifications) to fire protection systems and FP components
- FHA fire hazard analyses - status of preparation of new revisions or changes
- considers foreign operating experiences in the field of fire safety
- inclusion of aging issues in Krško NPP fire programs, procedures, and analyses
- training programs of NPP personel (stuff training and exersize)
- compliance of Krško NPP programs for ensuring fire safety, procedures and analyses (FHA, Ex-analyses) with American legislation/regulations (e.g. NUREG-0800 and RG 1.189) and international standards (IAEA SSR, IAEA TecDoc).

So far, no major discrepancies were observed.

3.2 Active Fire Protection

Active fire protection consists of detection/alarm system, automatic fire extinguishing systems and active fire spread prevention systems (fire dampers).

The operability of the fire detection instrumentation ensures that both adequate warning capability is available for prompt detection of fires and that the fire suppression systems, that are actuated by fire detectors will discharge extinguishing agents in a timely manner. Prompt detection and suppression of fires will reduce the potential for damage to safety-related equipment and is an integral element in the overall facility's Fire Protection Program.

3.2.1 Fire Detection and Alarm Provisions

Incorporated into the overall fire protection design is a fire detection and alarm annunciation system, designed in accordance with NFPA72 National Fire Alarm and Signalling Code [109].

Area smoke detectors are provided in all areas of the plant to give prompt indication of any fire condition therein. All detectors are addressable which means that they have discrete identification. These detectors alarm on a central panel give their address and display an appropriate message with graphical identification of fire location in the Main Control Room, Firefighter's office and in Emergency Control Room. Several types of fire detectors are installed at the plant.

3.2.1.1 Design Approach

Most of fire detectors are multi-criteria type with both photoelectric and thermal sensor which can distinguish nonthreatening deceptive phenomena from actual fire hazard.

Throughout the plant manual fire alarm boxes are installed with audible and visual annunciation in the MCR, Firefighter's office and in the ECR.

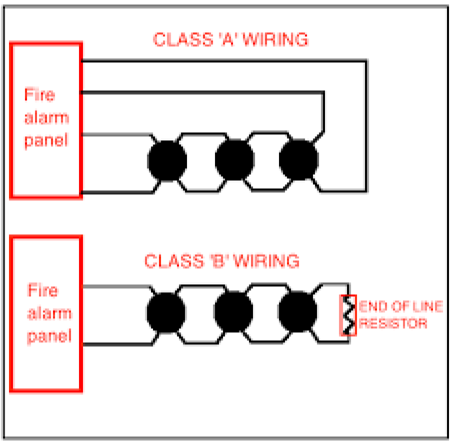
Heat detectors are associated with several of the fixed extinguishing systems as described in 3.2.2.

Local control panels associated with fixed extinguishing are equipped with monitor devices in order to supervise the status of systems.

Fire alarms and trouble signals, from all detectors, manual fire alarm boxes, monitor devices, give audible and visual alarm in the MCR. Additionally, graphical user interfaces are installed in the MCR, at the Fire brigade office and in the ECR. These interfaces display detailed information about every triggered detector and graphically present location of fire. In addition graphical and textual information about triggered fire detection is presented on the Plant Information System.

The arrangement of Fire Detection System provides reliable information about the status of the system. Since it is wired per Class "A" configuration (see Figure 43), a single defect in a loop does not jeopardize operation of any part of the system, but triggers trouble alarm that warns the operators about the defect. Loops of fire detectors also have isolation devices at borders of fire areas that prevent improper operation of the whole loop if fire damages the system in one fire area.

Figure 43: Configurations of Fire Detection Systems. Krško NPP Uses Class »A« wiring.



3.2.1.2 Types, Main Characteristics and Performance Expectations

All areas of the plant are provided with area smoke, heat or flame detectors. The area smoke, heat or flame detectors only perform a fire alarm function and they don't, by themselves, actuate any automatic fire extinguishing systems.

Area fire detectors are installed in all areas of the plant to give prompt indication of any fire condition therein. All detectors are addressable which means that have discrete identification. These detectors alarm, giving their address and display an appropriate message on a central panel (FP001OWS – MCR, FP002OWS – Fire Fighters' office and FP003OWS – ECR.

Figure 44: Fire Detection Central Panel

Several types of fire detectors are installed in the plant:

- Ionization type smoke detectors
- Photoelectric type smoke detectors
- Line-type smoke detectors
- Aspiration type smoke detectors
- Flame detectors
- Heat detectors

Most of the detectors are multi-criteria with both photoelectric and thermal sensors. All alarms and trouble signals give audible and visual alarm in the Main Control Room, Emergency Control Room and Fire Brigade Office.

In case of fire or trouble conditions event message is displayed on all of panels and workstations. Additionally, on fire protection workstations, exact graphical location together with more extensive event message is displayed. The Fire Detection System is supplied with AC power from the emergency AC power supply system train A or train B. Battery is used as a backup power supply with 24-hour autonomy.

Main types of fire detectors are:

- Spot-type smoke detectors

  The spot-type (photoelectric) detectors, type HFP-11, are multi criteria detectors and consist of photoelectric smoke sensor and temperature sensor. The next generation of photoelectric detectors are OH921 and OOH941 and they are identical by principal as HFP-11. The smoke detector is activated when combination of smoke and temperature reaches the predetermined value. The detectors installed in the area with high temperature (IB100, IB107 and RB) are activated only on smoke present.

- Line-type (Beam) detectors

  The Fireray 5000 Reflective Beam Detector System is an auto-aligning infrared beam smoke detector. The linear beam detectors, PB1191 type, provide reliable monitoring over long distance and they are installed in the large or high ceiling room.

- Aspiration detectors

  The VESDA LaserPLUS (VPL) smoke detector has high sensitivity and it detects fire at the earliest possible stage and reliably measures very low to extremely high concentrations of smoke. This type of detectors is used in areas with high consequences of potential fire.

- Flame detectors

  Flame detectors are installed in areas where flammable liquids are present and where a rapid emergence of an open flame is expected. Also, flame detectors are used for outdoor areas where potential wind can prevent smoke to reach the smoke detectors.

- Heat detectors

  Heat detectors are an integral part of automatic extinguisher systems and are designed for fire detection, alarming and sprinkler system automatic activation.

In case of fire in any compartment, the detection system could be damaged and detection in adjacent compartments jeopardized. To prevent this, all detection loops are isolated at compartments borders, so that damage to detection system in one compartment (e.g. short circuit, open loop, detector damage) does not have effect on the detection system in adjacent compartments.

3.2.1.3 Alternative/Temporary Provisions

The Krško NPP Technical Specifications [2] define fire zones with required number and type of operable fire detectors. These zones include areas with safety equipment and also some other crucial areas. Based on the number and type of potentially inoperable fire detectors, the specifications demand repair of detector(s) or establishment of fire watch patrol at least once per hour.

Fire detectors that are used to actuate fire suppression systems represent a more critically important component of a plant's Fire Protection Program than detectors that are installed solely for early fire warning and notification. Consequently, the minimum number of operable fire detectors must be greater for “activating” detectors. The loss of the detection capability in fire suppression systems, actuated by fire detectors, represent a significant degradation of fire protection for any area. As a result, the establishment of a fire watch patrol must be initiated at an earlier stage than would be warranted for the loss of detectors that provide only early fire warning. The establishment of frequent fire patrols in the affected areas is assured per procedure FPP-3.7.006 “Fire permit” [95] to provide detection capability until the inoperable instrumentation is restored to operability.

3.2.2 Fire Suppression Providions

Fire suppression is achieved by a combination of manual firefighting and automatic/semi-automatic fire extinguishing systems, that protect equipment, systems or areas as defined in FHA.

In case of fire, the procedure FPP-3.7.002 “Fire response procedure” [8] is entered by control room operators and fire brigade staff. Depending on the jeopardized area a suitable fire plan is used (DCM-TD-023 [83] (Technological part of the plant), DCM-TD 024 (Non-technological part of the plant) [110] or DCM-TD-037 (Large fires at Krško NPP area) [111]).

3.2.2.1 Design Approach

The plant has a separate fire protection water supply and distribution system capable of supplying water to the point of the largest demand. The primary fire protection water supply is provided by an electric motor driven fire pump with the capacity of 568 m^3/h at 9 bar and a secondary supply is provided by a diesel driven fire pump of identical capacity. The pumps are located in the essential service water pumphouse and take suction from the Sava River. In case of inoperability of both fire protection water supply pumps, the alternative mobile pump HS450 can be used, which can supply large quantities (660 m^3/h at 12 bar) of water to fire distribution system from up to 18 meters deep sources within 2 kilometers inside or outside of Krško NPP fence.

The fire protection water distribution system consists of outdoor underground piping with yard fire hydrants and interior fire protection distribution and standpipe system. The outdoor yard piping is arranged in a loop with several connections to the plant buildings to supply fire protection water within the buildings. Parts of fire protection system piping can be isolated for repair or other purposes without preventing water supply to other parts of the system. Attached to the underground yard piping loop are yard fire hydrants, each controlled by a curb box operated shutoff valve. A hose cabinet is located near each yard fire hydrant.

The interior fire protection distribution piping and standpipes supply water to all fixed fire extinguishing systems and to hose stations within the buildings.

Portable hand fire extinguishers of carbon dioxide and dry chemical types are provided for use on small incipient fires. These hand extinguishers are seismically secured and hung on walls or columns in highly visible areas in all plant buildings. The type and location of portable fire extinguishers are defined by fire expert in the process of building design. All fire extinguishers are annually inspected by authorized expert from local fire brigade.

Fixed fire extinguishing systems are provided for several specific fire hazards. The fixed extinguishing systems include both automatic systems and manually operated systems. In case of fire or trouble on the system, an alarm signal is sent to the Main Control Room (Fire Protection Cabinet) and to Fire Brigade Office by each fire protection panel/system.

Krško NPP Fire Protection System is not seismically qualified. In case of inoperability of fixed fire extinguishing system, firefighters would have to perform manual actions to suppress fire with alternate firefighting equipment (portable hand fire extinguishers, fire trucks with limited amount of water for initial firefighting, mobile pumps for delivery of large quantities of water from the river). This alternate equipment is stored in a separate building, which is seismically qualified and placed more than 150 meters from the closest safety system to minimize the possibility of common cause failure (e.g. plane crash).

Negative effects of inadvertent fire suppression actuation or breach of fire system piping on safety systems are analysed in DCM-TD-040 [91]. Each fire area provided with fixed water type fire protection systems, hose stations, or fire protection water distribution headers is provided with floor drains. The floor drains will remove water from Fire Protection Systems, hose streams, and foreseeable distribution system leaks. Additional safety from water damage is achieved for safety-related pumps and equipment by positioning them on raised concrete pads. Alarms are provided in the Main Control Room to indicate when a fixed system has been triggered and when a fire pump is running. Such alarms alert the plant operators that water is flowing and initiate a search for the exact location and cause for the alarm. Additionally, water level measurement in the building sump will be an indication of flooding. Where the cause is from a piping or valve leak failure, the proper sectionalizing valve or valves are closed. All fire protection water piping is routed in a way that exposure to Safety Class equipment is minimized (Table 9.5-1 USAR [1]).

In case of fire, the procedure FPP-3.7.002 "Fire response procedure" [8] is entered and actions to extinguish fire are started. Depending on the area under fire, firefighters act in accordance with Fire plans DCM-TD-023 [83] (Technological part of the plant), DCM-TD 024 (Non-technological part of the plant) [110] and DCM-TD-037 (Large fires at plant area) [111].

In parallel to that, MCR operator's response to a fire is in accordance with procedure FRP-3.9.100 "Operators actions in case of fire in technological part of plant" [9] which defines actions to mitigate consequences of fire to plan safety.

The following personnel will perform firefighting activities in case of fire:

- 3 professional firefighters (one fire brigade leader and two firefighters present at Krško NPP 24/7);
- 4 local shift operators (trained for extinguishing small fires and to provide support to firefighters);
- 3 professional firefighters at the local fire brigade (2 km from plant) with response time < 10min;
- Additional 10 professional firefighters from local fire brigade with response time < 30 min;

- Additional 20 professional firefighters from local fire brigade with response time < 60 min;
- Fire protection squad (20 maintenance workers; present on day shift only or on-call during off-hours).

