OCTOBER 2023

National Assessment Report of Finland

for the Purposes of Topical Peer Review "Fire Protection" under the Nuclear Safety Directive 2014/87/EURATOM

stuk
SÄTEILYTURVAKESKUS
STRÅLSÄKERHETSCENTRALEN
RADIATION AND NUCLEAR SAFETY AUTHORITY

Contents

List of acronyms and abbreviations

ATEX	potentially explosive atmospheres (atmosphéres explosibles)
BWR	Boiling Water Reactor
CDF	Core Damage Frequency
DiD	Defence in Depth
EDG	Emergency Diesel Generator
EPR	European Pressurized Reactor
FHA	Fire Hazard Analysis
FSAR	Final Safety Analysis Report
IAEA	International Atomic Energy Agency
ILW	Intermediate Level Waste
ISFS	Interim Spent Fuel Storage
KELPO	TVO's internal quality management information system
KTO	Periodic inspection programme
KÄKRY	Teollisuuden Voima Oyj's Group for Operational Experience
LLW	Low Level Waste
LO1	NPP unit Loviisa 1
LO2	NPP unit Loviisa 2
NAR	National Assessment Report
NI	Nuclear Island
NPP	Nuclear Power Plant
MCR	Main Control Room
OECD/NEA	Nuclear Energy Agency of The Organisation for Economic Co-operation and Development
OL1	NPP unit Olkiluoto 1
OL2	NPP unit Olkiluoto 2
OL3	NPP unit Olkiluoto 3
OLA	Operating Licence Application
OLC	Operational Limits and Conditions
PCP	Primary Coolant Pump
PSR	Periodic Safety Review
PRA	Probabilistic Risk Assessment
PVC/PE	PolyVinylChloride/PolyEthylene
PWR	Pressurized Water Reactor
RCA	Radiologically Controlled Area
RCO	Rescue route fire COmpartment
RCP	Reactor Coolant Pump
RSS	Remote Shutdown Station
S1	Seismic class: functional after earthquake
S2	Seismic class: shall not damage equipment of class S1 (obsolete)
S2A	Seismic class: integrity after earthquake, functionality not required
S2B	Seismic class: no seismic requirements
SBO	Station Black Out
SCE	Safety fire CEll
SCO	Safety fire Compartment
SFP	Spent Fuel Pool
SRL	Safety Reference Level
STUK	Radiation and Nuclear Safety Authority

TI	Turbine Island
TPR	Topical Peer Review
TVO	Teollisuuden Voima Oyj (NPP utility)
UCE	Unavailability fire CEll
UCO	Unavailability fire COmpartment
VLJ	Final disposal facility for low and intermediate level radioactive wastes
VTT	Valtion Teknillinen Tutkimuskeskus, Technical Research Centre of Finland
VVER	A type of PWR (Water Water Energetic Reactor)
WANO	World Association of Nuclear Operators
WENRA	Western European Nuclear Regulators Association
YVL	Regulatory Guides on nuclear safety

List of figures

List of tables

Foreword

This report has been prepared for the purpose of the second Topical Peer Review (TPR II) based on the European Union Directive 2014/87/EURATOM amending the 2009 Nuclear Safety Directive. Nuclear Safety Directive introduced a European system of topical peer reviews which began in 2017 and takes place at least every six years thereafter. The topic of the first TPR was Ageing Management. The topic of TPR II is Fire Protection.

TPR II process consists of each participating country preparing a National Assessment Report (NAR) in accordance with the technical specification document approved upon by ENSREG, where the state of fire protection arrangements and fire safety are presented, and the statements of the licensees and the regulator given. The NARs are then evaluated by experts thematically and in country groups. The goal of the process is to identify the good practices and areas, which require more attention. These will be presented in National Action Plans.

In Finland, the NAR covers all 5 nuclear plant units in operation (Loviisa 1/2 and Olkiluoto 1/2/3) and one interim spent fuel storage facility (Olkiluoto ISFS). The radioactive waste disposal facilities at the nuclear power plant sites are included in the assessment. The report has been prepared by the Radiation and Nuclear Safety Authority (STUK) with inputs from licensees.

This report is a public document.

1 General information

1.1 Nuclear installations identification

1.1.1 Qualifying installations identification

The Loviisa Nuclear Power Plant (NPP) comprises of two Soviet-designed (Atomenergoexport) VVER-440/213 Pressurized Water Reactors (PWRs), i.e., Loviisa unit 1 (LO1) and Loviisa unit 2 (LO2). The current capacity after some modernizations is 2 x 507 MWe. A general view of Loviisa NPP is presented in Figure 1. The Loviisa NPP units started commercial operation in 1977 (Loviisa 1) and 1981 (Loviisa 2) respectively. The plant is operated by Fortum Power and Heat Oy (Fortum). Loviisa NPP has an onsite fire brigade, that practices regularly with local fire department.

Figure 1. Loviisa nuclear power plant (image source: Fortum)

The Olkiluoto NPP consists of two Boiling Water Reactors (BWRs), i.e., Olkiluoto unit 1 (OL1) and Olkiluoto unit 2 (OL2) and one PWR, i.e., Olkiluoto unit 3 (OL3). A general view of Olkiluoto NPP is presented in Figure 2. Olkiluoto NPP is owned and operated by Teollisuuden Voima Oyj (TVO), a subsidiary of Pohjolan Voima Oyj. Olkiluoto NPP has an onsite fire brigade, that serves all TVO installations and Posiva facilities. Fire brigade is in close cooperation with local fire department.

After several modernizations, the current capacity of Olkiluoto units 1 and 2 is 2 x 890 MWe. Olkiluoto 1 started commercial operations in October 1979 and Olkiluoto 2 in

July 1982. The designer of the units 1 and 2 was Swedish Asea-Atom which nowadays belongs to Westinghouse.

The capacity of Olkiluoto unit 3 is 1600 MWe. Olkiluoto unit 3 is EPR-type (European Pressurized Reactor), designed by a consortium of Areva and Siemens. The construction license was granted by the Government in February 2005 and the operating license in March 2019. The plant started commercial operation in April 2023.

Figure 2. Olkiluoto nuclear power plant (image source: TVO)

Posiva, a joint company of Fortum and TVO, is constructing a spent nuclear fuel encapsulation plant and final disposal facility at Olkiluoto site. Posiva applied for operating license for its facilities in December 2021. Posiva or its facilities are not further discussed in this report, as final repositories of spent nuclear fuel are not in the scope of this review.

The research reactor FIR-1 (TRIGA Mark II) was located in Otaniemi Campus area. It was purchased for research purposes, and it started to operate in 1962. Later it was also used for producing isotopes for industry and medical purposes. Its thermal capacity was 250 kW. The responsible organization was originally Helsinki University of Technology and since 1971 VTT Technical Research Centre of Finland Ltd. The reactor is defueled and in decommissioning phase.

There are no fuel cycle facilities in Finland.

There are storages for spent nuclear fuel at both Loviisa and Olkiluoto sites. According to the plan, spent fuel is stored minimum 20–30 years at Olkiluoto and at

Loviisa in interim storages before disposal. Loviisa interim storage pools for spent fuel are located inside Loviisa 2 plant unit. The Olkiluoto NPP has a separate on-site facility for spent nuclear fuel storage common for all reactor units (Olkiluoto ISFS). The facility was expanded in 2015 so that it can fill the need for increasing spent fuel amount with the OL3 start date forthcoming.

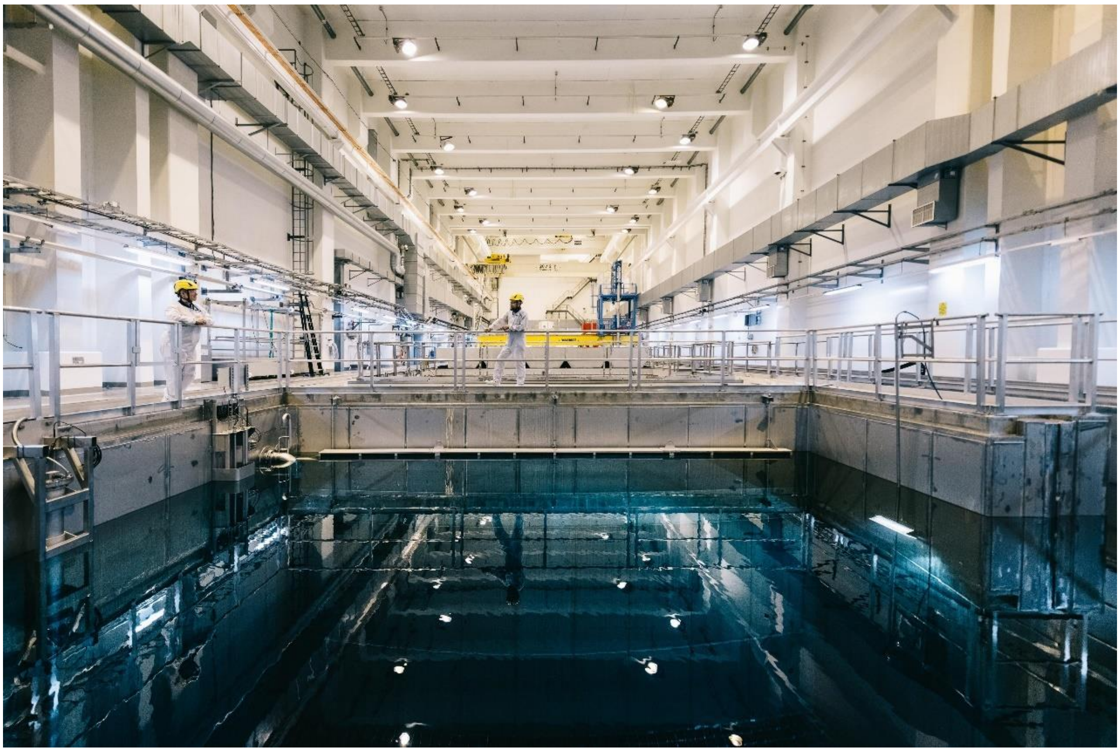


Figure 3. Olkiluoto ISFS, view in the storage pool hall (image source: TVO)

There are also final disposal facilities for low and intermediate level nuclear wastes at both NPP sites. The Loviisa disposal facility is located at a depth of approximately 110 m in granite bedrock. The facility consists of three halls for solid LLW and a cavern for immobilized ILW. Inside the cavern for ILW, the waste packages are emplaced in a pool-shaped structure made of reinforced concrete. One of the halls has been licensed only for storage that also facilitates the sorting of waste, allowing clearance from regulatory control of some of the waste. At Loviisa, for the time being, the majority of wet LILW (radioactive concentrates, such as spent ion exchange resins, evaporator concentrates and sludges) is stored in tanks at the NPP. The Loviisa plant uses Fortum's innovative selective ion exchange method to reduce the volume of liquid radioactive waste. Fortum started liquid waste solidification in 2016 in Loviisa NPP after STUK gave authorization for operation in February 2016. The aim is to solidify all wet waste stored in the tanks in the future.

The Olkiluoto disposal facility for LILW consists of two silos at a depth of 60 to 95 m in tonalite bedrock, one for solid LLW and the other for bituminized ILW (Figure 8). The silo for solid LLW is a shotcrete rock silo, while the silo for bituminized waste consists of a thick-walled concrete silo inside a rock silo where concrete boxes containing drums of bituminized waste will be emplaced. At Olkiluoto, wet LILW is immobilized in bitumen before transfer to the disposal facility. It is planned that sludge, radioactive concentrates and spent ion exchange resins from liquid waste treatment in Olkiluoto 3 (OL3) will be dried in drums or solidified in concrete.

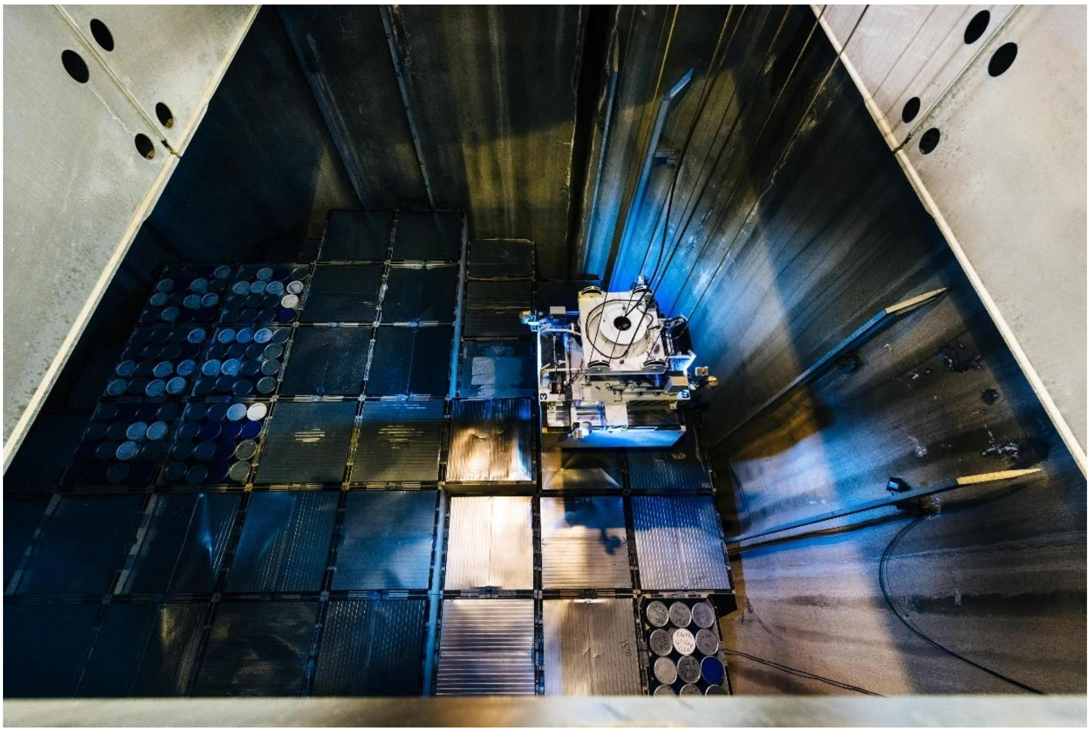


Figure 4. LLW transport at Olkiluoto waste disposal facility (image source: TVO)

1.1.2 National selection of installations for TPR II and justification

Finland reports on all its NPPs, i.e., Loviisa 1/2 and Olkiluoto 1/2/3. In this report Loviisa 1/2 are reported under chapters A, Olkiluoto 1/2 under chapters B and Olkiluoto 3 under chapters C.

At both sites there are interim storages for spent fuel as well as final disposal facilities for low and intermediate level nuclear wastes. The interim storage at Olkiluoto site has a separate operating license from the NPPs and will be reported on as a separate facility (Olkiluoto ISFS) under chapters D in this report. Loviisa interim spent fuel pools (SFP) are inside the Loviisa 2 NPP and will be reported on as a part of the NPP.

The final disposal facilities for low and intermediate level waste are included in the operating licenses for each plant site and therefore will be reported as part of the NPPs. If the facilities are not explicitly mentioned in a chapter, the same provisions apply for them than for the plant in question.

The research reactor FIR-1 is not in the scope of this NAR due to its low thermal power. Furthermore, the reactor is now permanently shut down and in decommissioning phase.

1.1.3 Key parameters per installation

The key parameters for Finnish NPPs are presented in Table 1. Loviisa NPPs had their operation license renewed in 2023. The plant units can now be used for energy production until 2050. Olkiluoto 1 and 2 plants had their operation license renewed in 2018 and the current operating license runs through 2038. Olkiluoto 3 had its first operation license granted in 2019. The license is valid until 2038.

Name	Licensee	Plant type	Thermal power (MW)	Electrical power (MW)	Started commercial operations	Current operating license
Loviisa 1	Fortum	PWR	1500	507	1977	2050
Loviisa 2	Fortum	PWR	1500	507	1981	2050
Olkiluoto 1	TVO	BWR	2500	890	1979	2038
Olkiluoto 2	TVO	BWR	2500	890	1982	2038
Olkiluoto 3	TVO	PWR	4300	1600	2023	2038

Table 1. Key parameters for nuclear power plants

The key parameters of interim spent fuel storages are presented in Table 2. In Loviisa, the spent fuel pools are located inside LO2. In Olkiluoto, the ISFS facility is separate from the NPPs, but is situated at the same site.

Name	Licensee	Plant type	Total capacity	Started operations	Current operating license
Loviisa SFPs	Fortum	wet storage	887 tHM	1980/1983	2090
Olkiluoto ISFS	TVO	wet storage	1666 tHM	1989	2038

Table 2. Key parameters for interim spent fuel storages

The estimated amount of radioactive waste to be disposed in Loviisa disposal facility is 10 600 m^3. The current operating license is valid until 2090. The facility is planned to be expanded to account for waste from decommissioning of the NPPs.

The estimated amount of packed radioactive waste to be disposed in Olkiluoto final disposal facility is 8800 m^3. The current operating license is valid until 2038. The facility will be expanded to allow for waste from OL3 to be disposed there as well.

Periodic safety reviews (PSR) are required by the Nuclear Energy Act to be conducted for nuclear power plants every ten years. In addition, there is a condition to conduct PSRs in each of the operating licenses.

A NPP units Loviisa 1 and 2

A general overview on the main layout and the main safety systems of Loviisa NPP is given in Figure 5 below.

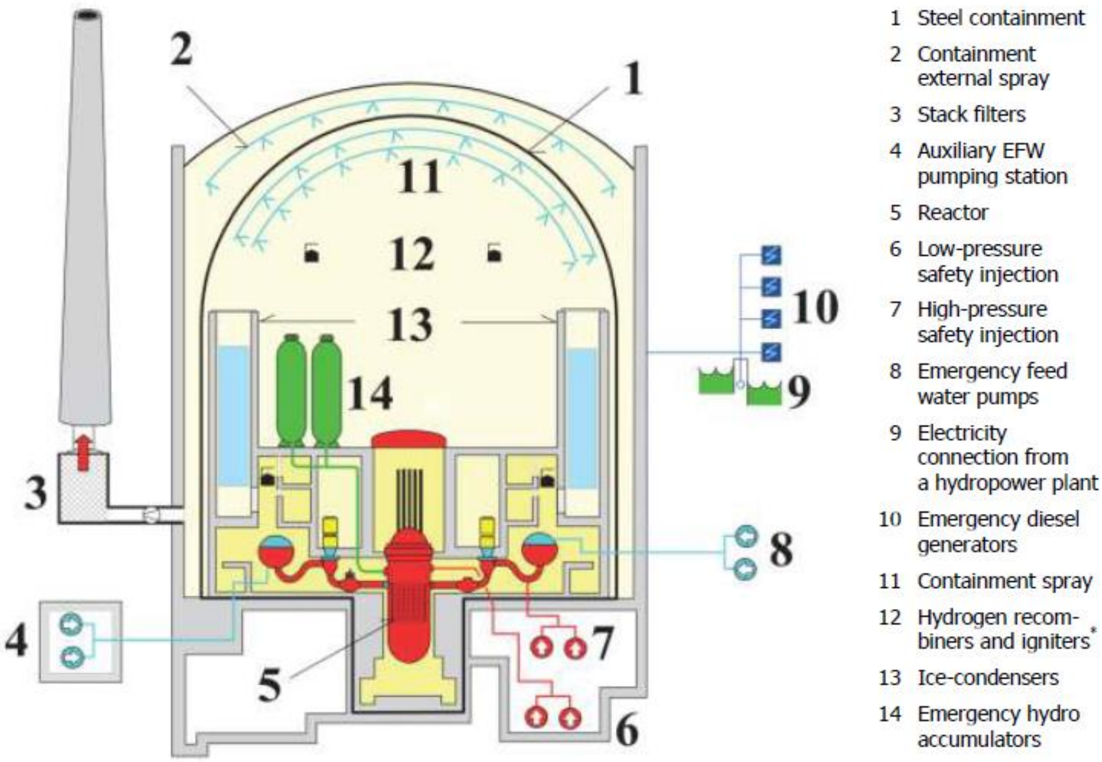
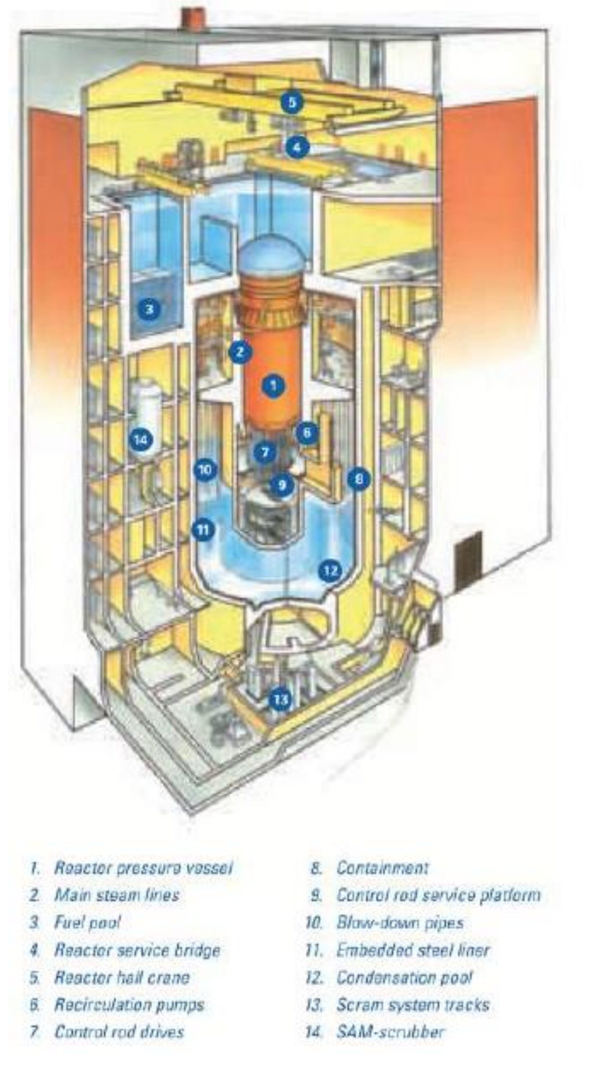


Figure 5. Main layout and main safety systems of Loviisa NPP. Hydrogen igniters are located only in the steam generator space (lower compartment) (image source: Fortum)

Loviisa 1 and 2 safety systems, typical from 1970’s are only partly four redundant and otherwise two redundancy systems. Layout is not originally designed to strictly support structural fire protection. This has been compensated with continuous development of active fire protection arrangements.

B NPP units Olkiluoto 1 and 2

A general overview on the main cross section of the reactor building and the containment and list of system identifiers of Olkiluoto 1/2 NPP is given in Figure 6 below.



System identifiers:

112 Cooling water channels
211 Reactor pressure vessel
243 Fuel pools
244 Reactor pools
311 Main steam lines in reactor building
312 Feed water system
314 Relief system
316 Condensation system
321 Shut-down cooling system
322 Containment spray system
323 Core spray system
324 Pool water system
327 Auxiliary feed water system
331 Reactor water clean-up system
342 Liquid waste system
361 Containment over-pressurization protection system
362 Containment filtered venting system
365 Containment water filling system

413 Turbine plant steam system
431 Condenser and vacuum system
434 Condenser cooling system
461 Turbine control system
662 Diesel backed 660 V system
664 Battery backed 380 V AC system
711 Cooling water screening plant
712 Shut-down service water system
713 Diesel-backed normal operation service water system
714 Non-diesel-backed normal operation service water system
721 Shut-down secondary cooling system
723 Diesel-backed normal operation secondary cooling system
731 Raw water treatment system
732 Water demineralising system
733 Distribution system for demineralised water
741 Containment treatment system
761 Tap water system
763 Heating system
861 Fire fighting water system

Figure 6. Cross-section of the reactor building and the containment and list of system identifiers (image source: TVO)

Olkiluoto 1 and 2 safety systems are four redundant. Layout is supporting structural fire protection of containment spray system, core spray system and auxiliary feedwater system. Cabling in A&C and B&D redundancies are in same rooms in cable tunnels and auxiliary buildings. This has been compensated with active fire protection arrangements.

C NPP unit Olkiluoto 3

Olkiluoto 3 design of the safety systems is based on quadruple redundancy of systems. It means that the systems consist of four parallel trains, each capable of performing the required safety task on its own. The four trains are physically separated and located in different parts of the reactor building in independent divisions.