3.2.2.2 Types, Main Characteristics and Performance Expectations

Automatic fire suppression consists of three types of sprinkler systems:

- Automatic wet pipe sprinkler systems with fusible sprinklers rated at 100 °C with the exception of sprinklers near steam pipes and near the auxiliary boiler. The wet pipe sprinkler systems are designed for ordinary hazard occupancies in accordance with the NFPA Standard No. 13, with the exception that sprinkler systems below the operating and mezzanine floors of the turbine building are hydraulically designed in accordance with the same standard. Each system alarm valve is provided with a waterflow pressure switch which alarms at a local fire protection panel and further to the MCR and Firefighter's office;
- Automatic preaction sprinkler system with fusible sprinklers rated at 100 °C (with the exception of sprinklers near turbine/generator bearings) and separate heat detectors. A fire condition would be sensed by a heat detector which would cause the respective system control valve to open. Water would then be discharged from only those fusible sprinklers that have been heated to their rated temperature by the fire condition. Each system has a waterflow pressure switch and a local control panel. Fire detection and waterflow would be annunciated as a fire condition at the Main Control Room and Firefighter's office;
- Automatic water spray system with open nozzles directed at the equipment, heat detectors arranged around the equipment, and an automatic deluge valve controlled by the heat detectors. A fire condition would cause the respective equipment involved in the fire to be automatically deluged with water spray, and a fire alarm would be annunciated at the MCR and Firefighter office. Manual actuation is provided locally or remotely from the MCR.

Manually actuated fire suppression sprinkler systems:

- An individual manual water spray system with open water spray nozzles is provided for each charcoal filter associated with the plant heating, ventilating, and air conditioning systems. Temperature detectors are located within each charcoal filter plenum to alarm the MCR of excessive overtemperature conditions. If an excessive overtemperature condition indicates a possible pre-fire condition, the respective water spray system for that filter can be manually actuated to deluge and cool the charcoal;
- An individual manual water spray system is provided for each of the two main reactor coolant pumps-motor drives (and associated high pressure oil piping) within the Reactor Building. Each system includes heat detectors to sense a fire condition, open water spray nozzles directed at the respective equipment, and a manually actuated deluge valve. An oil fire situation near either of the two main reactor coolant pumps would be detected by the respective heat detectors, and this fire alarm would be annunciated at the MCR (Fire Protection Cabinet). Fire can be confirmed by adjacent area fire detectors and video cameras, that are mounted in the reactor coolant pump cubicles. Each water spray system can only be actuated manually by personnel through the use of the respective local deluge valve control panel (located outside the reactor building near where the water spray piping penetrates the reactor building) or parallel control push buttons in the Main Control Room.

3.2.2.3 Management of Harmful Effects and Consequential Hazards

The Fire Protection System is designed in such a manner that system operation or failure does not create an unsafe condition. Floor drains are provided in all areas of the plant which are protected by sprinkler systems. Floor drains are also provided in all areas of the plant where fire protection piping is located in order to remove water discharged from any break in the fire protection system or water discharged from portable fire hose streams in an actual fire. Other plant equipment is located on raised concrete pads to reduce the possibility of damage due to flooding. The routing of the fire protection water piping is in such a manner as to minimize exposure to Safety Class equipment. Each charcoal filter plenum is protected by a separate manually operated water spray system. Each main reactor coolant pump is protected by a separate independent manually operated water spray system. All manually operated fire extinguishing systems require the operation of two devices (cover and switch, or cover and valve) to discharge the systems. Fire protection piping within the seismically qualified charcoal filters and near the reactor coolant pumps are supported to withstand a seismic event. All fire protection pipes penetrating the Reactor Building Containment (supply pipes for certain charcoal filter water spray systems, for the main reactor coolant pump water spray systems, and for the standpipe hose stations within the containment) contain Safety Class isolation valves which are normally shut or which would automatically close in the event of a nuclear emergency.

Alarms are provided in the Main Control Room to indicate when a fixed suppression system has operated and when a fire pump is running. Such alarms alert plant operators that water is flowing and initiates a search for the exact location and cause for the alarm. If the cause is from a piping or valve leak failure, the proper sectionalizing valve or valves are closed.

A failure mode and effect analysis of the Fire Protection System was prepared and Fire Hazard Analysis performed in order to determine compliance with fire protection requirements. Consequences of Fire Protection Systems response to fire (e.g. flooding) were analysed among other combinations of events in DCM-TD-040, "Krško NPP analysis of combination of fire and other postulated initiating events" [91].

3.2.2.4 Alternative/Temporary Provisions

The Krško NPP Technical Specifications demand operability of the fire protection water supply system at all times and are followed per procedure ADP-1.3.002 "Conduct of Operation" [112].

Spray/Sprinkler Systems as well as Fire hose stations are required to be operable whenever the equipment protected by these systems is required.

In the event that portions of fire suppression systems are inoperable, alternate backup fire-fighting equipment is required to be made available in the affected areas until the inoperable equipment is restored to service.

Alternate fire water supply is provided with mobile pump taking suction from the Sava River and discharging to connection point at fire water distribution system.

When an automatic fire extinguishing system becomes unavailable, manual extinguishing equipment is prepared for the affected area and a firewatch is established.

Inoperable fire-hose stations are substituted with additional equipment (fire hoses and wye's) so that the affected area is covered from adjacent operable fire hose station(s).

3.2.3 Administrative and Organisational Fire Protection Issues

Operational integrity of the Fire Protection System provided as part of the plant design is assured through the implementation of plant administrative, operating, and maintenance procedures, Fire Protection Program (TD-6) [96], and the Quality Assurance Program QD-5 [113]. These procedures are based on the guidance given in applicable NFPA standards and US NRC Regulatory Guide 1.189 [181].

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.

These detailed procedures and Fire Protection Program (TD-6) [96] constitute an integral part of the plant operating procedures.

3.2.3.1 Overview of Firefighting Strategies, Administrative Arrangements and Assurance

Upon a fire alarm, as for every alarm in the MCR, operators act in accordance with the Alarm Response Procedure ARP-3.329 [114], which instructs them on how to confirm the alarm, and provides basic background, requires immediate steps and directs operators to suitable further procedures.

In case of fire the procedure FPP-3.7.002 "Fire response procedure" [8] is entered by MCR operators and also by firefighters in their office. That procedure provides organisation of staff and initial steps that need to be performed (communication between MCR operators, firefighters, guards, off-site fire brigade, Radiation protection).

Guidelines and information for firefighters to combat fire are prepared in "Fire Plans" DCM-TD-023 [83], DCM-TD-024 [110] and DCM-TD-037 [111]. These fire plans are located at firefighters office, in firefighter's vehicles, in MCR and at local municipal Fire brigade.

MCR operators enter also the procedure FRP-3.9.100 "Operators response in case of fire [9]" [9], that provides instructions on how to adapt operation of the plant to cope with the fire. It provides information about safe shutdown equipment that could be jeopardized in case of fire in certain room.

Firefighting capabilities are controlled through conduct of several processes, which are part of plant surveillance procedures and include:

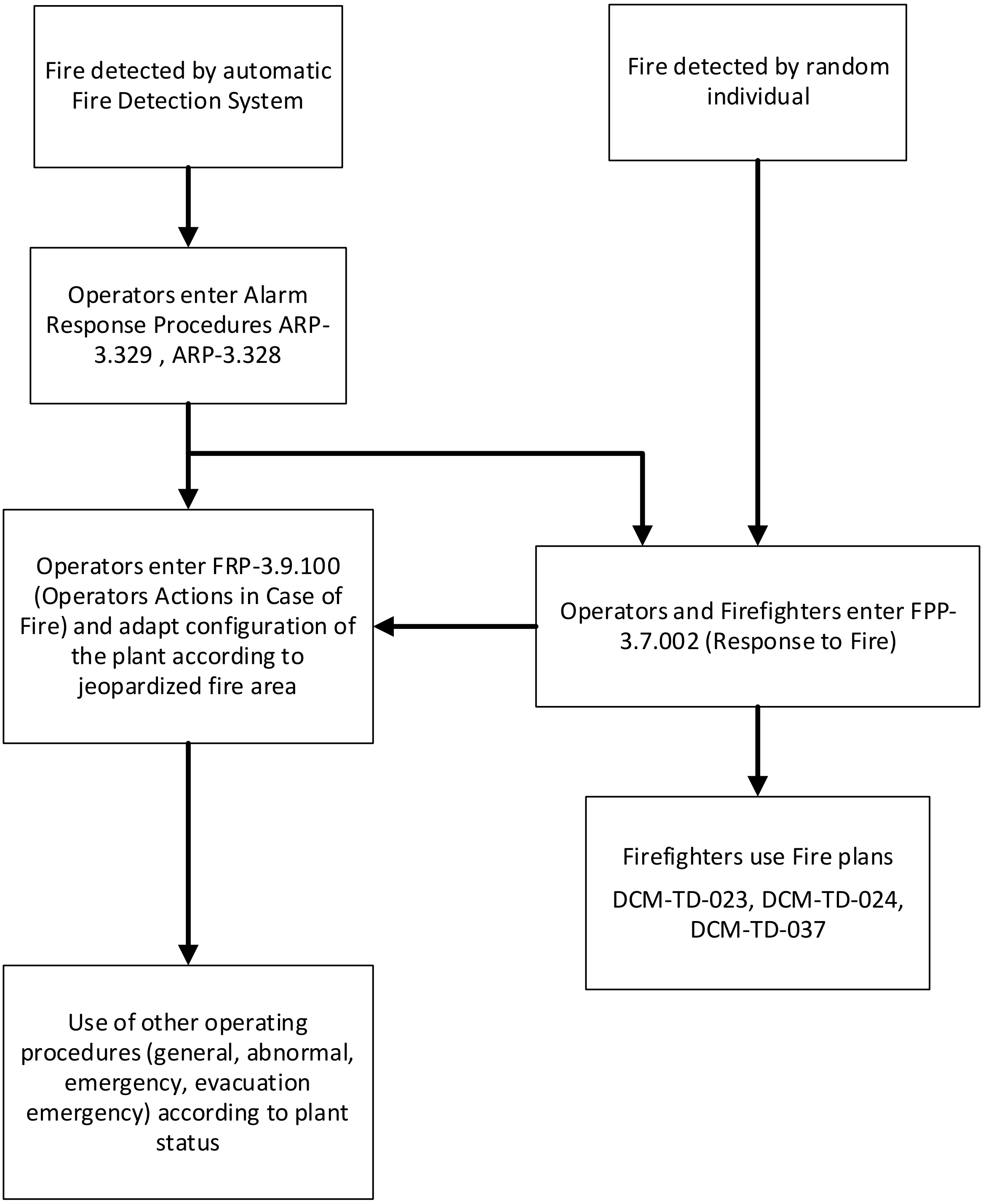
- Operating surveillance testing of fire detection systems, fire extinguishing systems, water supply system;
- Inspection of fire barriers including walls, floor, ceiling, fire-doors, fire resistant penetrations, fire dampers and fire barriers;
- Inspection of fire hose stations and hose testing;
- Inspection and testing of mobile fire protection equipment (pumps, trucks, hose trailers);
- Third-party inspection/testing of "active fire protection" including fire detection, fire extinguishing systems, fire water supply system;
- Aging management of fire protection system piping (program QD-5 [113]).

Information about fire is provided to the MCR operators by the automatic Fire Detection System which covers all parts of the plant or by random individual which might have detected initial fire before automatic detection system has been triggered. Depending on this the use of procedures for response to fire can differ slightly. The initial entry into procedures in case of fire is presented in Figure 47.

Figure 45: Operational Testing of Main Transformer Fire Extinguishing System

Figure 46: Testing of MCR Charcoal Filter Fire Extinguishing System

Figure 47: Entry into Procedures in Case of Fire



3.2.3.2 Firefighting Capabilities, Responsibilities, Organisation and Documentation Onsite and Offsite

The basic team of firefighters, which is present at the plant 24/7 consists of three professional firefighters.