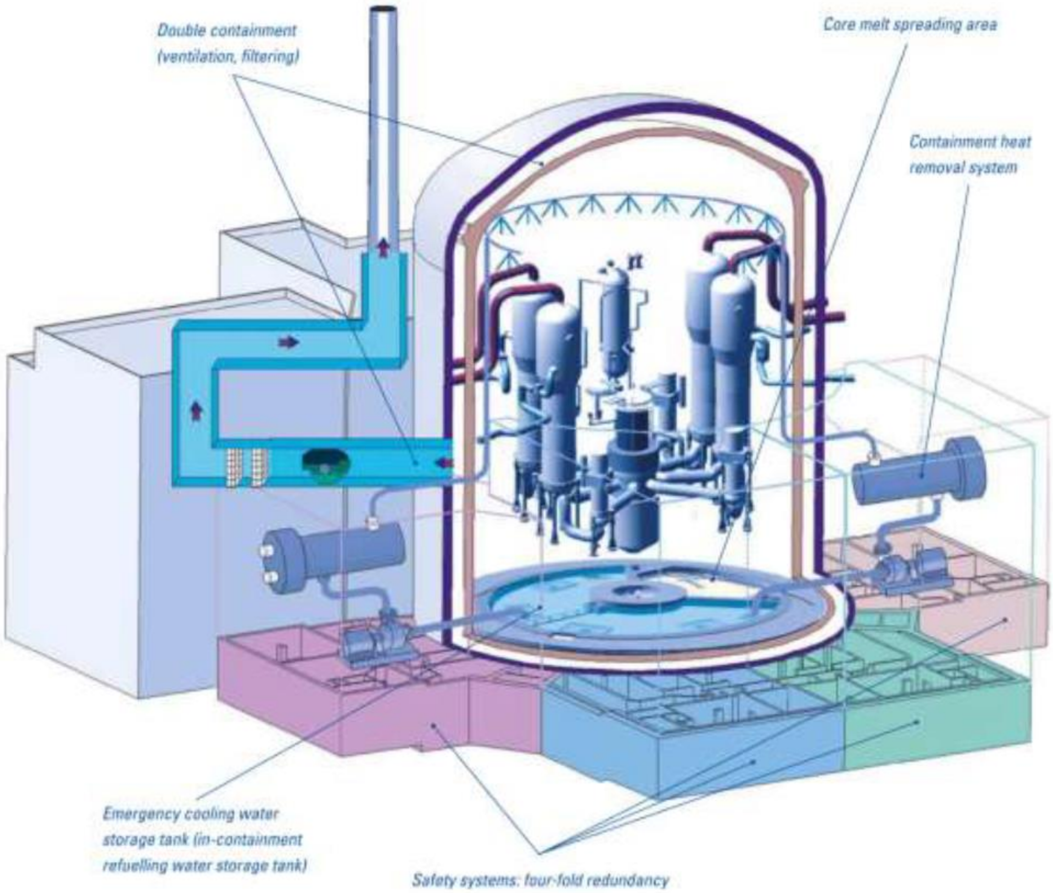


Figure 7. Principal safety features of OL3 (image source: TVO)

1.1.4 Approach to development of the NAR for the national selection

Radiation and Nuclear Safety Authority in Finland (STUK) is responsible for compiling the NAR with the help of licensees. STUK sent out a questionnaire to the licensees to specify needed source materials for compiling the report. All the material needed was already provided to STUK on the basis of regulatory oversight requirements. The questionnaire also included a requirement for the licensees to write the parts of the report, where the licensees experiences were explicitly demanded. In addition, the questionnaire enabled the licensees to provide other content to the report on a voluntary basis. STUK received some chapters on fire analyses and plant fire brigade that were utilized with some modifications as parts of the final version of the report.

1.2 National regulatory framework

1.2.1 National regulatory requirements and standards

The national regulatory framework of Finland is presented in Figure 8. Below the constitution there are laws regulating the use of nuclear energy. The most essential laws are Nuclear Energy Act (990/1987) [1] and Radiation Act (859/2018) [2]. The role of STUK is cemented in Act on Radiation and Nuclear Safety Authority in Finland (1164/2022). [3]

The continuous safety assessment and enhancement approach applied in Finland is based on the Nuclear Energy Act Section 7 a stating that the safety of the use of nuclear energy shall be as high as reasonably achievable. To further enhance safety, all actions justified by operational experience, safety research and the progress in science and technology shall be taken.

In addition to nuclear specific requirements, there are also laws that set fire safety requirements for all buildings. These include Land use and Building Act (132/1999) [4], Rescue Act (379/2011) [5] and Ministry of Environment Decree on Fire Safety of Buildings (848/2017) [6].

Nuclear Energy Decree (161/1988) [7] describes the license requirements and regulatory oversight.

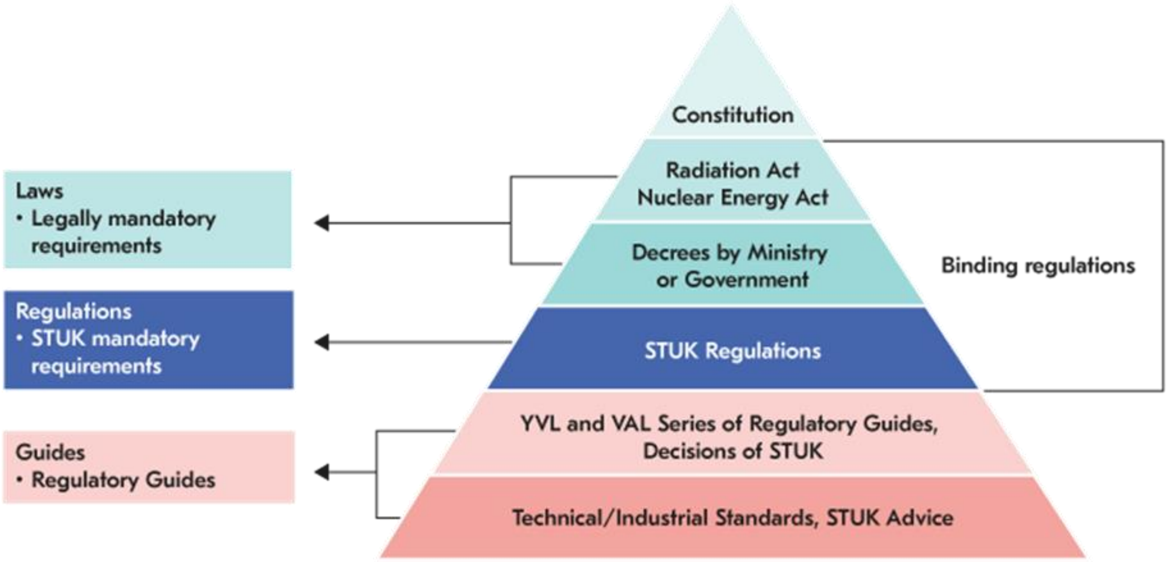


Figure 8. Regulation of nuclear energy in Finland

STUK Regulation on the Safety of a Nuclear Power Plant (STUK Y/1/2018) [8] is used to issue the provisions concerning the safety of a nuclear power plant that specify the provisions of the Nuclear Energy Act [1]. STUK regulation Y/1/2018 section 9 states general functional defence in depth safety principle to be implemented in the design, construction, and operation of a nuclear facility. In section 15 is stated, that the design of nuclear facilities shall take internal hazards, such as fires, into account. According to regulation, systems, structures, and components (SSC) shall be designed, located, and protected so that the probability of internal hazards is low and impacts on nuclear safety minor. The operability of SSCs shall be demonstrated based on room specific environmental conditions.

STUK has issued Regulation on the Safety of Disposal of Nuclear Waste (STUK Y/4/2018) [9] which sets similar requirement for internal hazards in section 18.

STUK has issued regulatory guide YVL B.8 Fire protection at a nuclear facility [10], which introduces more in-depth requirements on fire protection arrangements. YVL B.8 requires that fire protection at a nuclear facility be designed following the defence in depth principle for fire protection. Defence in depth is also applied for explosions resulting from fire load and arc faults. The guide also sets requirements for fire hazard analyses (FHA).

First version of YVL B.8 was issued in November 2013. Implementation of the YVL B.8 was done in 2015 for Loviisa 1 and 2, Olkiluoto 1 and 2 units. Implementation for Olkiluoto 3 was done in 2017. During the implementation process was ensured that mandatory radiation and nuclear safety level of STUK regulations was met in corresponding NPP units.

Current version of YVL B.8 was issued in December 2019, concentrating on clarifying analysis requirements stated in Appendix A. Implementation was done in 2021 and 2022.

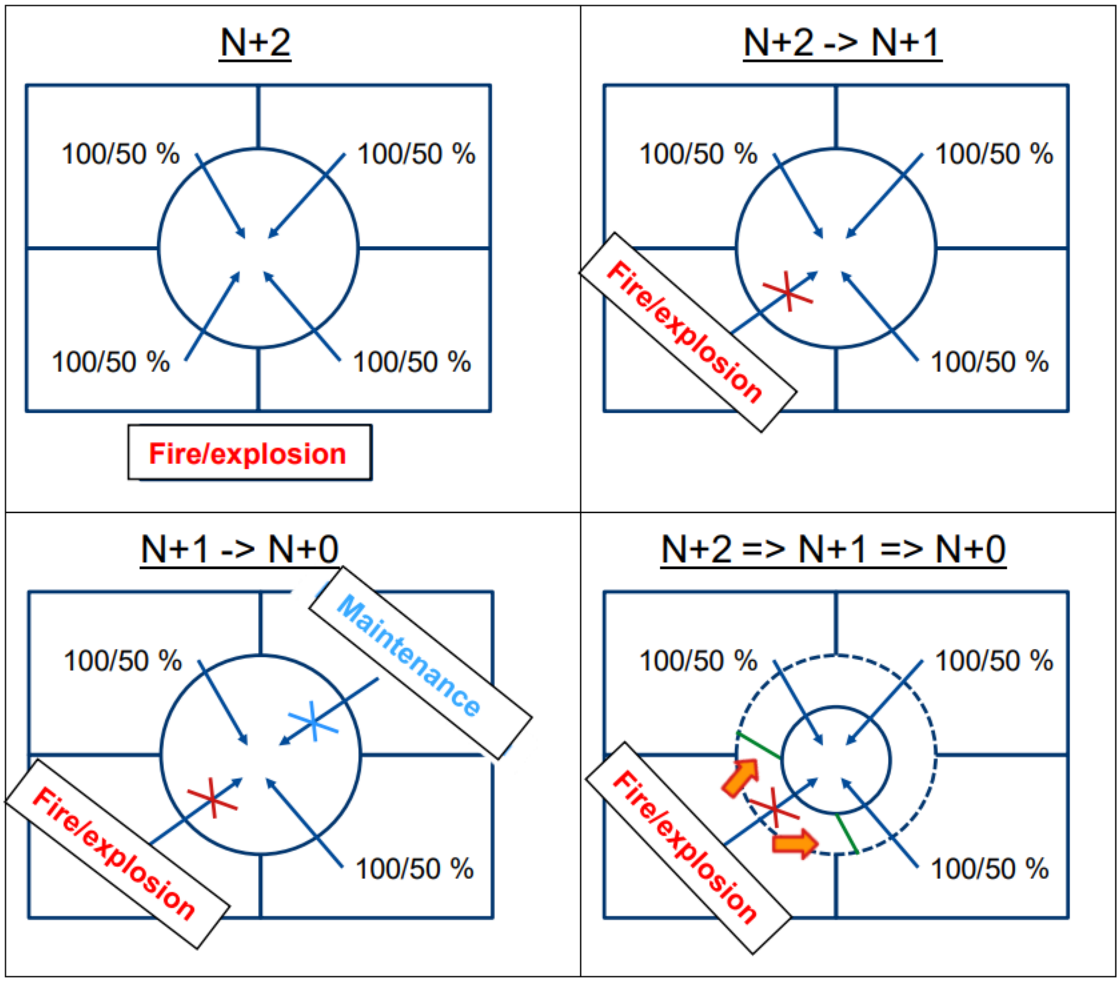


Figure 9. Assessment of defence in depth approach to fire protection by analysis

The requirements for plant safety systems and their failure criteria are issued in guide YVL B.1 Safety design of a nuclear power plant [11]. Figure 9 demonstrates the verification of the fulfilment of the fire safety requirements in accordance with the designed nuclear power plant failure criteria. Initiating event and fault condition analyses associated with the fire situations must be conducted by PRA according to guide YVL A.7 Probabilistic risk assessment and risk management of a nuclear power plant [12].