Their leader is employed by the plant and has professional firefighting skills also in addition to basic technical knowledge about plant systems and operation. He is annually examined to fulfil medical requirements for firefighting activities. The other two firefighters in the team are hired professional firefighters from the local fire brigade and are familiar with the plant buildings and rooms.

Organizational interfaces with External/Corporate support

Krško NPP has a contract with the local fire brigade PGE Krško. Beside the two professional firefighters from the local fire brigade that are present on-site 24/7, additional three professional firefighters are available 24 hours per day at the local fire brigade (2 km from the plant) and have a response time of less than 10 minutes. Additional 10 professional firefighters are available on-call with a response time of 30 minutes and additional 20 firefighters within 60 minutes.

The two firefighters from the local fire brigade are rotated based on a shift system agreed upon with the municipal professional fire brigade in Krško. With this system in place, detailed knowledge of the local situation in Krško NPP and daily experience of the firemen with real fires are maintained simultaneously.

Off-site public firefighters are qualified and trained to work at the plant in accordance with the TD-6 program [96]. Besides plant-employed firefighters, offsite firefighters are likewise permanently deployed on site as fire watch and for testing of fire protection equipment and systems. Thus, they are familiar with the plant buildings, equipment, procedures and personnel. On the other hand, these firefighters gain experience in more frequent real fires and other events that occur off site. After two weeks of shift at the plant, off-site firefighters go back to their normal shift at the public fire station. According to this all the individual off-site firefighters work at the plant for two weeks every three months.

The local fire station is equipped with updated NPP fire plans and with the plant's hand-held radio stations to establish immediate information exchange in case of emergency.

Regularly updated Fire response procedure FPP-3.7.002 [8] is kept in the MCR and at Firefighters' office. Fire plans are regularly updated and distributed to the MCR, Firefighters' office and also to the local Fire brigade.

Fire protection training:

An important segment of fire prevention is achieved by education of the plant staff, which is performed depending on the individual's profile/role.

Fire protection training is performed in accordance with procedure TD-6 "Fire Protection Program" [96].

All employees receive fire protection training appropriate to their responsibilities. There are several groups of employees:

- Administrative sector personnel or personnel who do not work in the technological part of plant are trained in fire prevention and in the use of portable fire extinguishers (training is performed every 3 years);
- Technical sector personnel are trained in fire prevention and in use of portable fire extinguishers (training is performed every 2 years);
- Local operators are trained annually in fire prevention, the use of portable extinguishers, fire hydrants, self-breathing apparatus, fire suppression systems;
- Professional firefighters from Krško NPP and the local fire brigade are trained once per year in fire prevention, use of fire suppression systems, portable extinguishers, fire hydrants, self-breathing apparatus, communication, fire plans, personal protective equipment, firefighting;
- Fire protection squad personnel are trained to use fire suppression systems, portable extinguishers, fire hydrants, personal protective equipment fire brigade equipment, firefighting, once per year;
- Fire watch personnel are trained for fire watch and use of fire extinguishing equipment.

Fire protection drills are performed in accordance with procedure FPP-3.7.018 "Performance of fire drills" [115]:

- at least four drills for each fire brigade shift per year (minimum of 16 drills in total);
- at least one drill per year shall be unannounced;
- at least one drill per year shall be performed with additional call of the local fire brigade;

- at least one set of drills per year shall be performed with the fire protection squad.

A fire drill scenario is prepared for each drill and includes instructions for participants and observers. The main objectives of fire drills are to force the proper use of protective equipment, firefighting techniques, fire plans, communication, coordination of off-site firefighters, knowledge of hazards and important equipment at the site. Acceptance criteria are defined in the scenario. After completion of a fire drill, a report is prepared and analysis performed. Conclusions are communicated with all participants and deficiencies recorded in the Corrective Action Program.

Figure 48: Fire Drills at Krško NPP

Figure 49: Fire Drill at National Firefighting Education Center

3.2.3.3 Specific Provisions, e.g. Loss of Access

Firefighters' access routes are of crucial importance for successful intervention. They are marked with yellow paint on the pavement. The configuration of roads around the plant in general provides two access routes to all points of the plant. Access routes are presented in DCM-TD-023 (Technological part of the plant) [83], DCM-TD 024 (Non-technological part of the plant) [110] and DCM-TD-037 (Large fires at plant area) [111].

If any need arises to put an obstacle on firefighters' route (e.g. maintenance work must be performed with crane that would stand on the route), a fire permit must be issued in advance and approved by fire protection department. In that case an alternate access route is defined.

In case of inaccessible route for the off-site fire brigade an alternate route is defined (and checked periodically) that enables off-site firefighters to reach the site in prescribed time frames.

At any unexpected blockage of an access route (e.g. fallen objects after seismic event), a tractor with plough and winch would be used to make way for intervention equipment. Firefighters are trained to use the tractor with plough.

Manual fire suppression capabilities were analysed and fire brigade response times estimated in document "PSA of NPP Krsko Internal Fire Analysis" [174]. The analysis showed that according to the established Fire Detection System, plant configuration, fire organization and training, probable fires in all critical areas would be extinguished in less than 30 minutes per a conservative scenario.

3.3 Passive Fire Protection

Passive fire protection features represent the third level of defence-in-depth principle which assumes that prevention and extinguishing of fire were not successful. The main purpose of a passive fire protection is to prevent the spread of fire from one affected area/equipment to another thus limiting the amount of damage.

A compartmentalisation principle is used to separate the plant to independent fire areas. SSCs important to safety are designed and located to minimize the probability and effect of the fire. The concept of compartmentalization uses passive fire barriers to subdivide the plant into separate fire areas. Their primary purpose is to confine the effects of fires to a single compartment or cell, thereby minimizing the potential for adverse effects from fires on redundant SSCs important to safety.

FHA provides the realistic fire loading that each fire compartment needs to withstand. The location of the SSCs important to safety that are relied upon to ensure post-fire safe shutdown and minimize radioactive release is provided in FHA. According to this, adequate fire compartment rating was defined to ensure adequate fire separation for the SSCs important to safety.

Systems and equipment required for safe shutdown are identified in the Krško NPP Separation Analysis. Fire hazards have been identified and a FHA has been prepared on a fire area basis. Administrative controls are implemented to maintain these analyses consistent with the plant configuration, and plant design changes are reviewed prior to implementation to assess their impact on these analyses.

3.3.1 Prevention of Fire Spreading (Barriers)

Fixed fire loads are controlled in FHA and margins are set for each fire area. The criteria for setting those margins are resistance of fire barriers in a fire area. Additional (transient) fire loads are controlled within a process (per ADP-1.1.105 [61]) which considers allowable fire load margins for each fire zone. Thus, control is established not to exceed the combined (fixed and transient) quantity of flammable material in a room.

The barriers (walls, floors, ceilings, fire dampers) which define the plant fire areas serve to separate the areas from fire hazards in adjacent areas. The use of combustible materials in safety-related equipment areas is minimized. The predominant combustibles are lubricating oil, diesel generator fuel, and insulation on electrical cables. Fire barriers are evaluated using a combustible loading methodology to verify that such structures are capable of containing a fire that consumes all combustibles within a given fire area. Any margins that remain could be used for potential transient combustibles in the area without exceeding allowable combustible load. Potential transient fire loads are controlled within a process (per ADP-1.1.105 [61]) which considers allowable combustible load margins for each fire zone and prevents overload of combustible material in a fire area.

3.3.1.1 Design Approach

In addition to the Fire Protection System itself, there are many design features of the plant which would also contribute to confining and limiting a fire condition. The building structures are constructed of fire resistive concrete. The power plant is divided into several buildings that are separated from each other by three-hour fire walls. Buildings are further divided into Fire Areas and Fire Zones in accordance with FHA [3].

In addition, stair towers in all but the reactor building, are enclosed with fire-rated walls. Extensive vertical runs of cables, ducts, and pipes are either enclosed in shafts with all shaft openings sealed with a non-combustible fire rated material or all openings around cables, ducts, and pipes passing through major floors are sealed with a non-combustible fire rated material.

Thermal insulation of piping, tanks, ducts and other equipment is made of non-combustible material or material with limited flame-spread rating in accordance with NFPA 255 [116].

Insulation and jackets of electric cables are made of fire-retarding and non-propagating material and meet IEEE-383 flame test requirements [117].

Large oil filled transformers are located outdoors so that a fire would not damage the plant buildings. In addition fire barrier walls are located between individual transformers and between the transformers and any air louvers in the walls of the turbine building. This limits a fire condition to only a single transformer without affecting the turbine building interior or an adjacent transformer. Collection tanks are provided under the transformers to collect oil and thus also prevent the spread of fire.

3.3.1.2 Description of Fire Compartments and/or Cells Design and Key Features

Krško NPP buildings and structures containing components and systems important to safety are of reinforced concrete construction. The materials of constructions are non-combustible, and afford a high degree of resistance to the effects of postulated fires. The plant configuration subdivides the unit into numerous fire areas containing safety-related equipment. The fire barriers (walls, floors, and ceilings) which separate these areas, isolate the areas from fire hazards in other areas. Specifically, the plant is divided into several buildings that are separated from each other by three hour rated fire walls. These buildings are:

- Reactor Building
- Auxiliary Building
- Control Building
- Fuel Handling Building
- Intermediate Building
- Diesel Generator Building
- Turbine Building
- Health Physics/Control Point Building
- Component Cooling Building
- Essential Service Water Building
- Decontamination Building
- Bunkered Building 1
- Bunkered Building 2
- Waste Manipulation Building
- Dry Storage Building

Stair towers in all but the Reactor Building, are enclosed with the rated fire walls. The two emergency diesel generators are separated from each other by a rated fire wall, while the third DG is located in a separate dislocated bunkered building. The turbine lube oil reservoir and lube oil conditioning equipment are in a room which is separated from other areas of the Turbine Building by rated fire barriers. Extensive vertical runs of cables, ducts, and pipes are either enclosed in shafts with shaft openings sealed with non-combustible fire rated materials and openings around cables, ducts, and pipes passing through major floors are generally sealed with non-combustible fire rated materials.

Any openings (penetrations) in fire area boundaries (walls, ceiling, floor) are sealed with material, structure or device that prevents the spread of fire with the same resistance as it is demanded for the fire area. These seals include:

- Fire doors
- Fire dampers
- Fire penetration seals

Fire doors are installed in accordance with the NFPA-80 standard, maintained to ensure adequate operation, and surveilled to ensure nearby components do not interfere with operation. Their closing function when not being used for access/egress is inspected on a daily basis per procedure OSP-3.4.181 [98].

Fire dampers are installed in accordance with the NFPA 90A and UL555 standards, maintained to ensure adequate operation, and inspected once per refuelling cycle per procedure OSP-3.4.591 [119] to ensure clean operating components within the respective duct so as not to interfere with operation.

Openings through the fire barriers for pipe, conduit, and cable trays that separate fire compartments are sealed to provide a fire-resistance rating at least equal to that required of the barrier itself. Penetration seals are installed per approved procedures in accordance with the tested configuration and surveilled to ensure environmental or physical characteristics are maintained per procedure OSP-3.4.590 [97].

The walls, floors, and ceilings which form barriers to separate fire areas are of heavy reinforced concrete construction. Fire doors, frames, and hardware, where provided, meet the fire resistance rating required by the hazards in each area. Fire barrier penetrations (electrical, piping, HVAC) are sealed using designs that are expected to provide significant fire resistance capability. Fire dampers, where installed, are UL-listed or tested in accordance with equivalence standards. Electrical penetration seals consist of silicone foam.

3.3.1.3 Performance Assurance Through Lifetime

All fire-rated assemblies (walls, floor/ceilings, cable tray enclosures, and other fire barriers) separating fire areas or separating portions of redundant systems important to safe shutdown within a fire area and all sealing devices in fire-rated assembly penetrations (fire doors, fire windows, fire dampers, cable, piping, and ventilation duct penetration seals) are inspected periodically to prove their operability per surveillance procedures OSP-3.4.181 [98], OSP-3.4.590 [97] and OSP-3.4.591 [119].

Each fire wall, ceiling and floor are inspected once per refuelling cycle to be without cracks or holes.