Figure 9 illustrates possible development of safety system redundancy from N+2 to N+0 caused by fire and/or explosion. In the situations where there is N+2 or N+1 criterion valid, a structural Fire Hazard Analysis (FHA) is sufficient to ensure fire compartmentation and thus functional nuclear safety. In situations where there is N+0 either in locations where there is no sufficient compartmentation between safety system redundancies or when one N+1 safety system redundancy is out for maintenance, a functional FHA is needed also.

1.2.2 Implementation and application of international standards and guidance

During the renewal process of the regulatory guides that was finished in 2013, WENRA SRLs (2008) were implemented in the new YVL guides. After the finalization of the guide, review was done for YVL B.8 with regards to SRLs series issues S (Protection against Internal Fires). It was concluded that each SRL was accounted for in YVL B.8 with a mention of which sections of the guide correspond the SRL in question. WENRA Safety Objectives for new reactors (2010) were also considered in the renewed guides.

The following updating of the guides was minor, with the current YVL B.8 guide being published in 2019. After the new WENRA SRLs were published in 2021, a review was done between issue SV and YVL B.8. The SRLs were accounted for in Finnish regulations.

In general, it can be said that the Finnish nuclear safety regulations are at least as stringent as the existing IAEA requirements. Guide YVL B.8 requires licensees or applicants to comply with IAEA guides and technical reports that pertain to fire protection where applicable.

1.3 Improvements in fire safety as a result of experience feedback

Both Loviisa 1/2 and Olkiluoto 1/2 plants have had many fire safety improvements done during their lifetime.

Fire safety has been improved with several measures at the Loviisa plant after its commissioning. These measures have been implemented in various fields of fire protection. As a result, the plant safety against the effects of fires has been essentially improved.

For a provision against oil fires in the turbine hall several measures have been taken. Fire insulators of the load-bearing steel structures of the turbine building have been installed. The turbine hall has been equipped with an automatic sprinkler system and the significant parts of the turbines have been protected. Later on, the fire wall of the turbine hall has been built up to protect components important to reactor decay heat removal. Furthermore, an auxiliary emergency feedwater system has been built for the case that both the feedwater and the emergency feedwater systems would be lost in a turbine hall fire. At the Loviisa NPP the decay heat removal systems are in the turbine hall. Thus, a separate building for additional decay heat removal system outside turbine hall was built in 2005. The new system is needed for cooling the plant to cold shutdown, if the normal systems are not operable. The turbine bypass line valve hydraulics were changed from oil-based to water-based to eliminate the possibility of hydraulic oil fire.

The main transformers have been protected with a sprinkler system, which essentially reduces the risk of fire spreading into the surrounding buildings, especially into the turbine hall. The risk to lose the AC-power (station black-out) during transformer fires has been reduced by protecting the diesel generators against fires. The 110 kV net connection has been physically separated from the 400 kV connection so that the loss of both connections as a result of a transformer fire is improbable. The original fire water pumps are supplied only from the off-site electrical network. Therefore, an additional fire water pump station has been constructed at the plant and equipped with diesel-driven fire water pumps and with a separate fire water tank. The fire water piping and fire extinguishing systems, as well as their coverage have been improved. A new addressable fire alarm system was completed in 1999 at Loviisa 1 and in 2001 at Loviisa 2.

Fire safety has been improved in different areas of the fire protection at the Olkiluoto 1 and 2 plant units after commissioning.

Although the loss of external electrical supply has been taken into account in the plant design, both units were provided with e.g., second start-up transformer, based on the experience gained from the fire of the electric supply unit in 1991, to improve the independency of plant's external grid connections. Furthermore, the main transformers, in-house transformers and start-up transformers are protected with a sprinkler extinguishing system, which reduces essentially the risks arising from transformer fires.

The use of halon is forbidden in Finland since the year 1999 with the exception of some special items. Due to this the halon extinguishing systems at the Olkiluoto 1 and 2 were replaced with other extinguishing systems by the year 2000. New Novec 1230 gas extinguishing system has been also added to replace a sprinkler system in the control building cable rooms in 2014.

Fire risks have been assessed in a probabilistic risk assessment that concentrates on fire issues. Based on this the fire protection of cables, that are crucial to safety, have been improved by renewing fire detectors and improving fire extinguishing systems in cable tunnels. Cable tunnels may contain two redundancies of cables on each side of the tunnel. The modernized system is designed against fire spread from one cable redundancy to the other. Also, some cable trays have been protected with casings and fire insulation boards. According to the probabilistic risk assessment these improvements reduce the risks arising from fires considerably.

The extinguishing capabilities in the turbine hall have been improved with water cannons.

The regulator (STUK) and both licensees (Fortum and TVO) have set up internal working groups for handling operational experiences. There is dialogue between the parties, when more information is needed on how the gained experiences affect Finnish NPPs and when it is thought that sharing experiences is beneficial.

1.4 Defence in depth principle and its application

STUK guide YVL B.8 defines defence in depth principle (DiD) in fire protection as having four levels, which differs slightly from IAEA definition:

308. The nuclear facility's fire protection shall be based on the defence in depth approach to fire protection, which aims to

a. prevent the ignition of a fire
b. rapidly detect and extinguish ignited fires
c. prevent fire growth and spreading of a fire
d. contain a fire so that the facility's safety functions can be reliably performed irrespective of the effects of the fire.

Each Finnish NPP has applied the principle in a way that sufficiently fulfils the requirements in the guide, even though the application doesn't follow STUK's definition to the letter.

A NPP units Loviisa 1 and 2

Fortum defines the goals for fire protection arrangements and design at Loviisa 1/2 plant units without explicitly mentioning defence in depth principle. However, the following goals are compatible with DiD:

- prevent ignition of a fire by identifying faults and other events possibly leading to fire and relative fire risk of materials
- limit the ignited fire with the means possible before it causes severe consequences to plant safety or use
- avoid the risk to safety of personnel
- avoid the negative consequences caused by fire protection systems to other systems and personnel. [13]

The goals are achieved by the application of following principles:

- layout and civil engineering design and minimizing fire loads, especially within the containment and main control room (MCR)
- fire compartmentation
- fire alarm system
- extinguishing and smoke removal systems. [13]

B NPP units Olkiluoto 1 and 2

In the Olkiluoto 1/2 plant units the aim of fire protection is threefold. The most basic goal is to prevent nuclear accidents and protect the safety of people living around the plant against radiation. Other goals are to protect persons from injury and to protect the plant from property damage. Principles corresponding to defence in depth levels are restrictions on combustible matter, fire compartmentation by building and by room groups, and active fire protection measures. [14] These are discussed in more detail in section 3.

C NPP unit Olkiluoto 3

The Olkiluoto 3 fire protection system provides assurance, through a defense in depth design, that occurrence of a fire will not prevent safe plant shutdown functions and will not significantly increase the risk of radioactive releases to the environment. The defense in depth strategy for achieving facility safety is performed by maintaining a balance between the following fire protection measures [4]:

- prevent fires from starting (Level 1: Fire Prevention)
- provide protection for structures, systems, and components essential to safety so that a fire not promptly extinguished does not impair safe shutdown capability (Level 2 Fire Containing)
- promptly detect, control, and extinguish those fires that do occur (Level 3: Fire Controlling). [15]

Olkiluoto 3 plant is designed in a way where fire protection is considered from the start and the principles of DiD are applied throughout the plant in a complete manner.

2 Fire safety analyses

2.1 Nuclear power plants

A NPP units Loviisa 1 and 2

A 2.1.1 Types and scope of the fire safety analyses

Fire protection planning and the adequacy of fire protection measures are assessed with deterministic fire safety analyzes and fire PRA. Situations in which the plant is either in operation or shutdown state are equally significant from the point of view of fire protection.

A 2.1.2 Key assumptions and methodologies

The fire risk assessment is based on plant walkdowns, mapping of locations of fire sources and safety critical equipment, plant-specific fire simulations and world-wide statistics on fires (from U.S. nuclear power plants and later on utilizing also OECD/NEA FIRE database) in different rooms and buildings of nuclear power plants. Fire PRA of unit 1 was completed in 1997 for power operation, integrated with other PRA as late as in 2005 and completed for shutdown states in 2011. The fire risk consists of the frequency of fire, the initial event caused by the fire, possible safety system faults caused by the fire and the unavailability of the safety systems.

The original fire analysis has been carried out in two steps. In step 1, it has been assumed that the fire will damage all the equipment and cables contained in the room considered in the fire PRA. Regarding fire spread situations, only those scenarios have been taken into account, as a result of which the fire risk may increase compared to the fire risk of the initial room. This requires either an increase in the probability of the initial fire event compared to the ignition room or increase in the severity of the consequences of the fire. In case of fire spreading, the probability of the scenario includes the unavailability of fixed extinguishing systems and the probability of a spread path, but extinguishing measures performed by staff have not been taken into account, except for the use of hand-triggered sprinklers in cable rooms. In step 2, the most important fire scenarios of step 1 have been examined in more detail. Fire situations in the ignition room have been divided into fires initiating from different ignition sources, and the effect of extinguishing measures has been evaluated to determine the extent of damage caused by the fire.

Loviisa 2 identification of preliminary initial events as a result of the fire has been done as Loviisa 1 with fault tree models, but the actual fire scenario modeling has been done with chained event tree models. In the initial event tree, the progression of the scenario is modeled from ignition to the creation of the final initial event. PRA level model covers the progression of the scenario from the final initial event to core damage. PRA level 2 model covers the progression of the scenario from core damage to radioactive release. Mapping the cable routes and the rooms for fire risk evaluation have been the most time consuming tasks.

A 2.1.3 Fire phenomena analyses: overview of models, data and consequences

The most significant fire loads of the plant, the location of the safety systems and the results of the fire risk analysis have been taken into account in the selection of the fire phenomena analyses to be evaluated. The following analyses have been analyzed in the Final Safety Analysis Report [16]; fire protection of power supply cables, fire hazards of the turbine hall, switchgear rooms, main transformers, control building (including transformers), emergency diesel generator (EDG) rooms, carbon filters and the transmitter rooms in reactor building.

A 2.1.4 Main results / dominant events (licensee's experience)

The fire risk is spread around the plant, with no single dominating room. According to the plant fire risk assessment, most of the risk consists of fire situations in the control building and the turbine building. There are no large fire loads inside containment. The required separation of buildings containing subsystems important for nuclear safety (fire class EI-M 120) has been compensated by active fire protection in the case of cable rooms in the turbine hall and the control building. All of the plant's cable rooms and significant parts of the turbine hall are equipped with fixed extinguishing systems. The generator is protected from hydrogen fires with an emergency nitrogen system. A heavy fire scenario (oil fires) in the turbine hall can cause the structures to collapse and also causes the loss of the emergency feed water and residual heat removal system. With the backup systems, which are located outside the turbine hall, the plant can be operated to a cold shutdown state, even after a total loss of the turbine hall.

A 2.1.5 Periodic review and management of changes

A 2.1.5.1 Overview of actions

PRA is updated annually according to plant modifications. Plant specific reliability data is also updated every year.

A 2.1.5.2 Implementation status of modifications/changes

The most important safety improvements have been completed earlier in the plants' lifetime and are described in section 1.3.

Tens of safety improvements have been completed during the last years (2018-2022) including:

- Improving the fire safety of generator magnetization rooms 2018
- New hot work building outside the protected area in 2020
- Procurement of spare parts for the main and sub-centers of the fire alarm system 2019
- Replacement of cargo pallets with non-combustible ones 2020-2022
- Reforming the fire load permit procedure based on fire safety assessments 2020-2022
- Development of aging management of fire doors (identification of doors and places of use)

- Renovation project for fire doors 2018-2022, renewal of doors according to fire risk significance
- Expanding the condition monitoring of fire doors in accordance with the Fire PRA
- Closing, locking or walling up of some fire doors in accordance with the fire PRA
- Development of the fire protection organization 2019-2022
- Regular renewal of fire equipment (every 4 years).

A 2.1.6 Licensee’s experience of fire safety analyses

A 2.1.6.1 Overview of strengths and weaknesses identified

The original design of Loviisa NPP was vulnerable to fires due to shortcomings in functional plant layout design, in passive fire protection (unprotected load carrying steel structures and inadequate functional fire compartments), in active fire protection (heavy fire loads), in safety system physical separation and location (turbine building, some process and electric rooms), and in cable routings. Some modifications have been evident based on engineering judgement and case analyses, while others have been strongly influenced by probabilistic fire risk analysis (fire PRA).

A 2.1.6.1 Lessons learned from events, reviews, fire safety related missions, etc**.**

Different operating experiences, peer reviews, other missions and inspections have played an important part of continuously improving and evaluating the performance and practices within the plant. The plant has established practices for evaluating internal and external events. Same applies for evaluating and handling the recommendations from peer reviews, OSART-missions, authority inspections and audits. These are all important practices to continuously evaluate and improve the performance.

A 2.1.7 Regulator’s assessment and conclusions on fire safety analyses

A 2.1.7.1. Overview of strengths and weaknesses identified by the regulator

Fire PRA is based on conservative assumptions especially considering consequences of instrumentation and control circuit failures (possibility for spurious signals is included). This ensures scope of possible initiating events but simultaneously increases the quantified fire induced core damage frequency.

A 2.1.7.2. Lessons learned from inspection and assessment as part of the regulatory oversight

Lot of plant improvements have been done before Fire PRA (see section 1.3) and they have strong impact on Fire PRA results.

Fixed extinguishing systems are very important to reduce fire risk.

Fires are not significant in the PRA of spent fuel pools or interim spent fuel storages. Fires may affect the cooling function of the spent fuel pools causing minor risk sequence.

STUK contracted VTT to manage fire tests to study especially fire propagation in PVC/PE-cables and instrument cabinets, as well as to perform fire simulations of cable fire, instrument cabinet fire and large turbine oil fire.

A 2.1.7.3. Conclusions drawn on the adequacy of the licensee's fire safety analyses

Fire PRA is a full scope analysis of the units Loviisa 1 and Loviisa 2. It covers all plant operation modes, as well as PRA Level 1 and Level 2 analyses.

PRA has helped identify needs for safety improvements in fire protection arrangements and plant systems that have lowered the risks related to internal fires.

B NPP units Olkiluoto 1 and 2

B 2.1.1 Types and scope of the fire safety analyses

Probabilistic risk assessment [17]has been carried out. Many analyses have been made using fire simulation e.g., for main transformers, turbine building, large oil tanks, battery rooms, where among other things have been analyzed the spread of fire and smoke, the thermal stress on structures, and the conditions of the burning space, such as visibility, temperature, and intensity of thermal radiation.

B 2.1.2 Key assumptions and methodologies

PRA: The documentation of the fire survey and the determination of the fire frequencies of the rooms have been done using an Excel spreadsheet program. The determination of fire frequencies is based on the method presented in report NUREG/CR-6850. Screening of initial events and determination of initial event frequencies has been done with an Excel spreadsheet program. Fault trees created with the FinPSA program have been used as reliability models in connection with internal initial events, from which the so-called combined event trees of external initial events. According to ABB Atom's comments, the assumptions made in the fire analysis are conservative.

B 2.1.3 Fire phenomena analyses: overview of models, data and consequences

Generally, all components within the compartment are assumed to fail. Especially in cable rooms, expert judgement is applied to define probabilities for different fire spreading sequences based on e.g. important cable locations, room conditions and sprinkler system operation. [17]

B 2.1.4 Main results / dominant events (licensee's experience)

The most significant risks are associated with those cable rooms and control cabinet rooms, which contain equipment from two redundancies.

The most significant changes made to reduce the frequency of core damage are the changes to the sprinkler system in the cable tunnels/shafts and the addition of passive protection to rooms that are important for safety. The possibility of losing the external electric power network was reduced by adding a second start-up transformer to the plant units.

B 2.1.5 Periodic review and management of changes

B 2.1.5.1 Overview of actions

Review is done when necessary, according to plant modification projects or operational experiences. The fire analyzes are up to date and have been submitted to STUK for approval in due course. In plant modifications and projects, the possible effects on the performed analyses are evaluated, and the analyses are updated accordingly, if necessary.

B 2.1.5.2 Implementation status of modifications/changes

Multiple modifications are implemented (see section 1.3). Most important PRA based implemented improvements are:

- sprinkler system changes in the cable rooms of two subsystem pairs
- passive fire protection was improved in the rooms of the auxiliary building containing safety-critical systems pumps
- door locking changes in the rooms below the main control rooms.

B 2.1.6 Licensee’s experience of fire safety analyses

B 2.1.6.1 Overview of strengths and weaknesses identified

Strengths: The results of the fire analyzes have been utilized by carrying out several improvement measures at the nuclear facilities. [17] Examples of these modifications are new cable penetrations implementation, fire barrier modifications and the installation of additional EDG (EDG9) on separated building.

Weakness: AC and BD subdivisions separation isn’t complete by physical separation (EI-M 120) according to YVL B.8. Other deviations from YVL B.8 are listed in STUK's implementation decision.

B 2.1.6.2 Lessons learned from events, reviews, fire safety related missions, etc.

External and internal operational experience reports (KÄKRY) and WANO peer reviews are in an important position regarding users’ experiences. KÄKRY's are handled first by the operational safety engineer who coordinates the reports. After this, all necessary parties go through the reports and mark any comments or measures needed in the system. WANO reports are handled via KELPO, which is TVO's internal quality management information system. The findings from WANO inspections are always tried to be processed by the deadline and they will be presented in the following inspections.

B 2.1.7 Regulator’s assessment and conclusions on fire safety analyses

B 2.1.7.1. Overview of strengths and weaknesses identified by the regulator

Fire PRA is mainly based on conservative assumptions in the scope of fire induced damages inside the compartment. Use of expert judgement to estimate limited fire spreading sequences contains some uncertainty.

B 2.1.7.2. Lessons learned from inspection and assessment as part of the regulatory oversight

Fixed extinguishing systems are important to reduce fire risk.

Possible failure of two divisions due to fire is most dominant factor in Fire PRA results.

STUK contracted VTT to manage fire tests to study especially fire propagation in PVC/PE-cables and instrument cabinets, as well as to perform fire simulations of cable fire.

B 2.1.7.3. Conclusions drawn on the adequacy of the licensee's fire safety analyses

Fire PRA is a full scope analysis of the unit Olkiluoto 1. It covers all plant operation modes, as well as PRA Level 1 and Level 2 analyses.

Olkiluoto 1 and Olkiluoto 2 are identical units, therefore the Fire PRA applies to the unit 2 without specific analysis.

C NPP unit Olkiluoto 3

C 2.1.1 Types and scope of the fire safety analyses

Structural and functional fire hazard analyses, as well as fire PRA have been completed. [15] [18]

C 2.1.2 Key assumptions and methodologies

To ensure the adequacy of the fire protection measures for the safety structures, systems, and components during all operational states of the plant, a Fire Hazard Analysis (FHA) was performed, prior to the construction of the facility. This analysis specifically addresses the following aspects of the OL3 fire protection system:

- potential fixed and transient fire hazards
- the impact of a fire in any location in the plant on the ability to safely shutdown the reactor and on the ability to minimize and control the release of radioactive matter to the environment
- measures for fire prevention, fire detection, fire suppression, fire containment and alternative shutdown capability for each fire area containing structures, systems, and components important to safety.

This Fire Hazard Analysis demonstrates the adequacy of the fire barriers between different redundancies as well as the common fire protection concept.

Further analysis on fire safety is provided in the Fire Hazard Functional Analysis and in the probabilistic fire analysis as described below.

Functional Analyses has been carried out to demonstrate that even in the event of losing one entire safety fire compartment by a fire, the reactor can safely shut down and the interconnections between the different redundancies will not inadmissibly jeopardize the safety function of the adjacent redundant safety systems.

The Fire Hazard Functional Analyses are carried out considering certain boundary conditions such as:

- fire barriers between the different redundancies are adequate to withstand the fire and prevent the fire spread to adjacent redundancies
- no credit is taken from automatic fire-extinguishing systems and manual firefighting.

Probabilistic Safety Analysis with respect to fire is carried out in a separate probabilistic fire analysis the scope of which is limited to fires that are initiated from fire sources within OL3 (internal fires). Internal fires are analyzed for power states and shutdown states considering all areas within the plant boundary where a fire may lead to a core damage sequence.

To show the consistency between deterministic and probabilistic analyses, an interface analysis was performed with a focus on strange cables. [15]

C 2.1.3 Fire phenomena analyses: overview of models, data and consequences

Fire simulations have been carried out to provide information to fire hazard analyses. Simulations have been done for locations where fire cells are utilized, such as annulus and different areas in the containment. This is done to verify that a fire cannot influence the safety related equipment in multiple redundancies.

In addition, simulations have been performed for cable rooms to verify the fire phenomena of FRNC cables. In these analyses, the heat flux to the adjacent compartments has been analyzed to verify that the temperature rise in them would not lead to equipment failures or fire spread.

C 2.1.4 Main results / dominant events (licensee's experience)

The contribution of initiating event categories shows IH Fire as the largest contributor to the overall CDF (38%) and is dominated by fire in Reactor Building (remaining areas) – 5%. IH Fire is a major contributor to CDF during power states (51 %) but not during the shutdown states (~1 %) because the frequencies of Fire events are very low.

The relatively high contribution of fire in reactor building annular space is due to modeling approach, particularly to assignment of rooms to fire areas. The compartmentalization of reactor building is performed by fire cells where different divisions are spatially separated but assigned to same room number and consequently to individual fire area Thus, two divisions are simultaneously affected in case of fire in reactor building annular space. [18] [19]

OL3 has a spent fuel pool in the fuel building. In general, the entire building consists of two large fire compartments separating the building in nearly two halves to provide the separation between the two main redundancies 1 and 4 which contain the safety related Fuel Pool Cooling Systems, and the Borating System.

The Fuel Building is divisionally separated mainly in two parts FB1 and FB2, each one forming a Safety Fire Compartment: one, mainly assigned to Division 1 and the other, mainly assigned to Division 4.

The analysis shows that the Fuel Pool Cooling System is capable to perform their safety function in case of fire in one of the two parts of the Fuel Building.

C 2.1.5 Periodic review and management of changes

OL3 is still contractual transition phase (2 years warranty time, begin 4/2023). Changes will be done to the plant design during these two years. Modifications' impact study to OL3 documentation (including fire safety analyses) is prepared by plant supplier and TVO is reviewing it. After warranty time is expired and plant is finally taken over to TVO then periodic review needs and sequences will be defined. TVO own change management process considers impacts to OL3 documentation.

C 2.1.5.1 Overview of actions

Fire protection safety analyses were completed in OL3 operating license application (OLA). After OLA was approved by STUK and during plant commissioning phase, fire safety analyses documents are kept up to date. There have been minor modifications which have had an impact to the analyses. However, fire safety analyses' conclusions which were made in OLA phase are remained intact. Appeared modifications are not challenged the fire safety design requirements. OL3 license holder will keep on tracking the modification to identify possible impacts to fire safety analyses in OL3 commercial operation.

C 2.1.5.2 Implementation status of modifications/changes

Identified fire protection improvements were implemented before OL3 first criticality.

C 2.1.6 Licensee's experience of fire safety analyses

TVO could say that after OLA phase, fire safety analyses / design has been ready for fire safety engineering purposes. So far performed self-assessments relating to fire safety, has been unproblematic to perform within these documents. In case of questions, it has been fluent cooperation with plant supplier to explain the content more in detail. This has happened seldom. TVO makes additions/correction into safety analyses´ documentation if needed with supported by supplier. In general content on fire safety analysis gives proper and easy understandable information about fire safety design.

C 2.1.6.1 Overview of strengths and weaknesses identified

Main strength of OL3 analyses is their scope and thoroughness.

There are deviations of cable laying concept, power / I&C supply of the component needs to be routed through same division associated rooms. These deviations are defined to two types of cases: Foreign and Visiting cables. The start or the destination of the cable is located in safety fire compartments or cells, which belong to a different division than the cable. This cable is named "foreign".

The cable is located in safety fire compartments or cells of the division of either its source or its destination but in between the cable is routed through safety fire compartment or cell assigned to a foreign division. This also applies to a cable route interrupted by a junction box. The cable is called “visiting”. Conclusion document [20] is prepared to justify these cable laying deviations. Some cases are protected from fire or justified acceptable by applying the following statement "systems are not required for the transfer of the plant to the safe shutdown."

C 2.1.6.2 Lessons learned from events, reviews, fire safety related missions, etc.