At least 10% of each type of sealed penetration is inspected once per refuelling cycle. A seal must be integral, without holes or cracks, the gap between the seal and wall must not exceed 6 milimeters and sealant material must not be hardened. If apparent changes in appearance or abnormal degradations are found, a visual inspection of an additional 10% of each type of sealed penetration is made. This inspection process shall continue until a 10% sample with no apparent changes in appearance or abnormal degradation is found. Samples are selected such that each penetration will be inspected every 15 years.

At least 33% of fire barriers between cable trays is inspected every refuelling cycle. Fire barrier plates must keep integrity without cracks or missing pieces.

Fire insulation (wrapping) of cables, cable trays, conduit and ventilation ducts are inspected every refuelling cycle to be without degradation or cracks and insulating material must be firmly attached to the protected structure.

Fire doors that are locked closed are checked to be closed once per 7 days. Each unlocked fire door without electrical supervision is checked to be closed at least once per 24 hours.

The operability of each fire door is tested once per 6 months. Integrity, tightness, gaps, cracks and any potential damage are checked and locking and closing mechanisms tested.

Fire dampers in ventilation ducts are inspected once per refuelling cycle. Cleanliness and integrity of damper mechanism is inspected, and proper installation of the fuse is checked.

3.3.2 Ventilation Systems

The ventilation systems, installed at the Krško NPP maintain the environmental conditions of various spaces where safe shutdown equipment is located. Separate Fire Hazard Analysis for Heating, Ventilation and Air Conditioning (HVAC) was performed in Krško NPP (Report DCM-TD-039 [120]), which evaluated ability of the HVAC systems to support safe plant shutdown, prevent fire propagation, and prevent release of radioactive material in case of fire.

3.3.2.1 Ventilation System Design: Segregation and Isolation Provisions (as applicable)

The air conditioning, heating, cooling and ventilation (HVAC) systems, installed in the NPP Krško are designed in respect to fire protection principals in accordance with applicable National Fire Protection Association (NFPA) standard [81]. Fire prevention and mitigation is included in the design of the HVAC system. Fire dampers provide passive fire protection for barriers, and they limit the spread of fire from one area to another by their automatic closing when exposed to heat. In addition, the ventilation ducts themselves, provided as part of the ventilation system, offer an effective barrier (limited for low fire exposures) when subjected to fire exposures. These systems are designed to accomplish the following:

- Provide sufficient redundancy in active system components, duct systems, control and power supplies to satisfy the single failure criterion.
- Maintain the required ambient air temperatures in all plant areas for environmental requirements of equipment and for habitability by plant personnel.
- Adequately meet the radiation control requirements of 10 CFR Parts 20 and 50 (where the charcoal filters are installed), ensure the safety of plant operating personnel in various plant areas, and ensure that the gaseous radioactivity emission to the environment is kept to as low a level as practicable and below permissible discharge limits.

The ventilation systems related to the areas where the Safe Shutdown equipment is located, and the whole Krško NPP were designed to provide sufficient redundancy in active system components, duct systems, control, and power supplies to satisfy the single failure criterion and perform their safety functions. The fire areas, where the HVAC systems are located and the fire areas served by the HVAC systems are arranged so that each fire area fulfils its purpose of separation in the event of a fire. The systems redundancies assure that either of the two sub-system trains (fan, plenum or air-handling unit) is capable of fulfilling the system functions. Parts of the ventilation system (e.g. connecting ducts, fan rooms) that are located in an adjacent fire compartment have the same fire resistance rating as the compartment, and the fire compartment penetrations are mostly isolated by appropriately rated fire dampers (deviations are identified in FHA [3]), which operate automatically and close when the temperature in the duct reaches the melting point of fusible links, installed in fire dampers. In the case where the ventilation system serves more than one fire compartment, the separation between the fire compartments is achieved by installed fire dampers at the boundaries of each fire compartment and fire-resistant ducts to prevent the spread of fire, heat or smoke to other fire compartments.

Fire and smoke safeguards have been provided through the Fire Detection System (instrumentation and monitoring devices including intelligent design smoke detectors) in each system to provide alarm in MCR, Fireman brigade office and in ECR upon indication of high smoke levels; as well as multiple temperature detectors in each system plenum to alarm in MCR so that plenum water sprays can be manually initiated from the control room upon indication of high temperature.

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. Smoke removal provisions are provided for various plant areas; the HEPA filters and radioactive monitoring capability are provided in the ventilation systems for areas containing radioactive material.

The penetrations through the fire barriers are closed with non-combustible and fire-rated materials, the doors are fire-rated and fire dampers are mostly installed where the ventilation ducts penetrate the fire barriers, in accordance with NFPA 90A standards [81]. The fire barriers and fire-rated doors in Krško NPP are controlled through applicable Krško NPP procedures [97] and [98].

The general design objectives of HVAC systems with respect to radiation protection are to ensure that maximum airborne radioactivity levels for normal and emergency conditions including anticipated operational occurrences are within the limits of national regulations, for areas within the plant structures and to provide a suitable environment for continuous occupancy of the personnel in the main control room and emergency control room under normal and post-accident conditions in accordance with 10 CFR 50, Appendix A, Criterion 19. In order to meet the design objectives related to radiation protection, the HVAC systems in Krško NPP, for area where the radioactive material exists, are designed to reduce the on-site and off-site radiation levels so that potentially radioactive material is released only after passing through the roughing, HEPA and charcoal filters.

All charcoal absorber plenums, installed in the HVAC systems where necessary, are physically separated so that a single local fire or accident cannot affect more than a single unit of a particular system and charcoal plenums are shielded for radiation protection of plant personnel. All charcoal plenums are provided with fire protection systems which include internal temperature detecting devices in the charcoal bed and in the plenum space and manual spray water deluge systems. High temperature in the plenum is alarmed to the control room. The plenum spray water deluge system is manually actuated from the control room or at the plenum respective water spray system control panel.

Based on the initially performed FHA and FPAP [4], some gaps regarding the requirements based on the original design where the strict separation of Safe Shutdown equipment was not respected due to the design limitation. Since the Krško NPP does not cover HVAC systems, the gaps related to HVAC systems are not identified, but in scope of implementing design changes, including SUP, the most important discrepancies were resolved, including proper separation between HVAC trains in Electrical rooms, Battery rooms and Turbine AF pump room. However, some discrepancies still exist, but by implementing SUP, equipment and systems that would become inactive due to an inoperable HVAC system have an alternative to achieve their function, as described in Section 2.

3.3.2.2 Performance and Management Requirements under Fire Conditions

Since, the current revision of FHA [3] does not cover the HVAC systems and does not address their operability in case of fire, a separate report was developed DCM-TD-039 [120], which evaluate the HVAC systems which could be needed to support post-fire shutdown. The HVAC systems were selected as support systems for the systems and equipment needed for Safe Shutdown, and based on the Safe Shutdown Analysis [3] and on the NPP Krško specific configuration, as described in detail in Section 2.1.2.6.

All selected HVAC systems that service areas that contain safety-related equipment, are designed as a redundant system, where either of the two system trains is capable of fulfilling the system functions. Provision of redundant system components, redundant distribution ducts where required, and safety-related power supply ensures that any single failure of an individual component will not prevent the system from performing its required safety function in accordance with the design bases.

During normal operation, one of each redundant train operates continuously, while the other train is in stand-by mode. In case of fire event, which could affect one train of HVAC system, the spread of fire, heat or smoke to other fire compartments is prevented by system's design, ventilation duct layout, by installed passive fire protection (fire dampers, sealed penetrations in the fire barriers, fire-rated doors and fire-resistant ducts) and by control of combustible materials.

If the one train of the HVAC system is affected by fire, the operators will be immediately warned through alarm (smoke alarms are provided on the MCR Fire Protection Panel, at the Fireman brigade office and in the ECR) to start the implementation of the appropriate procedure [9], to stop affected and start the other train or perform any other action needed to maintain required condition in the areas where the safe shutdown equipment is located.

Additionally, smoke removal system is provided for MCR and Electrical Rooms, while the other areas with the potential for smoke introduction from adjoining areas may be rendered uninhabitable, but their habitability is not required for safe shutdown. In case of a fire event that causes introduction of smoke into the MCR, the MCR ventilation system can be placed into a purge mode of operation through the Control Building Relief and Exhaust System. The fresh-air intakes that supply air to safety-related areas in the MCR are independent of the exhaust air outlets and smoke vents of other fire areas.

Some HVAC systems, installed in Krško NPP (in Auxiliary Building and Fuel Handling Building), are designed as cascade HVAC systems, to provide a suitable environment for personnel and equipment by ensuring temperature control, exhausting airborne contamination and by providing isolation between potentially contaminated areas and clean areas. Principal features of the systems include separate low and high activity exhaust, progressive flow of air from areas with low radioactivity levels and/or low thermal loads to areas with potentially higher activity levels and/or thermal loads and the ability to maintain the building spaces at a negative pressure with respect to the outside. Maintenance of negative pressure in the building spaces ensures inward leakage and prevent exfiltration of contaminated air to the outside. In order to maintain a negative pressure in the building spaces, a differential pressure transmitters are provided to sense the corridor static pressure and the outside barometric pressure and provide a modulating signal to the inlet vane controllers. When the differential pressure exceeds the pre-determined value of negative pressure, the alarm will be annunciated in the MCR and necessary actions follow in accordance with corresponding ARP procedure to establish normal condition in the affected areas.

3.4 Licensee's Experience of the Implementation of Fire Protection Concept

In general, operating experience and lessons learned are integrated into the Corrective Action Program (CAP). Each external event is analysed and actions for preventing a similar event is defined for events which are applicable for Krško NPP.

Krško NPP Fire Hazard Analysis [3] was revised in the 1990's in accordance with 10CFR50, Appendix R [43].

That analysis considered the effects of fire on the plant equipment and identified methods for achieving safe shutdown. The fundamental assumption made in this analysis was that a single fire occurs in any plant area coincident with a complete 72-hour loss of offsite power. However, offsite power was assumed to be present for those situations where availability of offsite power could have adversely impacted safe shutdown. All equipment normally present in the plant was assumed to be functional at design capability and may be lost only as a result of fire damage. No other external events, accidents, or equipment failures were assumed to occur in connection with either the postulated fire or through achieving a stable cold shutdown condition.

Several weaknesses were found and an action plan was set to improve Fire protection at the plant as described in 2.1.6.1.

Organizational changes included: the RO licensed engineer is assigned for the Fire Protection Program; professional firefighters receive additional training; outsourced firefighters are included in the training and activities at the plant; operation shift workers (5 per shift) are trained for firefighting activities; additional group of 20 “volunteer” firefighters (members of different organizations) are trained for firefighting.

A Fire Detection System was installed in all rooms with safety equipment and a redundant fire detection terminal was installed in the firefighters’ control room.

Additional 8-hour emergency lighting was installed to facilitate safe shutdown of the plant in case of fire or another situation.

Safe Shutdown Capability Analysis was performed and consequential Krško NPP Fire Protection Action Plan was derived. This included cable rerouting, cable wrapping, installation of additional automatic fire extinguishing systems, additional fire detection systems, fire barriers, control circuits isolation and installation of additional controls for safe shutdown capability. These modifications improved the Core Damage Frequency (CDF) almost by factor of 10.

A list of improvements that arose from various missions and inspections is presented in 3.1.3.2.

A large scale Safety Upgrade Project was performed, which significantly improved not only resilience of the plant to low-probability accidents but also its response to fire at safety systems. The improvements include:

- Alternative auxiliary feedwater system
- Alternative residual heat removal system
- Alternative spent fuel cooling system
- The use Emergency diesel generator DG3 as an independent power supply to alternative equipment or as a substitute for DG1 or DG2;
- The control of the plant from Emergency Control Room or the use of ECR as alternative way to control the plant using alternative equipment and independent instrumentation.

The benefits of this project are incorporated in the Fire Hazard Analysis [3].

3.5 Regulator’s Assessment and Conclusions on Fire Protection Concept

SNSA inspectors are organized in the Radiation and Nuclear Safety Inspection Service, i.e. one of the units of the SNSA. When appropriate other SNSA staff is involved in the inspection process (e.g. fire safety/protection expert).