TVO has reviewed and approved the OL3 fire safety design documents. TVO has also presented the design documentation to local fire protection authority and to STUK. In that manner, TVO’s personnel responsible for fire safety have got proper knowledge of fire safety concept and the boundaries that need to be respected. There have been no key human resource changes in fire safety area. We could say that knowledge is now in excellent level. To keep it on that level, we should face the fact that fire safety knowhow is focused on 1-3 persons. Some information is not documented in a way that newcomers can find it easily. This can be seen as a risk which need to take care in the next coming years.

Also, one important thing is to focus on fire safety measures during outages.

Lessons have been learned based on:

- User experience activity (KÄKRY)
- WANO peer reviews
- TVO fire safety self-assessment.

C 2.1.7 Regulator’s assessment and conclusions on fire safety analyses

C 2.1.7.1. Overview of strengths and weaknesses identified by the regulator

The extensive deterministic fire hazard analyses (structural and functional) and fire PRA are used to verify fire safety of plant design.

Fire PRA is based on conservative assumptions in the fire induced damages inside the fire areas. Individual fire areas are sometimes very large.

Foreign and visiting cables were assessed in detail to identify necessarily needed fire protection measures in order to achieve safe shutdown mode.

C 2.1.7.2. Lessons learned from inspection and assessment as part of the regulatory oversight

Additional casing was designed on PCP motors to contain oil leaks and improve fire safety.

The importance of the installed fixed extinguishing systems is low in relation to the fire PRA results.

STUK contracted VTT to manage fire tests to study especially fire propagation in FRNC-cables, as well as to perform fire simulations of cable fire.

C 2.1.7.3. Conclusions drawn on the adequacy of the licensee's fire safety analyses

Fire PRA is a full scope analysis of the unit Olkiluoto 3. It covers all plant operation modes, as well as PRA Level 1 and Level 2 analyses.

Fire Hazard Functional Analysis is completed for the safety relevant buildings and justifies the plant can be transferred to the safe shut down in case of fire.

2.2 Spent fuel storage facility

D Olkiluoto ISFS

D 2.2.1 Types and scope of the fire safety analyses

PRA of the ISFS covers probabilistic fire risk assessment. [21]

Fire simulations have been used to justify the performance-based fire safety design of the expansion of the ISFS facility.

D 2.2.2 Key assumptions and methodologies

The documentation of the fire survey and the determination of the fire frequencies of the rooms have been done using an Excel spreadsheet program. The determination of fire frequencies is partially based on the method presented in report NUREG/CR-6850. In the distribution of ignition sources in the ISFS, the method presented by NUREG/CR-6850 has been used. In the evaluation of the component-specific ignition frequency of ignition sources, the ignition frequencies presented in OL1/2 have been used. Since the ISFS contains significantly fewer components than the plant units, the component-specific ignition frequency would increase very much if the NUREG/CR-6850 method was applied directly to the evaluation of the component-specific ignition frequency.

D 2.2.3 Fire phenomena analyses: overview of models, data and consequences

The quantitative analysis of the ISFS has taken into account the fire compartments where equipment or cables are located, the damage of which leads to the loss of one pool circuit needed for the residual heat removal of the fuel pools. In terms of fuel damage, the loss of residual heat removal is the only possible initiating event from a fire.

D 2.2.4 Main results / dominant events (licensee's experience)

According to the PRA, the total frequency for the ISFS pool water to boil is 7.2E-8/a.

After a long term boiling phase, PRA assesses the frequency of fuel exposure, which results in a large release from the ISFS. According to the PRA, the frequency of fuel exposure in the ISFS 2.6E-10/a and fire events' contribution is insignificant.

D 2.2.5 Periodic review and management of changes

D 2.2.5.1 Overview of actions

Review is done when necessary, according to plant modification projects or operational experiences. The fire analyzes are up to date and have been submitted to STUK for approval in due course. In plant modifications and projects, the possible effects on the performed analyses are evaluated, and the analyses are updated accordingly, if necessary.

D 2.2.5.2 Implementation status of modifications/changes

No significant changes based on fire PRA have been made.

D 2.2.6 Licensee's experience of fire safety analyses

D 2.2.6.1 Overview of strengths and weaknesses identified

Regardless of the fire load, cables, switchgear, instruments and devices of different redundancies (A- and C-sub) are placed in different fire compartments. Thus, in the event of the destruction of one fire compartment, both redundancies, which verify each other, will not be damaged.

D 2.2.6.2 Lessons learned from events, reviews, fire safety related missions, etc.

Similar to section B 2.1.6.2.

D 2.2.7 Regulator's assessment and conclusions on fire safety analyses

D 2.2.7.1. Overview of strengths and weaknesses identified by the regulator

Fire PRA of the ISFS is based on conservative assumptions in the fire induced damages.

D 2.2.7.2. Lessons learned from inspection and assessment as part of the regulatory oversight

Fires are not meaningful in the PRA of the ISFS. Fires may affect the cooling function of the spent fuel pools causing very low risk for the spent fuel exposure and radioactive release.

D 2.2.7.3. Conclusions drawn on the adequacy of the licensee's fire safety analyses

Fire events affecting the ISFS have been assessed systematically and based on conservative assumptions.

3 Fire Protection Concept and Its Implementation

3.1 Fire prevention

A NPP units Loviisa 1 and 2

A 3.1.1. Design considerations and prevention means

First principle of fire protection at Loviisa 1/2 NPP is to prevent ignition of a fire by identifying faults and other events possibly leading to fire and relative fire risk of materials. Practically this has been done by layout and civil engineering design and by minimizing fire loads, especially within the containment and main control room (MCR). However, the plant units still contain much fire load in the form of PE- and PVC-cables, diesel generator fuel and turbine lubricants etc. Layout design aims to separate fire loads from ignition sources.

The fire compartment with the most fire load is the turbine hall which is shared between the two plant units. There are four turbine-generators in the hall each with over 50 m^3 of lubricant oil. The oil is in the main oil tanks, gravitational tanks sufficient for ensuring lubrication during turbine shutdown and intermediate tanks. There are oil mist vacuums high in the turbine hall to collect possible oil mist. The generators are cooled with hydrogen. When there is a heightened fire risk, the hydrogen is replaced with nitrogen. [22]

The main and auxiliary transformers also contain large amounts of oil. This has been considered in the design with a collection pool under the transformer where the oil cannot combust freely as a pool in the atmosphere.

The magnetizing transformers of both plants no longer contain oil. They were changed to dry transformers in 2015.

Main facets of preventative fire protection are listed in internal guide for Fire Protection and Rescue Operations [23]. There shall be no unnecessary storage of flammable materials, liquids, or gases in the plant premises. Escape rooms and stairways shall be kept clean of all materials. Storage of flammable materials in the plant always requires a permit from the authorized personnel from plant fire brigade. Fire safety shall be considered when modifications or reparations are made to plant systems. Used solutions shall be approved by Fire Chief or Head of Nuclear Security and Risk Management unit. Flammable materials are not allowed to be used in plant structures without the explicit approval of Fire Chief or Head of Nuclear Security and Risk Management unit. Functionality of structural and active fire protection arrangements shall be verified.

The main fire risks of final disposal facility for low and intermediate level radioactive waste (VLJ) are vehicle fires in the tunnel and fires of soft maintenance waste in the steel barrels.

A 3.1.2. Overview of arrangements for management and control of fire load and ignition sources

Control of external fire loads is aimed to improve fire safety by lowering risk of ignition and fire spread. It’s also essential to ensure conformance to internal and external requirements. Fire Brigade has up-to-date fire load accounting of all external flammable materials in the plant [24]. Accounting includes the following information:

- date of the account
- person who has issued the permit
- permit ID-code
- description of the fire load and justifications
- quality of the fire load
- weight of the fire load (kg)
- calculated fire load (MJ)
- location of the fire load (room code)
- ID of the fire compartment
- Information whether the area is identified as risk area
- compensative measures in case risk area
- additional approval if risk area
- permits validity period
- verification that fire load has been removed after validity period
- person responsible of the fire load.

Following procedures are in place for different types of fire loads in addition to accounting [23]:

- Small fire loads; protective materials and packaging: Materials shall be removed before entry to the protected area. In specials cases, where protective materials can only be removed inside, firefighters make sure that materials are taken out of the plant.
- Flammable pallets, crates, and scaffolding materials: To be removed before entry to the plant. Exceptions shall be approved by Fire and Security lieutenants. Exceptions need to be marked with a marking card for where and when the materials are allowed inside the plant.
- Flammable gases: Gas cylinders are transported to the protected area with a marking card and a fire load permit sticker. Fire and Security lieutenant evaluates and approves the cylinders with an approval mark on the marking card. Gas welding equipment is stored in three specific rooms inside the RCA (radiologically controlled area) or the hot work building next to turbine hall.
- Hazardous chemicals: The storage practices for hazardous chemicals are described in a separate guide [25]. External flammable liquids can only be stored at the facility in separately approved and marked storage areas (storage for flammable liquids or fire safety cabinet). Maximum amount of flammable liquids at the work site is 3 liters for extremely or highly flammable and 20 liters for others. All flammable liquids shall be kept in their original packaging with appropriate markings. If larger amount of flammable liquids is needed for a work project, there shall be separate fire safety instructions in the work order. These are approved by fire safety lieutenant.

Fire brigade has the authority to stop work if deviations from these instructions and processes are observed.

Storage arrangements are an important part of fire prevention. Storage of materials is approved in marked and approved storage rooms or areas that have been evaluated for fire safety. Setting up a new storage area is done following the guides [23] and [26]. Evaluation includes the planned usage of the area, conjoining fire compartments, effect on operational fire protection, extinguishing systems in the area, and the restrictions on the use of area. Evaluation is done by by Fire and Security Captain, Fire Chief or Head of Nuclear Security and Risk Management unit The storage area shall be marked with a sign that denotes the purpose for the storage, responsible organization and person, room number, fire compartment, and the restrictions on the use of area.

Hot work is regulated via permits which are given out by plant fire brigade. The licensee requires alternative work methods to be used instead of hot work whenever possible. Safety measures for hot work are defined by work order. Predefined safety measures can be supplemented by decision of fire and security lieutenant, if necessary. Permission to start hot works is granted by fireman or fire safety supervisor at the work site after checking that the conditions for hot work are met. Also, separate permission is required after the hot works has been finished to verify that area has been left to secure state. [27]

A hot work certificate is required for everyone who carries out or authorizes hot works on the plant in addition to plant specific orientation. Training for the certificate takes one day and it shall be renewed every 5 years. Training also includes the use of portable fire extinguisher. [27]The equipment used for welding or other special works have to be tested and calibrated periodically. [28]

Explosion risk areas are covered by the plant's ATEX explosion protection document [29]. The measures at the plant can be preventive, such as the processes being close for minimal access of combustible substances to the environment. Equipment in the classified areas has been selected so that they do not cause sparks and do not have hot surfaces.

Plant fire brigade conducts designated fire safety inspection rounds three times a year. The contents of the inspections are listed comprehensively in appendix 2 of the guide [30]. Inspection areas are divided into 6 parts:

- General cleanliness and order, waste management
- Control of fire loads (chemicals, flammable liquids)
- Fire compartmentation
- Manual firefighting equipment
- Active fire protection systems
- Exit routes and fire brigade attack routes.

A 3.1.3 Licensee's experience of the implementation of the fire prevention

A 3.1.3.1. Overview of strengths and weaknesses

The plant has highly trained and experienced full time professional fire brigade with wide responsibilities related to plant's fire protection and fire safety activities.

The plant has developed comprehensive plant level risk analysis for identification of risk areas and combustible materials/fire loads to be used in relation to fire load permit management. The analysis has also been integrated to be as part of fire load management, storage area managements, area approval procedures, etc.

A 3.1.3.2. Lessons learned from events, reviews fire safety related missions, etc.

Based on the recent peer review missions and other reviews the management of combustible materials and hot works are in good level. The current procedures provide systematic and disciplined procedures for management and control of the issues.

The plant has utilized mission and peer reviews (e.g., WANO) to identify and define improvement actions especially in the areas of combustible material management and analysis. Necessary actions have been implemented.

Based on the power plant operation experience process, the fire department also handles fires or other accident events that have occurred at other nuclear power plants, both nationally and internationally.

A 3.1.3.3. Overview of actions and implementation status

During the past years plant has developed the following actions related to fire prevention:

- Plant wide analysis of risk areas and combustible materials
- Combustible materials/fire load management procedures: instructions, trainings, permits, log book/accounting, follow up
- Updated procedures related to hot works on roof areas
- Targeted fire safety trainings for maintenance and operations departments for identification of fire loads in addition to regular and normal fire safety training.
- Approval procedures for storage areas and usage of areas in general. Separate fire safety/protection evaluation and approval.

A 3.1.4. Regulator's assessment of the fire prevention

A 3.1.4.1. Overview of strengths and weaknesses in the fire prevention

In general, it can be said that the measures for fire prevention at Loviisa 1 and 2 plants are at a very high level. The strengths include measures for handling of transient fire loads, storage of hazardous materials and procedures for hot work. All of these have been improved continuously based on past incidents or perceived risks.

Weaknesses in fire prevention include large amounts of fire load, especially PVC/PE-cables and turbine lubricant oil system which is vulnerable to uncontrolled leakages.

Human factors are seen as a major contributor to possible ignition events, especially during maintenance outages. There have been three incidents at the plant in the last 10 years that have been classified as fires. None of the fires posed a risk to plant safety systems or caused plant shutdown.

A 3.1.4.2. Lessons learned from inspection and assessment on the fire prevention as part of its regulatory oversight

All STUK inspectors have been trained to oversee fire hazards when conducting inspections at the plant.

STUK inspections at the site have uncovered for example a case in 2012 where large amounts of combustibles and highly flammable liquids were stored near the PCPs related to maintenance activities during LO1 outage. This led to stricter policies on use and storage of flammable materials.

B NPP units Olkiluoto 1 and 2

B 3.1.1. Design considerations and prevention means

Main design principles to prevent fires are the use of fire-resistant construction always when technically feasible, the application of fire-resistant materials and the reduction of combustible material to a minimum. [31]

Control of fire loads aims to lower the risk of fires and their spreading. Most of the material can be changed to an alternative that is non-flammable or fire-retardant. [32]

The original design of the plant doesn’t consider storing of flammable materials inside the plant. Therefore, the licensee has strict policies for accepting transport of fire load to the plant. [33]

The final disposal facility for low and intermediate level radioactive wastes (VLJ) contains plant maintenance waste stored in non-combustible containers. The containers are then placed in concrete silos. Fire risk is assumed to be very low. [34]

B 3.1.2. Overview of arrangements for management and control of fire load and ignition sources

There shall be no unnecessary fire load inside the fire compartments. If there is a need for transient fire load in a compartment containing safety system equipment, a plan must be formulated to maintain the level of fire safety. [35]

Storage of materials in the plant is described in TVO guide [32]. The guide refers to Rescue Act [5], Decree on the Fire Safety of Buildings [6] and STUK guide YVL B.8 [10]. The permanent storage of materials is allowed only in accepted and marked storage areas, which include storage rooms and marked areas e.g., in corridors. Permanent storage areas are marked with green lines on the floor while temporary areas are marked with blue lines. Storage signage must include intended usage, responsible organization, responsible person, and possible restrictions on use (e.g., no flammable material).

TVO has a guide for establishing new storage areas. [32] In this guide, the process and responsibilities for establishing new storage areas are presented. The proposition has to include location and size of the intended storage, stored material, how often the storage is used, pictures of the material and storage location (incl. surroundings), alternative solutions, responsible organization and person, and other relevant factors. The proposition is then evaluated by plant fire brigade, risk analyst, and the fire protection expert of civil engineering department among others. After evaluation, the proposition is processed in plant modification meeting, where the meeting decides to move forward with the proposition or decline it. Depending on the storage in question, the process will then continue as a structural modification or non-structural change. For non-structural changes, an acceptance memorandum is then written. Said memorandum is then reviewed by plant fire brigade, risk analyst, and the fire protection expert of civil engineering department, and accepted by fire chief and chief of civil engineering department. The accepted storage is the documented in the plant database and marked accordingly with painted area and signage. Seismic fastenings are also installed if necessary.

TVO has a guide for the procedures related to hot work [36]. The guide also includes provisions for opening of fire compartment structures, dust-inducing work, transport of fire load to the plant, ATEX-work and temporary storages. The protective measures related to how work shall be defined in the work order. A hot work certificate is required for everyone who carries out or authorizes hot works on the plant in addition to plant specific orientation. Hot works require supervision during the work and for a minimum of one hour after conclusion of work (can be longer if defined in the permit). Hot work and other fire safety permits are given by plant fire brigade. Hot work certificate is also required from issuer of permits and supervisor of hot work.

Protocol for temporary storage at a work site is defined in Appendix 7 of the hot work guide [36]. Plant fire brigade gives out the permit for temporary storage. After the printing of the permit, fire personnel check the area for suitability. Attention is paid to nuclear safety and safety of exit routes. Temporary storage is then marked with orange tape and the permit is attached to a wall next to the storage. Permit dictates which materials can be stored at the site. Extra fire loads must be removed. Extra surveillance rounds are performed if deemed necessary. After the storage is not needed anymore, fire brigade archives the permit. The area must be cleaned from all leftover materials.

The use, transport and storage of hazardous materials is described in guide [37]. This guide includes provisions for flammable materials. Flammable liquids and gas cylinders are stored separately from other chemicals. Small amounts of flammable liquids can be stored at the plants in a separate metal cabinet for flammable liquids. Combustible material such as paper, textiles, wood, empty cardboard boxes and flammable packaging filling materials must not be kept in the same storage as chemicals. No more than 5 litres of flammable liquid may be temporarily stored at a worksite. Flammable liquids and gases must be, after the daily work is done, stored in metal fireproof cabinets.

The plant fire brigade does internal fire inspection rounds to ensure that fire safety is on an adequate level [38]. The rounds are done twice a year. Additional inspection rounds are performed always when fire protections systems that are listed in

Operational Limits and Conditions (OLC) are disconnected or faulty. Extra inspection rounds are also done before, during and after annual outages. TVO hires extra personnel during the outages to work as fire guards that do inspection rounds and perform surveillance on hot work. In addition to nominal inspection rounds, the plant fire brigade personnel perform surveillance on fire safety always when moving in the plant for other activities. The field operators are also trained to notice any non-conformances related to fire safety. All remarks and non-conformances are reported in TVO’s KELPO database and are addressed by fire brigade. The contents of the inspections are listed comprehensively in appendix 1 of the inspection guide [38]. Inspection areas are divided into 8 parts:

- Control of fire loads (general)
- Control of fire loads (storage)
- Control of fire loads (chemicals, flammable liquids)
- Removal of ingnition sources
- Fire compartmentation
- Manual fire fighting equipment
- Acitive fire protection systems
- Exit routes and fire brigade attack routes.

Most of the inspections are visual, but there are some functional checks included.

B 3.1.3 Licensee’s experience of the implementation of the fire prevention

B 3.1.3.1. Overview of strengths and weaknesses

The original fire protection concept/philosphy has mainly been found to be good, even though it does not meet the current regulations regarding passive fire protection in all respects.

Strengths:

- For all storing (temporary / permanent) at nuclear power plant permit is required. Temporary storage permit is implemented in the work management system**.** Permanent storage places are processed in the plant change process.
- Work related to fire safety, such as hot works, dust-causing works, opening fire compartment structures, working in an explosive area and temporary storing. For example, all hot works are inspected before the work starts, and post-inspections are also carried out.

B 3.1.3.2. Lessons learned from events, reviews fire safety related missions, etc.

Many improvements have been implemented over the years, which have been based on operating experiences (Internal and external), recommendations from authorities or other parties, etc. As a single example, a fire at the switchgear building led to numerous improvement measures over the years:

- Arc resistance was improved with additional insulation of the wall between the supply cells (1992)

- A second starting transformer was installed for both plants, 1993 In the MODE project, the generator circuit breaker was renewed (KATKA project), can also interrupt short-circuit currents (1997-1998)
- In the REMES project, 6.6 kV switchgears were renewed, self-use and starting transformer feeds were distributed to different ends of the switchgear and arc protections were installed (2005-2006).

Since the 2012 WANO Peer review, major improvements have been made to fire protection.

- A working group was established for the development of fire protection, which drew up goals for the development of fire protection.
- A large amount of fire load was removed from the plants. All possible fire load was changed to non-combustible, or non-flammable, or protected with non-combustible structures.
- In the work permit system, an export permit was established for the combustible material plant. Permanent and temporary storage also became subject to a permit.
- The storage of chemicals and flammable liquids changed to fire compartmentalized cabinets.

The rescue authority considered the fire safety improvements to be significant.

A recent event, which led to corrective actions, was discovered regarding the activities of plant fire brigade. Shortcomings had been observed at all Olkiluoto nuclear power plants in adherence to compensatory fire protection practices during the isolation of fire protection systems in 2022. Shortcomings in fire safety rounds constitute a deviation from both procedures and Technical Specifications. Corrective and development activities:

- The expectations for the operation have been summarized with the shift personnel of the plant fire brigade.
- When making surveillance rounds, a device is used, which is used to read code markings installed in the room. This ensures the performance of safety rounds.
- An electronic diary is used to ensure that control rounds are carried out in accordance with the instructions and technical specification and to manage other abnormal procedures. Monitoring the completion of rounds in both morning and afternoon meetings.
- Many trainings for the plant fire brigade, for example technical specification, Human performance, Nuclear professional and the importance of the safety of one’s own work in a nuclear power plant.
- Managers in the field practice has been started by plant fire brigade.

B 3.1.3.3. Overview of actions and implementation status

In the WANO inspection carried out in 2020, TVO received a call to improve the management process of temporarily closed penetrations. The call has been responded to and administrative improvement measures have been implemented. The management of temporarily closed penetrations is now handled in the team network in the workspace "opening of cable and pipeline penetrations".

Structural changes related to fire prevention have either been related to the development of passive fire safety solutions or to changes in active fire prevention systems. The purpose of developing passive fire safety solutions has been to improve e.g., fire compartmentalization so that the fire load not part of the process causes as little threat to the safety or usability of the plant units as possible.

B 3.1.4. Regulator's assessment of the fire prevention

B 3.1.4.1. Overview of strengths and weaknesses in the fire prevention

The fire prevention measures in OL1/2 NPPs are at a high level. The strengths include guidance for storing materials and hot works. Hot work instructions include different types of permits for works that can cause fire risk.

Main weakness in fire prevention is the large amount of fire load, especially PVC/PE-cables, and turbine lubricant oil.

Human factors are seen as a major contributor to possible ignition events, especially during maintenance outages.

There has been one incident that has been classified as a fire in the plant in the last 10 years.

B 3.1.4.2. Lessons learned from inspection and assessment on the fire prevention as part of its regulatory oversight

TVO has improved fire protection measures continually and has been proactive in discussions with the regulator.

Fire protection arrangements are overseen with design reviews and onsite inspections. All STUK inspectors have been trained to oversee fire hazards when conducting inspections at the plant.

C NPP unit Olkiluoto 3

C 3.1.1 Design considerations and prevention means

The fire protection system follows three levels of the defense-in-depth principle:

- Level 1: Fire Prevention
- Level 2: Fire Containing
- Level 3: Fire Controlling

Arrangements are made to prevent fires from starting or to make it difficult for fires to start. This means that non-flammable or fire-resistant materials, structures, equipment, and fluids are used as far as technically reasonable. Ignition sources are avoided. Special attention is paid to the necessity of the application of combustibles, particularly inside the containment and inside the main control room (MCR).

A major influence on the fire protection concept results from the application of fire retardant, halogen-free and of low smoke emission cable insulation instead of standard materials (e.g., PVC cable). This special cable insulation results in a high protection level against cable fires and their impacts on personnel and on the plant. Therefore, manual firefighting for cable areas is possible without any need for fixed fire extinguishing systems (e.g., sprinklers, spray water). [15]

C 3.1.2. Overview of arrangements for management and control of fire load and ignition sources

OL3 plant unit abides mainly by the same set of guides as OL1/2 when it comes to fire safety. As presented in section B 3.1.2. Overview of arrangements for management and control of fire load and ignition sources for OL1/2 in more detail, the guides for storage [32], hot work [36], inspections [38], hazardous materials [37] and temporary arrangements when fire protection features are not fully functional [35] are all followed at OL3 also.

C 3.1.3 Licensee’s experience of the implementation of the fire prevention

Possible extra fire load is monitored via plant walkdowns (also fire safety engineering participates) performed before main milestones fuel loading / 1. criticality / outage, continuing observation is performed by fire safety department and KELPO observations is requested to be made by plant worker in case of notice.