The SNSA management system addresses the inspection as one of the core processes. The process is based on the Annual Inspection Plan, i.e. plan addressing inspection activities of the SNSA inspectors. Preparation of the plan is documented and realization of the Plan is followed. Preparation of the Plan is a legal obligation.

The fire safety of the nuclear power plant is also an important part of the inspection plan. A few inspections on the topic of fire safety are carried out annually (1 to 3 inspections per year and one inspection with the participation of a inspectors for protection against natural and other disasters (fire inspector) every two years).

Liaisons with other inspections is exercised on a regular basis. In particular, joined inspections are exercised when inspecting fire protection and emergency preparedness managed by the NPP Krško. Inspectors for protection against natural and other disasters cooperate with SNSA inspectors in supervising the implementation of regulations regulate the planning and implementation of fire protection measures in individual areas or activities.

As a consequence of fire protection action plan, proposed risk-based plant modifications were implemented as described in chapters above.

As a response to Fukushima accident, Krško NPP upgraded safety with availability of mobile equipment and with the Safety Upgrade Program. Within the program, additional emergency control room was constructed to shut down and cool the plant from alternative location in case of evacuation from main control room. This safety upgrade was beneficial from the fire risk, as fire in MCR.

After the implementation of the Krško NPP's safety upgrade program (SUP), which included installation of an independent safety train (separated physically and electrically) in a dislocated bunkered building, as well as installation of the ECR, from where operators can control the plant (shut down and cooldown the reactor as well as manage design based accidents), 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.

3.6 Conclusions on the Adequacy of the Fire Protection Concept and its Implementation

The fire protection concept in Krsko Nuclear Power Plant is based on the defence-in-depth principle as expected per international standards and is in compliance with national regulations.

All three levels of protection are achieved by the design of systems, structures and components; managed by organisational measures and covered by operating, surveillance and administrative procedures.

Periodic assessments of fire protection are performed at different levels. Self-assessments of the Fire Protection department, periodic revisions of the Fire Hazard Analysis, internal audits performed by the Quality Assurance department, external audits performed by national inspectors and international institutions (WANO, IAEA, Insurance Pools), reveal occasional impairments and suggest improvements, which are satisfactorily taken into account and contribute to the increasing level of overall fire protection at the plant. Significant improvements have been achieved in the last three decades.

Low numbers of fires and minor fire events show that Fire prevention is at a high level, though the efforts to continue with improvements shall not be reduced.

4 Overall Assessment and General Conclusions

4.1 General Assessment

Fire Protection Systems in Krško NPP are designed to provide adequate fire protection from all known fire hazards. The Fire Protection System cannot always prevent a fire from occurring but does provide the facilities available for detecting and extinguishing fires in order to limit the damage caused by a single fire.

The Krško NPP Fire Protection Program TD-6 [96] defines strict rules and organization of the Fire protection measures, controls and activities. It also defines the rules for the fire prevention and response to fire events.

Part of fire prevention measures in Krško NPP is achieved with the design of systems, structures and components. Where practical, non-combustible materials were used to prevent the occurrence of fire, its spreading and consequential loss of safety functions. Technical specifications which were followed during the original design and later upon all the operating life-time during the maintenance and modification processes require the use of fire-retarding and non-propagating material for cable insulation and also non-combustible material for thermal insulation of piping, tanks, ducts and other equipment.

Apart from being included in the plant structural design, fire prevention is of a high concern in performing operation, maintenance and modification activities at the plant. Several processes (such as limitation of usage of wood, minimization of the transient combustible, control of works related to the heat sources, fire patrols, Fire brigade organization, etc. as stated in Chapter 3.1.2) were established to minimise the amount of fire loads present at the plant and also to minimise ignition sources and the probability for a fire event to occur during operation and plant activities. Housekeeping at Krško NPP is one of the priorities of the plant. This policy was accepted a long time ago and one of the reasons was to ensure all the activities on the field can be performed in a safe and controllable working environment.

In addition to the Fire Protection System itself, there are many design features of the plant that would also contribute to confining and limiting a potential fire condition. The building structures are constructed of fire resistive concrete. The power plant is divided into several buildings that are separated from each other by three-hours fire walls. Most of the redundant safety related systems needed for shutdown and cooldown of the plant are located in separated fire areas with adequate fire protection provisions (e.g., fire rated walls, ceilings, doors, etc.). Likewise, the two emergency diesel generators are separated from each other by a two-hour fire rated wall, and the third totally independent diesel generator, which was installed as a result of the first Krško NPP Periodic Safety Review performed in 2003, is located in a separate bunkered building. All new buildings built in the last few years (as part of SUP), regardless if they are hosting the safety equipment or not, were are also built in the accordance with all fire-related requirements (structure, resistance, fire protection, etc.).

Extensive vertical runs of cables, ducts, and pipes are either enclosed in shafts with all shaft openings sealed with a non-combustible fire-rated material, or all openings around cables, ducts, and pipes passing through major floors are sealed with a non-combustible fire-rated material. There were also other recommendations and requirements followed during the original design for other equipment like large oil filled transformers, which are located outdoors so that a fire would not damage the plant buildings. In addition, fire barrier walls are located between the individual transformers, as well as between the transformers and any air louvers in the walls of the turbine building. This limits potential fire condition to only a single transformer without affecting the turbine building interior or an adjacent transformer. In addition, the oil spilling reservoirs (pools) will prevent the potential uncontrolled oil spreading.

Originally the plant Fire Protection Systems were designed in accordance with the intent of the requirements for fire protection for nuclear plants established in:

1. The National Fire Protection Association (NFPA) - National Fire Codes.
2. International Guidelines for the Fire Protection of Nuclear Power Plants (Published by the Swiss Pool for the Insurance of Atomic Risks on behalf of the National Nuclear Risks Insurance Pools and Associations).

Expert missions of the Insurance Pool's Fire protection area are conducted every 4 years to review the current situation on the fire safety and to give recommendations for improvement for that area.

In addition to and in compliance with the above listed standards and guidelines, all the United States manufactured fire protection equipment is approved for fire protection use by Underwriters' Laboratories Inc. (UL) or Factory Mutual Engineering Corp. (FM). Where, during the initial construction in the state of Yugoslavia, the Yugoslavian manufactured equipment was provided for fire protection, that equipment met all performance requirements of the applicable NFPA Standards and applicable Yugoslavian fire protection standards. All needed upgrades and modifications (e.g. the replacement of the Krško NPP Fire protection underground hose system, the installation of additional sprinkler systems, the renewal of the Fire Detection System, etc.) followed applicable NFPA and Slovenian applicable rules. The Fire Protection Systems are a Non-Safety Class system with the exception of the containment penetrations. However, it is designed in a way that the operation or failure of any portions of the Fire Protection System does not produce an unsafe condition.

In the past, the Krško NPP's was exposed to several international expert missions, whether dedicated or partially dedicated to fire protection assessment. The recommendations and findings of such missions were always respected and followed, which resulted in many implemented improvements that have further enhanced the Fire protection Program in Krško NPP.

It is required by the law to perform Periodic safety reviews every 10 years, in order to confirm that the plant is safe as originally intended, to determine if there are any structures, systems or components that could limit the life of the plant in the foreseeable future, to compare the plant against modern safety standards, and to identify where improvements would be beneficial at justifiable costs. All improvements (in program and systems) ensure the Fire response capabilities have been continuous improved.

All modifications over or including the Fire Protection systems are treated as an Augment Quality and special quality requirements are listed during the design and purchasing. The QA Department is included in such modifications by the Modification Procedure (See Ref. [103]).

4.2 Fire Safety Analyses

4.2.1 Krško NPP's Deterministic Fire Hazard Analysis

First Fire Hazard Analysis (FHA) Ref. [3] was implemented in the early 90's. In general, the evaluation of Krško NPP Fire Protection Program and systems was done from the perspective of Slovenian and U.S following Fire Protection rules. The following was included in the first revision covering the current situation at that time:

1. Compliance with requirements stated in the BTP APCSB 9.5-1, Appendix A "Guidelines for Fire Protection for Nuclear Power Plants" [127]
2. Safe Shutdown Analysis in accordance with 10CFR50 Appendix R [43]

The safe shutdown systems selected for Krško NPP for initial FHA shall be capable of achieving and maintaining subcritical conditions in the reactor, maintaining reactor coolant inventory, maintaining reactor coolant pressure control, removing decay heat, achieving cold shutdown condition within 72 hours, and maintaining cold shutdown conditions thereafter.

Initially prepared FHA demonstrates the Krško NPP ability to ensure the general compliance with the NRC regulation and demonstrates compliance of Fire Protection Program with requirements and ability to implement the plant shutdown and cooldown capability in the case of the fire in any of plant fire areas. The fire hazard analysis for the Krško NPP was carried out, and kept updated to demonstrate that the fire safety objectives for the plant are met through the fire design principles satisfied, and that the fire protection measures are appropriately designed, and any necessary administrative provisions are properly identified and implemented. By the Law the FHA has to be reviewed every 2 years to reflect as-built situation. Most of the changes incorporated in the FHA were caused due to the extensive upgrading of the plant's SSCs, but some were also related to the changes in the programs, procedures, etc.

The first (initial) revision of FHA also shows some gaps regarding the requirements based on the original design where the strict separation of Safe Shutdown equipment was not respected due to the design or construction limitations. The Krško NPP's Fire Protection Action Plan [12] was prepared (see also section 2.1.5) based on the probabilistic approach to quantify the identified gaps (particular fire areas which appears not to be in compliances). Until the end of the 90's the identified more important gaps were eliminated by (in most cases) implementing the design changes. The prioritization of design changes (elimination of gaps) was done based on CDF for the fire areas where the threshold for the elimination of the particular gap was evaluated as an impact on the common CDF for more than 10 E-6.

Based on FPAP [12], different design changes, organizational and procedural improvements were implemented, as described in detail in Section 3.1.3.3.

Since then, all planned changes have been evaluated also from the perspective of the Fire Protection requirements and have been revised by the Krško NPP FHA engineers to reflect the as-built situation regarding the fire protection requirements and current plant configuration measured by the calculated impact on the Core Damage Frequency if applicable. Based on FHA, also the first revision of Fire response procedures was prepared, which was not significantly changed until the implementation of SUP [55].

Central Fire detection system was migrated to FP SCADA located in MCR, ECR (added recently during the ECR project) and at the Fireman centre which provides all additional information and alarms to the Fire brigade members and to the MCR staff. Years ago, the FP SCADA data link was established to the Process Information System (PIS) where all addressable fire detectors will be shown (if actuated) to each PIS working station (to any operator).

Based on the Fukushima accident in 2011, SNSA issued an article where a severe accident analysis and preparation of a programme of safety upgrades was demanded. The first response on the Fukushima (in the time span less than 6 months) was however to ensure the mobile equipment was purchased primarily for the following roles:

- Mobile equipment as an alternative equipment for Safe Shutdown* and
- Mobile equipment for Firefighting (additional mobile pumps, truck with the water cannon etc.).

Note:

- (*) Many minor modifications have been implemented on different Plant system to ensure connection points for the mobile equipment to the plant systems (See section 3.1.3.3)

Procurement of the mobile equipment in combination with all procedural changes (new procedures were prepared for the mobile equipment) at that time ensure Krško NPP was able to close completely the Action Plan regarding the events of 11 September 2001 and potential terrorist attacks on nuclear facilities.

Krško NPP carried out an in-depth analysis of beyond design-basis accidents and the Safety Upgrade Programme has been developed to evaluate the response of the plant to BDBA and to propose the measures and modifications to prevent BDBA and to limit the potential BDBA consequences. Whole Safety Update Program [55] and adjacent modifications have been planned and designed to ensure the alternative capabilities in the case of the fire in Krško NPP. The following was requested:

1. Modernization of the Off-site and internal electrical Power sources;
2. Cooling of the primary reactor core based on the direct alternative water injection and based on the improvement of the cooling with the alternative secondary side cooling;
3. The improvement of the capabilities to ensure the integrity of the Containment from the aspect of the controlling of increased pressure and the concentration of the hydrogen was ensured with the passive systems PARs;
4. Establishment of the capability of the minimal and controlled RB Containment radioactive releases;
5. Construction of the Alternative Control Room with diverse and alternative instrumentation designed and installed to be available in DEC conditions and;
6. Installation of the alternative Spent Fuel cooling capabilities.

The SUP project was very comprehensive. It took Krško NPP approximately 8 years to be implemented.

Before implementation of the SUP, the Krško NPP's preparedness for the Design Extension Condition was evaluated within the Post Fukushima Stress Report and the preparedness was scored as appropriate and sufficient. Upon the recent implementation of the SUP the Plant preparedness was evaluated taking in the consideration latest SUP improvements, with the combination of the preparation of special procedures for the response with the usage of alternative systems. The latest installed alternative systems show a big positive improvement to Krško NPP's Fire response capabilities. See Figure 36 which presents the reduction in Fire initiated CDF from the 90-ties to nowadays.

During the preparation of the National Assessment Report, additional FHA analyses have been performed to cover all required topics as requested by WENRA. These 4 new analyses (see points 3 to 6 below) with the first two analyses prepared in the 90-ties, now form a complete and comprehensive Krško NPP FHA:

1. Compliance with requirements stated in BTP APCSB 9.5-1, Appendix A "Guidelines for Fire Protection for Nuclear Power Plants" [127].
2. Safe Shutdown Analysis in accordance with 10CFR50 Appendix R [43]
3. Deterministic Fire Hazard Analysis of Shutdown Operational Modes [126]

4. Fire Hazard Analysis for Spent Fuel Heat Decay Removal function [57]
5. Deterministic Analysis of Combinations of Fire and Other Events[91]
6. Fire Hazard Analysis for Heating, Ventilating and Air Conditioning Systems (HVAC) [120]

These analyses together now cover all required aspects and requirements, as well as demonstrate the Krško NPP's ability to respond to any condition and fire related consequences. Updated FHA therefore covers the following:

1. Krško NPP's ability for the plant shutdown (if needed) in the case of fire in technological part of the plant;
2. Krško NPP's ability to perform plant cooldown until the Plant Cold Shutdown in the case of fire;
3. Krško NPP's ability to establish safe cooldown in any of the operation modes including Mode 0 with all nuclear Fuel in the Spent fuel;
4. Krško NPP's ability to maintain removal of the Decay Heat of the Spent Fuel stored in the Spent Fuel Pool;
5. Krško NPP's ability to respond to fire in a combination of any related credible combination of the events;
6. Krško NPP's ability to respond to fire in any plant fire area to prevent the release of radioactivity in the environment;
7. Krško NPP's compliance with the Fire Protection Program requirements.

The first Fire Response Procedures (FRPs) have been prepared in 90-ties after the implementation of the FPAP. The scope of the FRP's, until the preparation of the NAR as requested per TPR2 [136], cover Safe Shutdown and Cooldown of the plant. All those new abilities (after the implementation of the SUP) need detail instructions for the operators to respond to ensure additional equipment will be used if needed in the case of fire. The revision of Fire Response Procedures is needed and is under preparation. Based on the implementation of additional FHA analyses the operators will have to take actions also to ensure abilities, listed below. The procedural instructions for operators to respond to a fire event are enhanced to cover instructions for:

1. Use the Alternative systems to perform the plant Safe Cooldown regardless of the mode of the plant when the postulated fire event occurs;
2. Ensure the SFP Decay Heat Removal in the case of fire event;
3. Implement measures/activities to prevent radioactive release.

Revised FRP's are prepared to be used in addition (in parallel to) to normal operating (SOP/GOP), standard Emergency (EOPs) or Evacuation Emergency Operating Procedures (EEOPs). Upgraded FRP's will be validated on the simulator and approved until the end of 2023.

A periodic review of FHA (of course covering all particular recently prepared analyses) is required after each 2 years to evaluate and summarize the changes done in the plant and to reflect the as-built configuration of the plant.

4.2.2 Fire Probabilistic Safety Assessment

Krško NPP has the following Level 1 and Level 2 fire PSA analyses available in accordance with the national legislation for all suitable and reasonable conditions of the power plant (second point of the third paragraph of Article 50 of ref. [22]):

- TS Mode 1, Power Operation, Level 1 and Level 2 fire PSA
- TS Mode 2, Startup (Low Power Operation), Level 1 and Level 2 fire PSA
- TS Mode 3, Hot Standby, Level 1 and Level 2 fire PSA

- TS Mode 4, Hot Shutdown, Level 1 and Level 2 fire PSA
- TS Mode 5, Cold Shutdown, Level 1 fire PSA
- TS Mode 6, Refuelling, Level 1 fire PSA
- Spent fuel pool, Level 1 and Level 2 fire PSA
- Dry storage, Generic Annual (Fire) Risk Estimation

Additionally, in 2019 Krško NPP performed extensive analyses of combinations of fire triggered events with other events [23]. The results of engineering judgment, deterministic and probabilistic safety assessments indicate that combinations of events could lead to anticipated operational occurrences or to accident conditions. Consideration of credible combination of fire and other events likely to occur independently of a fire are to be analysed in accordance with the given combinations. The combinations of fire and other postulated initiating events with their impact are analysed. It generally includes the following combinations:

- Fire and Internal Initiating Event
- Fire and Internal Hazard (Internal Flooding and HELB)
- Fire and Seismic Initiating Event
- Fire and Other External Events
- Fire and Explosion
- Multiple Compartment Fire Interaction Analysis

The fire safety at the plant was constantly improved and therefore risk from fires was minimized, what can be also observed from the reduction of fire CDF, as presented in the Figure 36. It must be noted that all the above analyses were performed based solely on the FHA [3] revision from that time. At that time, fire hazard analyses for transition modes, shut down modes, combinations of events and ventilation were not yet available. Therefore, the Fire PSA will have to be updated in the following years to reflect the latest available support documents and latest available standards. The action to update the fire PSA analyses is also part of the third periodic safety review action plan (PSR3 Action Plan, PSR3-NEK-9.2 in preparation and SNSA review).

4.3 Fire Protection Concept and its Implementation

Krško NPP's The Fire Protection Program [96] is prepared in accordance with national and US regulations and standards (National Fire Safety Code [101], National Firefighter Organization Code [102], Rules on radiation and nuclear safety factors [21], Rules on providing safety at radiation or nuclear facilities [22], 10 CFR 50 App. R [43], BTP 9.5-1 App. A [127], NFPA).

The Krško NPP's Fire Protection Concept and its implementation are summarized in Chapter 3 and described in detail in the Krško NPP Fire Protection Program [96]. The Fire Protection Program is based on the defense-in-depth principle, which was focused on achieving an adequate balance in:

1. Preventing fires from starting;
2. Quickly detecting and promptly extinguishing those fires that do occur to limit consequences;
3. Providing protection for structures, systems and components, needed for safe shutdown so that a single fire in the plant that is not promptly extinguished will not prevent the safe shutdown of the plant.

Those goals can be achieved by a comprehensive set of designated and alternative systems installed initially or during the last year between the Safety Upgrade Program and additional and improved Fire response procedures that provide instructions to fulfil the main goals.

Fire prevention is partially achieved through SSCs design, using the non-combustible material, which should prevent occurrence of fire and consequences. Technical specifications for SSCs, which are followed at modification processes, require use of fire-retarding and non-propagating material for cable insulation and also non-combustible material for thermal insulation of piping, tanks, ducts and other equipment and with implementation of procedures, which controls. Additionally, several processes were established to minimise the amount of combustible loads present at the plant and also to minimise ignition sources during operation and plant activities.

Fixed fire loads are controlled in FHA and margins are set for each fire area. Criteria for setting those margins are resistance of fire barriers in a fire area. Introducing of a new combustible material is controlled through the modification' process, in accordance with procedure ESP-2.602 "Plant Design Modification" [103], which includes control of fire barriers, fire protection equipment impact and revision of Fire Hazard Analysis [3]. Additional (transient) fire loads are controlled within a process per ADP-1.1.105 "Controlled disposal and storage of material" [61], which considers allowable fire load margins for each fire zone. Beside the ADP-1.1.105 process, each introduction of burnable material into technological part of the plant is also controlled per procedure FPP-3.7.004 "Control of burnable material" [104].

The fire detection and alarm annunciation system are incorporated into the overall fire protection design, in accordance with NFPA72 National Fire Alarm and Signalling Code [109]. The area smoke detectors are provided in all areas of the plant to give prompt indication of any fire condition therein, by alarming on a central panel, giving their address and display an appropriate message with graphical identification of fire location in the Main Control Room, Firefighter's office and in Emergency Control Room. The arrangement of Fire Detection System provides reliable information about the status of the system. Since it is wired per Class "A" configuration (Figure 43), a single defect in a loop does not jeopardize operation of any part of the system, but triggers trouble alarm that warns the operators about the defect. Loops of fire detectors also have isolation devices at borders of fire areas that prevent improper operation of the whole loop if fire damages the system in one fire area.

Fire suppression is achieved by a combination of manual firefighting and automatic/semi-automatic fire extinguishing systems, that protect equipment, systems or areas as defined in FHA. In case of fire, the procedure FPP-3.7.002 "Fire response procedure" [8] is entered by MCR operators and fire brigade staff. Depending on the jeopardized area a suitable fire plan is used (DCM-TD-023 [83] (Technological part of the plant), DCM-TD 024 (Non-technological part of the plant) [110] or DCM-TD-037 (Large fires at Krško NPP area) [111]).

The principles of achieving every level of the defense-in-depth are described in detail in corresponding sub-chapters of Chapter 3.

On the other side significant improvements have been implemented to upgrade the Fire Protection Systems and systems needed for Safe Shutdown in the case of fire. The Safe Shutdown Capability Analysis was performed at that time and consequential Krško NPP Fire Protection Action Plan was derived. Discrepancies have been evaluated from the Probabilistic impact on the CDF and more important ones (criteria was CDF >10 E-6) have been implemented. The following have been done:

- Safe Shutdown components (SSC) cable rerouting;
- SSC cable wrapping;
- installation of additional automatic fire extinguishing systems;
- additional fire detection systems;
- fire barriers;
- control circuits isolation; and
- installation of additional controls for safe shutdown capability.

Additionally, Krško NPP has introduced significant capabilities for the mobile fire-fighting immediately after the Fukushima event (2011). This mobile equipment is included for use as the last level of defense either in case of an emergency situation or a single fire accident.

However, the greatest improvement of the Krško NPP's capability for the fire safety (in the sense of improving the Safe Shutdown Capability) presents the recently implemented Safety Upgrade Program where the following was installed and commissioned:

- New Emergency Control Room for the Alternative Shutdown in the case of Fire in MCR;
- Additional diesel generator 3 for the supply of the emergency busses or as a sand alone source of electrical source in the case of the Design Extended Conditions;
- New bunkerized buildings BB1 and BB2 with the alternative systems for AAF and ASI;
- Alternative RHR system for the removal of the decay heat from RCS or RB;
- Alternative SFP cooling and sprinkling system for the SFP Decay Heat removal.

All these systems, buildings and capabilities were installed based on the post-Fukushima or Periodic Safety Review 2 program findings action plan for the usage in the case of the Design Extended Conditions to prevent Beyond DBA but can also be used as an alternative system in the case of fire and consequential inoperability of the originally installed dedicated systems.

Figure 36 shows the reduction of Fire-initiated CDF through all the years of operation. The improvements caused the CDF reduction in 1992 from CDF=2.30 E-4/ry to CDF=1.35 E-5/ry in 2022 after the implementation of SUP [55].

4.4 General Conclusion

Prevention measures are incorporated into all activities and processes of the plant (operation, maintenance, or modification activities) to prevent the fire ignition and spreading. The management is giving clear message continuously to prevent occurrence of complacency at the workers and to motivate the personal to strictly respect all the rules from the Fire Protection area with no exceptions in all processes.

Krško NPP developed its Fire Probabilistic Safety Analysis (PSA) already in the 90-ties, and PSAs were used to prioritize the proposed solutions/changes based on their influence on the Core Damage Frequency (CDF). To mitigate the fire risk, Fire Protection Action Plan (FPAP) [12] was initiated and plant fire safety was crucially increased by fire protection upgrade, proposed by FPAP. Consequently, fire PSA analyses were updated to reflect plant changes [13]. After the comprehensive plant safety upgrade which includes additional alternative systems, the PSA model has to be re-modelled to use the newest standard and to take into consideration new system configuration. This action is identified within PSR3.

On the other hand, all changes done in the plant were and will be continuously evaluated from the perspective of the impact on Fire Safety. Deterministic analyses have been upgraded recently due to TPR2 and reflect the As-built (post SUP) plant condition/configuration. They also cover fire in all operating modes, fire in SFP areas and systems dedicated to DHR and the combination of events.

All of the above-mentioned improvements are clearly seen on the Figure 36, as all of those enhancements had impact on the fire safety of the Krško NPP. Not all of those improvements were credited in the Krško Fire PSA, but the largest improvements programs, such as FPAP and SUP, are clearly distinguished as major reduction of the fire risk in Krško NPP's overall PSA. As could be observed, internal fires CDF was reduced from initial 9.78E-05/ry from year 1992 to 3.53E-07/ry in the year 2022, what represents the reduction of internal fires CDF to 0.4% of initial internal fires CDF value.

In a Figure 12 Safe Shutdown (SSD) Functions Evolution in Fire Areas (the same table attached also as Appendix 6.3) is clearly presented how the number of the non-compliances to the FHA requirements were changed (improved) during the last 20 years. It is also clear that there are still gaps (non-compliances), however after the implementation of SUP, sufficient alternative and independent capacities (systems) to cover all safety functions after the postulated Fire and combination of Fire Event have been installed.

All those alternative systems ensure the back up methods to perform the plant Safe Cooldown regardless of the mode of the plant when the postulated fire event occurs to ensure the SFP Decay Heat Removal in the case of fire event and to implement measures/activities to prevent radioactive release. Existing Fire Response Procedures however have to be revised (until the end od 2023) to prescribe all required actions.

The safe and stable operation of Krško NPP without major or minor events, including events related to fire, is also the result of the robust Fire Protection Program where all prescribed precautions and instructions are strictly followed. The fact is that there was no fire event in the Krško NPP since 2000; only one minor fire events (such as smoldering) occurs per year.

The national regulatory body (SNSA) finds the fire protection of the Krško NPP to be on a quite high level. It is also appretiative that the Krško NPP conducted the self-assessment regarding the fire protection in the light of the TPR II and addressed the shortcomings in its own fire protection concept.

SNSA regularly carries out several thematic inspections, including dedicated inspections on fire protection at the Krško NPP. These comprise also joined inspections with inspectors for protection against natural and other disasters exercised particularly when inspecting fire protection and emergency preparedness of the Krško NPP. So far, some minor issues from these inspections were recorded and consequently appropriate addressed, but no major findings were detected.

In addition to the Fire Protection Program and Fire Protection System, there are many design features of the plant that would contribute to confining and limiting a potential fire condition, as identified in this report. Krško NPP introduced various plant changes, purchased additional mobile equipment and performed modifications as a response to NEI 06-12 B.5.b "Phase 2&3 Submittal Guideline" [53] requirements. In the framework of the EU stress tests conducted by the European Commission following the Fukushima accident and as a precondition for long term plant operation, Krško NPP has performed continuous safety improvements in the scope of Safety Upgrade Program (SUP). With the availability of mobile equipment and implementation of the "Krško NPP's Safety Upgrade Program" that introduced the installation of an independent safety train (separated physically and electrically) in a dislocated bunkered building, as well as installation of the ECR, the fire safety of the Krško NPP was substantially enhanced, as these systems provide an alternative shutdown capability and ensure the safety of the plant even when considering the worst fire scenarios. Additionally, any change performed in Krško NPP were and will be continuously evaluated from the perspective of the impact on Fire Safety in accordance with applicable program and procedures.

Krško NPP conducted in 2022 the self-assessment regarding the fire protection and identified some gaps, which were resolved by complementing the existing FHA with four addendums as presented/ described in the report. It is also important to note that NPP Krško has in place continuous improvement process which also have resulted in major improvements and modifications in the area of fire protection and presented in the report.

5 References

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[6] LEVEL 2 INTERNAL FIRE ANALYSIS OF NUCLEAR POWER PLANT KRŠKO, Lambright Technical Associates, Inc., 1999;

[7] NUREG-1150, Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants, 1990;

[8] FPP-3.7.002, "Postopanje v primeru požara (Fire Response Procedure)", Rev. 4;

[9] FRP-3.9.100, "Postopanje operatrejev v primeru požara v tehnološkem delu elektrarne (Operators actions in case of fire in technological part of plant)", Rev. 5;

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6 APPENDICES

6.1 Safe shutdown (SSD) Functions Evolution in Fire Areas – 1992
6.2 Safe shutdown (SSD) Functions Evolution in Fire Areas – 2007
6.3 Safe shutdown (SSD) Functions Evolution in Fire Areas – 2022

6.1 Safe shutdown (SSD) Functions Evolution in Fire Areas – 1992

FIRE AREA	DESCRIPTION	SAFE-SHUTDOWN FUNCTION						
		REACTOR COOLANT SYSTEM INVENTORY, PRESSURE, AND REACTIVITY CONTROL	SECONDARY SYSTEM COOLING	PLANT MONITORING INSTRUMENTATION	RESIDUAL HEAT REMOVAL/SHUTDOWN COOLING	COMPONENT COOLING WATER	SERVICE WATER	ELECTRICAL DISTRIBUTION
AB-1	AUXILIARY BUILDING OPERATING FLOOR							
AB-2	AUXILIARY BUILDING MEZZANINE FLOOR							
AB-3	AUXILIARY BUILDING BASEMENT							
AB-4	RADWASTE DRUMMING STATION							
AB-5	RHR HEAT EXCHANGER ROOM A							
AB-6	RHR HEAT EXCHANGER ROOM B							
AB-7	TRAIN B ELECTRICAL CHASE							
AB-8	TRAIN A ELECTRICAL CHASE							
AB-9	SAFETY-RELATED PUMP ROOMS AREA							
AB-10	CHARGING PUMP ROOM B							
AB-11	CHARGING PUMP ROOM A							
AB-12	POSITIVE DISPLACEMENT CHARGING PUMP ROOM							
AB-13	SAFETY INJECTION PUMP ROOM A							
AB-14	SAFETY INJECTION PUMP ROOM B							
AB-15	PIPE SPREADING AREA							
AB-16	AUXILIARY BUILDING SUMP AREA							
AB-17	CONTAINMENT SPRAY PUMP ROOM A							
AB-18	CONTAINMENT SPRAY PUMP ROOM B							
AB-19	RHR PUMP ROOM A							
AB-20	RHR PUMP ROOM B							
AB-21	AUXILIARY BUILDING STAIR TOWER							
AB-22	COMBINATION ELECTRICAL/PIPING/HVAC CHASE							
AB-23	AUXILIARY BUILDING PIPING CHASE							
AB-24	AUXILIARY BUILDING ELECTRICAL CHASE							
AB-25	AUXILIARY BUILDING HVAC CHASE							
AB-26	HEPA PENTHOUSE							
AB-27	SUPPLY AIR INTAKE PENTHOUSE D							
AB-28	SUPPLY AIR INTAKE PENTHOUSE E							
CB-1	MAIN CONTROL ROOM							
CB-1B	COMPUTER ROOM							
CB-1C	CHART ROOM							
CB-1D	KITCHEN							
CB-1E	CONTROL BUILDING UPPER OFFICE AREA							
CB-2	CABLE SPREADING AREA							
CB-3A	6.3KV SWITCHGEAR ROOM A							
CB-3B	6.3KV SWITCHGEAR ROOM B							
CB-4	CABLE SPREADING AREA							
CB-5	CONTROL BUILDING BASEMENT							
CB-5A	COUNTING ROOM							
CB-5B	RADIOCHEMISTRY LABORATORY							
CB-6	CONTROL BUILDING STAIR TOWER							
CB-7	CONTROL BUILDING HVAC CHASE							
CB-8A	TRAIN A ELECTRICAL CABLE CHASE							
CB-8B	TRAIN-B ELECTRICAL CABLE CHASE							
CC	COMPONENT COOLING BUILDING							
DG-1	DIESEL GENERATOR ROOM A							
DG-2	DIESEL GENERATOR ROOM B							
FH-1	FUEL HANDLING BUILDING							
FH-2	HOT MACHINE SHOP							
FH-3	SPENT FUEL PIT ROOM							
FH-4	SPENT FUEL PIT HEAT EXCHANGER ROOM							
FH-5	FUEL HANDLING BUILDING STAIR TOWER							
IB-1	MAIN CONTROL ROOM HVAC ROOM							
IB-2	CRDM ROOM							
IB-3	SERVICE AIR AREA							
IB-4	CONTROLLED ACCESS HVAC ROOM							
IB-5	INTERMEDIATE BUILDING HVAC CHASE							
IB-6	MAIN CONTROL ROOM HVAC ROOM B							
IB-7	STEAM HEADER ROOM							
IB-7A	STEAM HEADER ROOM A							
IB-8	MAIN CONTROL ROOM HVAC ROOM A							
IB-9	DC BATTERY ROOM B							
IB-9A	BATTERY CHARGER ROOM B							
IB-10	DC BATTERY ROOM A							
IB-10A	BATTERY CHARGER ROOM A							
IB-11	INTERMEDIATE BUILDING BASEMENT							
IB-11A	EMERGENCY AIRLOCK ACCESS AREA							
IB-12	AUXILIARY FEEDWATER PUMP C ROOM							
IB-13A	TRAIN-A ELECTRICAL CABLE CHASE							
IB-13B	TRAIN-B ELECTRICAL CABLE CHASE							
IB-14	ELEVATOR SHAFT							
IB-15	PURGE SUPPLY AIR INTAKE PENTHOUSE B							
RB-0	CONTAINMENT VESSEL							
SW	ESSENTIAL SERVICE WATER PUMPHOUSE							
TB-1	TURBINE BUILDING OPERATING FLOOR							
TB-1A	TURBINE BUILDING MEZZANINE							
TB-2	TURBINE LUBE OIL TREATMENT AND RESERVOIR ROOM							
TB-3	TURBINE BUILDING BASEMENT							
TB-4	ELEVATOR SHAFT							
TB-5	SOUTHEAST STAIR TOWER							
TB-6	SOUTHWEST STAIR TOWER							
TB-7	NORTHWEST STAIR TOWER							
TB-8	AUXILIARY BOILER ROOM							
YD	YARD AREA							

6.2 Safe shutdown (SSD) Functions Evolution in Fire Areas – 2007

FIRE AREA	DESCRIPTION	SAFE-SHUTDOWN FUNCTION						
		REACTOR COOLANT SYSTEM INVENTORY, PRESSURE, AND REACTIVITY CONTROL	SECONDARY SYSTEM COOLING	PLANT MONITORING INSTRUMENTATION	RESIDUAL HEAT REMOVAL/SHUTDOWN COOLING	COMPONENT COOLING WATER	SERVICE WATER	ELECTRICAL DISTRIBUTION
AB-1	AUXILIARY BUILDING OPERATING FLOOR							
AB-2	AUXILIARY BUILDING MEZZANINE FLOOR							
AB-3	AUXILIARY BUILDING BASEMENT							
AB-4	RADWASTE DRUMMING STATION							
AB-5	RHR HEAT EXCHANGER ROOM A							
AB-6	RHR HEAT EXCHANGER ROOM B							
AB-7	TRAIN B ELECTRICAL CHASE							
AB-8	TRAIN A ELECTRICAL CHASE							
AB-9	SAFETY-RELATED PUMP ROOMS AREA							
AB-10	CHARGING PUMP ROOM B							
AB-11	CHARGING PUMP ROOM A							
AB-12	POSITIVE DISPLACEMENT CHARGING PUMP ROOM							
AB-13	SAFETY INJECTION PUMP ROOM A							
AB-14	SAFETY INJECTION PUMP ROOM B							
AB-15	PIPE SPREADING AREA							
AB-16	AUXILIARY BUILDING SUMP AREA							
AB-17	CONTAINMENT SPRAY PUMP ROOM A							
AB-18	CONTAINMENT SPRAY PUMP ROOM B							
AB-19	RHR PUMP ROOM A							
AB-20	RHR PUMP ROOM B							
AB-21	AUXILIARY BUILDING STAIR TOWER							
AB-22	COMBINATION ELECTRICAL/PIPING/HVAC CHASE							
AB-23	AUXILIARY BUILDING PIPING CHASE							
AB-25	AUXILIARY BUILDING HVAC CHASE							
AB-26	HEPA PENTHOUSE							
AB-27	SUPPLY AIR INTAKE PENTHOUSE D							
AB-28	SUPPLY AIR INTAKE PENTHOUSE E							
CB-1	MAIN CONTROL ROOM							
CB-1B	COMPUTER ROOM							
CB-1C	CHART ROOM							
CB-1D	KITCHEN							
CB-1E	CONTROL BUILDING UPPER OFFICE AREA							
CB-2	CABLE SPREADING AREA							
CB-3A	6.3KV SWITCHGEAR ROOM A							
CB-3B	6.3KV SWITCHGEAR ROOM B							
CB-4	CABLE SPREADING AREA							
CB-5	CONTROL BUILDING BASEMENT							
CB-5A	COUNTING ROOM							
CB-5B	RADIOCHEMISTRY LABORATORY							
CB-6	CONTROL BUILDING STAIR TOWER							
CB-7	CONTROL BUILDING HVAC CHASE							
CB-8A	TRAIN A ELECTRICAL CABLE CHASE							
CB-8B	TRAIN-B ELECTRICAL CABLE CHASE							
CC	COMPONENT COOLING BUILDING							
DG-1	DIESEL GENERATOR ROOM A							
DG-1A	DIESEL GENERATOR ROOM A							
DG-2	DIESEL GENERATOR ROOM B							
DG-2A	DIESEL GENERATOR ROOM B							
FH-1	FUEL HANDLING BUILDING							
FH-2	HOT MACHINE SHOP							
FH-3	SPENT FUEL PIT ROOM							
FH-4	SPENT FUEL PIT HEAT EXCHANGER ROOM							
FH-5	FUEL HANDLING BUILDING STAIR TOWER							
IB-1	MAIN CONTROL ROOM HVAC ROOM							
IB-2	CRDM ROOM							
IB-3	SERVICE AIR AREA							
IB-4	CONTROLLED ACCESS HVAC ROOM							
IB-5	INTERMEDIATE BUILDING HVAC CHASE							
IB-6	MAIN CONTROL ROOM HVAC ROOM B							
IB-7	STEAM HEADER ROOM							
IB-7A	STEAM HEADER ROOM A							
IB-8	MAIN CONTROL ROOM HVAC ROOM A							
IB-9	DC BATTERY ROOM B							
IB-9A	BATTERY CHARGER ROOM B							
IB-10	DC BATTERY ROOM A							
IB-10A	BATTERY CHARGER ROOM A							
IB-11	INTERMEDIATE BUILDING BASEMENT							
IB-11A	EMERGENCY AIRLOCK ACCESS AREA							
IB-12	AUXILIARY FEEDWATER PUMP C ROOM							
IB-13A	TRAIN-A ELECTRICAL CABLE CHASE							
IB-13B	TRAIN-B ELECTRICAL CABLE CHASE							
RB-0	CONTAINMENT VESSEL							
SW	ESSENTIAL SERVICE WATER PUMPHOUSE							
SW-2	ESSENTIAL SERVICE WATER PUMPHOUSE							
TB-1	TURBINE BUILDING OPERATING FLOOR							
TB-1A	TURBINE BUILDING MEZZANINE							
TB-2	TURBINE LUBE OIL TREATMENT AND RESERVOIR ROOM							
TB-3	TURBINE BUILDING BASEMENT							
TB-4	ELEVATOR SHAFT							
TB-5	SOUTHEAST STAIR TOWER							
TB-6	SOUTHWEST STAIR TOWER							
TB-7	NORTHWEST STAIR TOWER							
TB-8	AUXILIARY BOILER ROOM							
DB-1	STEAM GENERATOR STORE							
DB-2	DECONTAMINATION AREA							
DB-3	MOCK-UP AREA							
DB-4	ENTRANCE AND AUXILIARY ROOMS							
DB-5	HVAC UNITS AREA							
CP-1	RZ Second Floor							
CP-2	TECHNICAL SUPPORT CENTER							
CP-3	RADIOLOGICAL PROTECTIVE CONTROL POINT							
CP-4	ENGINE ROOM							
CP-5	STAIRS							
YD	YARD AREA							

6.3 Safe shutdown (SSD) Functions Evolution in Fire Areas – 2022

FIRE AREA	DESCRIPTION	SAFE-SHUTDOWN FUNCTION						
		REACTOR COOLANT SYSTEM INVENTORY, PRESSURE, AND REACTIVITY CONTROL	SECONDARY SYSTEM COOLING	PLANT MONITORING INSTRUMENTATION	RESIDUAL HEAT REMOVAL/SHUTDOWN COOLING	COMPONENT COOLING WATER	SERVICE WATER	ELECTRICAL DISTRIBUTION
AB-1	AUXILIARY BUILDING OPERATING FLOOR							
AB-2	AUXILIARY BUILDING MEZZANINE FLOOR							
AB-3	AUXILIARY BUILDING BASEMENT							
AB-4	RADWASTE DRUMMING STATION							
AB-5	RHR HEAT EXCHANGER ROOM A							
AB-6	RHR HEAT EXCHANGER ROOM B							
AB-7	TRAIN B ELECTRICAL CHASE							
AB-8	TRAIN A ELECTRICAL CHASE							
AB-9	SAFETY-RELATED PUMP ROOMS AREA							
AB-10	CHARGING PUMP ROOM B							
AB-11	CHARGING PUMP ROOM A							
AB-12	POSITIVE DISPLACEMENT CHARGING PUMP ROOM							
AB-13	SAFETY INJECTION PUMP ROOM A							
AB-14	SAFETY INJECTION PUMP ROOM B							
AB-15	PIPE SPREADING AREA							
AB-16	AUXILIARY BUILDING SUMP AREA							
AB-17	CONTAINMENT SPRAY PUMP ROOM A							
AB-18	CONTAINMENT SPRAY PUMP ROOM B							
AB-19	RHR PUMP ROOM A							
AB-20	RHR PUMP ROOM B							
AB-21	AUXILIARY BUILDING STAIR TOWER							
AB-22	COMBINATION ELECTRICAL/PIPING/HVAC CHASE							
AB-23	AUXILIARY BUILDING PIPING CHASE							
AB-25	AUXILIARY BUILDING HVAC CHASE							
AB-26	HEPA PENTHOUSE							
AB-27	SUPPLY AIR INTAKE PENTHOUSE D							
AB-28	SUPPLY AIR INTAKE PENTHOUSE E							
BB2-1	VENTILATION ROOM 1&2, HALLWAY							
BB2-2	ELECTRICAL ROOM, AUXILIARY ROOM, PIPE CHASE							
BB2-3	ASI PUMP & TANK ROOMS							
BB2-4	AAF PUMP & TANK ROOMS							
BB2-5	STAIRCASE WEST							
BB2-6	STAIRCASE EAST							
CB-1	MAIN CONTROL ROOM							
CB-1B	COMPUTER ROOM							
CB-1C	CHART ROOM							
CB-1D	KITCHEN							
CB-1E	CONTROL BUILDING UPPER OFFICE AREA							
CB-2	CABLE SPREADING AREA							
CB-3A	6.3KV SWITCHGEAR ROOM A							
CB-3B	6.3KV SWITCHGEAR ROOM B							
CB-4	CABLE SPREADING AREA							
CB-5	CONTROL BUILDING BASEMENT							
CB-5A	COUNTING ROOM							
CB-5B	RADIOCHEMISTRY LABORATORY							
CB-6	CONTROL BUILDING STAIR TOWER							
CB-7	CONTROL BUILDING HVAC CHASE							
CB-8A	TRAIN A ELECTRICAL CABLE CHASE							
CB-8B	TRAIN-B ELECTRICAL CABLE CHASE							
CC	COMPONENT COOLING BUILDING							
DG-1	DIESEL GENERATOR ROOM A							
DG-1A	DIESEL GENERATOR ROOM A							
DG-2	DIESEL GENERATOR ROOM B							
DG-2A	DIESEL GENERATOR ROOM B							
ED-1	DIESEL GENERATOR 3 ROOM							
ED-2A	SWITCHGEAR ROOM							
ED-2B	BATTERY AND BATTERY CHARGER ROOM							
ED-3	ENTRANCE ROOM AND STAIRS							
ED-4	CABLE SPREADING ROOM							
ED-5	CABLE SPREADING ROOM							
ED-6	EMERGENCY CONTROL ROOM							
ED-7	TECHNICAL SUPPORT CENTER							
ED-8	TECHNICAL SUPPORT CENTER ENTRANCE AREA							
ED-9	400V SWITCHGEAR ROOM							
ED-13	BUNKERED BUILDING 1 HVAC ROOM							
FH-1	FUEL HANDLING BUILDING							
FH-2	HOT MACHINE SHOP							
FH-3	SPENT FUEL PIT ROOM							
FH-4	SPENT FUEL PIT HEAT EXCHANGER ROOM							
FH-5	FUEL HANDLING BUILDING STAIR TOWER							
IB-1	MAIN CONTROL ROOM HVAC ROOM							
IB-2	CRDM ROOM							
IB-3	SERVICE AIR AREA							
IB-4	CONTROLLED ACCESS HVAC ROOM							
IB-5	INTERMEDIATE BUILDING HVAC CHASE							
IB-6	MAIN CONTROL ROOM HVAC ROOM B							
IB-7	STEAM HEADER ROOM							
IB-7A	STEAM HEADER ROOM A							
IB-8	MAIN CONTROL ROOM HVAC ROOM A							
IB-9	DC BATTERY ROOM B							
IB-9A	BATTERY CHARGER ROOM B							
IB-10	DC BATTERY ROOM A							
IB-10A	BATTERY CHARGER ROOM A							
IB-11	INTERMEDIATE BUILDING BASEMENT							
IB-11A	EMERGENCY AIRLOCK ACCESS AREA							
IB-12	AUXILIARY FEEDWATER PUMP C ROOM							
IB-13A	TRAIN-A ELECTRICAL CABLE CHASE							
IB-13B	TRAIN-B ELECTRICAL CABLE CHASE							
RB-0	CONTAINMENT VESSEL							
SW	ESSENTIAL SERVICE WATER PUMPHOUSE							
SW-2	ESSENTIAL SERVICE WATER PUMPHOUSE							
TB-1	TURBINE BUILDING OPERATING FLOOR							
TB-1A	TURBINE BUILDING MEZZANINE							
TB-2	TURBINE LUBE OIL TREATMENT AND RESERVOIR ROOM							
TB-3	TURBINE BUILDING BASEMENT							
TB-4	ELEVATOR SHAFT							
TB-5	SOUTHEAST STAIR TOWER							
TB-6	SOUTHWEST STAIR TOWER							
TB-7	NORTHWEST STAIR TOWER							
TB-8	AUXILIARY BOILER ROOM							
DB-1	STEAM GENERATOR STORE							
DB-2	DECONTAMINATION AREA							
DB-3	MOCK-UP AREA							
DB-4	ENTRANCE AND AUXILIARY ROOMS							
DB-5	HVAC UNITS AREA							
CP-1	RZ Second Floor							
CP-2	TECHNICAL SUPPORT CENTER							
CP-3	RADIOLOGICAL PROTECTIVE CONTROL POINT							
CP-4	ENGINE ROOM							
CP-5	STAIRS							
WM-1	WASTE PROCESSING ROOM							
WM-2	STAIRS							
WM-3	BORIC ACID PUMP AND TANK ROOM							
WM-4	RADIOLOGICAL LABORATORY							
WM-5	PIPE HANGER REPARING AND TESTING AREA							
WM-6	MULTIPURPOSE AREA 2							
WM-7	PASSAGE							
WM-8	HOT WORK AREA							
WM-9	WELDING AREA							
WM-10	AREA INTENDED FOR LABORATORY							
WM-11	ELECTRICAL AREA							
YD	YARD AREA							