C 3.1.3.1. Overview of strengths and weaknesses

Strengths:

- For all storing (temporary/permanent) at nuclear power plant permit is required. Temporary storage permit is implemented in the work management system. Permanent storage places are processed in the plant change process.
- Work related to fire safety, such as hot works, dust-causing works, opening fire compartment structures, working in an explosive area and temporary storing. For example, all hot works are inspected before the work starts, and post-inspections are also carried out.

C 3.1.3.2. Lessons learned from events, reviews fire safety related missions, etc.

A recent event, which led to corrective actions, was discovered regarding the activities of plant fire brigade. Shortcomings had been observed at all Olkiluoto nuclear power plants in adherence to compensatory fire protection practices during the isolation of fire protection systems in 2022. Shortcomings in fire safety rounds constitute a deviation from both procedures and Technical Specifications. Corrective and development activities:

- The expectations for the operation have been summarized with the shift personnel of the plant fire brigade.
- When making surveillance rounds, a device is used, which is used to read code markings installed in the room. This ensures the performance of safety rounds.
- An electronic diary is used to ensure that control rounds are carried out in accordance with the instructions and technical specification and to manage other

abnormal procedures. Monitoring the completion of rounds in both morning and afternoon meetings.
- Many trainings for the plant fire brigade, for example technical specification, Human performance, Nuclear professional and the importance of the safety of one's own work in a nuclear power plant.
- Managers in the field practice has been started by plant fire brigade.

C 3.1.3.3. Overview of actions and implementation status

When identifying stored material which is considered as potential fire load / ignition source, these cases are solved in high priority. Opportunities are transporting material out from the plant or to safe storage area inside the plant.

C 3.1.4. Regulator's assessment of the fire prevention

C 3.1.4.1 Overview of strengths and weaknesses in the fire prevention

The fire prevention measures at OL3 NPP are at a very high level. The strengths include provisions for storing materials and hot works. Hot work instructions include different types of permits for works that can cause fire risk.

PCP motors are protected with casing to reduce the effects from potential oil leaks improving fire safety.

Although there is much fire load in the plant, the cabling has been mainly done with FRNC-cables that do not ignite easily and reduce the fire spread. The smoke from the burning cables is non-corrosive.

C 3.1.4.2 Lessons learned from inspection and assessment on the fire prevention as part of its regulatory oversight

The oversight of a new build has been great opportunity for STUK to improve its competencies on inspections of fire protection arrangements.

STUK has contracted VTT to do fire tests and analysis for verifying FRNC-cable concept and structural protection.

D Olkiluoto ISFS

D 3.1.1 Design considerations and prevention means

The fire protection arrangements for Olkiluoto IFSF are described in a topical report [39] as part of the FSAR. The fire loads of different rooms are listed. Largest concentrations of fire loads are in cable tunnel and transport corridor.

D 3.1.2. Overview of arrangements for management and control of fire load and ignition sources

The ISFS is managed by the same licensee, TVO, as the Olkiluoto NPPs. Therefore, the same guides and instructions regarding fire safety apply for all of the facilities. The measures for management of fire loads and ignition sources are described in more detail in section B 3.1.2. Overview of arrangements for management and control of fire load and ignition sources

D 3.1.3 Licensee's experience of the implementation of the fire prevention

D 3.1.3.1. Overview of strengths and weaknesses

Possible extra fire load is monitored via fire safety inspection rounds and continuing observation is performed by fire safety department. Safety observations are requested to be made by plant workers. Other strengths include the fire safety permit process (hot works, storing, opening of penetrations) and the alternative measures for maintaining required fire safety level defined in Technical specifications (TTKE).

D 3.1.3.2. Lessons learned from events, reviews fire safety related missions, etc.

The facility is subject to same inspections and fire safety missions as OL1/2/3.

D 3.1.3.3. Overview of actions and implementation status

When identifying stored material which is considered as potential fire load / ignition source, these cases are solved in high priority. Opportunities are transporting material out from the plant or to safe storage area inside the plant.

D 3.1.4. Regulator's assessment of the fire prevention

D 3.1.4.1 Overview of strengths and weaknesses in the fire prevention

The fire prevention measures at Olkiluoto ISFS facility are at a high level. The strengths include guidance for storing materials and hot works. Hot work instructions include different types of permits for works that can cause fire risk.

D 3.1.4.2 Lessons learned from inspection and assessment on the fire prevention as part of its regulatory oversight

There have been no recent findings related to fire prevention measures at the facility.

3.2. Active fire protection

A NPP units Loviisa 1 and 2

A 3.2.1. Fire detection and alarm provisions

A 3.2.1.1. Design approach

The fire alarm system function is to alarm of a fire both acoustically and optically at the local central unit of the building and the master central unit at the MCR. Alarm is also transmitted to the graphic user interfaces (UI) in the MCR, alarm center, fire station, and the graphic info panel (MCR). Primary user interface is the graphic UI in the MCR and the secondary is the master central unit in the MCR. [40]

The system is used to actuate automatic spray deluge systems in the cable rooms, extinguishing systems in diesel generator rooms, CO_2-extinguishing systems, and some ventilation systems.

The fire alarm system covers almost all plant rooms with any significant fire load. Some rooms with very high radiation levels have been excluded as it was thought that it would be difficult to adequately maintain the equipment. The automatic fire detectors are installed as loop circuits, where the system can locate the fire accurately.

The fire alarm system also covers the final disposal facility for low and intermediate level radioactive wastes (VLJ). [41]

A 3.2.1.2. Types, main characteristics and performance expectations

The system uses a variety of automatic fire detectors. Mainly, ionization and photoelectric smoke detectors are used. Laser smoke detectors are used in e.g., electrical and computer rooms, where quick detection is required. Heat detectors are used where other types are not suitable. The system also includes gas detectors in emergency diesel building, which alarms if there are flammable gas leaks from fuel tanks. Fire alarm can also be given manually via the button at fire alarm call points.

Detectors are generally installed in the ceiling of the room, but in some special cases they are installed in ventilation ducts, beneath projections, or walls.

Detectors have encompassing fault detection with alarms. There is also a separate system monitoring the condition of detectors.

Some fire detector loops cover rooms in different fire compartments. However, the fire can always be located to the right room based on the detector address.

Fire alarm panels of the buildings are located at the rescue routes near the entrances. Exceptions to this rule are three panels that are below ground because of space issues and three panels that are in MCR.

The fire alarm system is backed up by batteries if connection to the grid is lost. Batteries enable the system to work independently for at least 72 hours.

Actuation of automatic fire suppression systems, fire dampers and ventilation systems is done when there is fire detection from two separate detectors. If there is only one detector in the room, there is first a pre-alarm before the actual fire detection which actuates the equipment in question. [40]

A 3.2.1.3. Alternative/temporary provisions

When maintenance or modification work may cause false fire alarm, the affected fire detectors shall be disabled temporarily. The disabled detectors shall be listed in the fire protection instructions of the work order. When hot work is performed, the hot work overseer asks the alarm center for the disabling of detectors when work is ready to start and restoration of the detectors when work is finished. In other types of work (dust inducing etc.) the fire lieutenant asks for the disabling and work supervisor for the restoration.

Fire lieutenant arranges surveillance rounds to be performed every hour in rooms where fire alarm system is disabled or faulty in areas that are related to the plant process. Surveillance rounds are triggered when a room is without a functioning fire detector or when half of the detectors of a fire group are disabled or faulty. Surveillance rounds are not performed in rooms where work is ongoing as these rooms are under constant surveillance. Surveillance rounds can also be substituted by a portable fire extinguishing system or CCTV. For areas that are not related to the plant process, the need for surveillance rounds is decided case by case. [23]

A 3.2.2. Fire suppression provisions

A 3.2.2.1. Design approach

The fire suppression arrangements have been realized according to Finnish legislation and regulatory guides. Fire suppression has a significant role in the fire protection concept, because the original passive fire protection features and layout design of the plant do not meet the standards of today. Fire suppression provisions are mainly based on water as the extinguishing agent. In addition, there are CO_2 gas extinguishing systems in limited locations.

The basis for fire suppression systems in the fire water network and pumping stations. The primary firefighting water pumping station houses four large electrically powered pumps and two pumps to keep the pressure up when there is no consumption in the system. The function of the system is to feed fire water to all LO1/2 extinguishing systems and fire hydrants with adequate pressure. The capacity is designed to be able to feed all spray deluge systems (5 pcs.) of a single turbine generator; or three of the deluge systems, and the largest coverage area of the sprinkler system in the turbine hall and a single water hydrant, water cannon, or foam cannon; or all the fire hydrants and foam cannons in the turbine hall. Fire water is taken from two storage tanks mined in the bedrock. Volume of the tanks is 2 * 1500 m^3. The minimum amount of water needs to be at least 1400 m^3. The large pumps are started automatically via signal from pressure gauges or flow gauges when an extinguishing system is actuated.

Secondary firefighting water pumping station houses three diesel-powered pumps. The three pumps combined have equal capacity to the pumps at primary pumping station. Pumps at the secondary firefighting water pumping station are operated manually from MCR of LO2 or at the pumping station. UJ30 has a 1500 m^3 steel water tank. [42]

Firefighting water is delivered from the pumping stations to plant location via fire water distribution network UJ/UK. Network is circular, so that water can reach every point in the loop from both directions. Some connections to buildings detached from main plant buildings are not doubled. The lines can be isolated in case of a leak in the pipes. There are 9 main isolation valves operated from MCR of LO2 in the distribution network.

A 3.2.2.2. Types, main characteristics and performance expectations

There are multiple different types of extinguishing systems used at LO1/2 plant units. This includes water sprays systems, sprinkler systems and CO_2 gas extinguishing systems.

Water spray systems in cable rooms and corridors cover cable rooms where the conditions are not suitable for manual extinguishing. The qualifying cable rooms where this system is not suitable are generally protected with CO_2 gas extinguishing systems. System actuation is done via fire detection from two separate fire detectors or one manual fire alarm button for most parts of the system. The system can also be manually actuated from local valve stations and from MCR. The system has open nozzles and upon actuation the dry pipes are filled with pressurized water that sprays to covered area from all the nozzles. There are 40 valve stations in LO1 and 39 in LO2. Special cases are cable rooms in the control building and reactor building annulus, where the systems are manually actuated to avoid harmful side effects in case of accidental actuation. The safety significance of this system is large as the system extinguished cable fires quickly, so that nuclear safety is not compromised. [43]

The turbine hall of LO1/2 plant units houses three extinguishing systems. The importance of these systems is great because they prevent the collapse of the turbine hall and spread of fire to a wide area. Turbine hall frame is constructed of steel structures, which are only partially protected from fire. Also, the cable rooms and tunnels in the adjacent fire compartments heat up with the possibility of cable failure if the extinguishing doesn't adequately lower the temperature. Operational firefighting is difficult in the turbine hall, which is an open space with many platforms. In the turbine hall, water spray system covers the turbine generators, sprinkler system covers the general areas of the turbine hall and water cannons are used operatively to support the other systems and to cool the steel structures above the turbines. All these systems are mainly designed against oil fires. Water spray system is meant to extinguish an oil pool fire and to limit a spraying oil fire. It also helps locating the fire as the system transmits actuation signal to the fire alarm system. The system has five protected areas per turbine generator. The nozzles of the system have bulbs that break at high temperature. The piping from the nozzles to the valve station is filled with pressurized air, and the breaking of the bulb gives an alarm to the fire alarm system. With the fire detection signal, groups 1 and 2 are actuated automatically as they protect the largest oil tanks, while groups 3, 4 and 5 are manually actuated based on fire detection and assessment of the situation. Detection of fire from group 5 closes oil intake for the turbine and leads to turbine shutdown. Sprinkler system extinguishes fires that have spread to horizontal platforms in the turbine hall. It also limits three-dimensional oil fires and protects the structures, cables and equipment from the effects of fire. The sprinkler system is activated with temperature bulbs breaking, one nozzle at a time. Breaking temperature of the bulbs have been adjusted based on location to account for hot equipment and the possibility of steam leakage. The six water cannons are located in the main turbine maintenance platform and are situated so that it is possible to target each possible oil fire with two cannons. The steering of the cannon can be locked to a target and the nozzle can be adjusted for the water to come out as mist also. The cannons are actuated manually. [44]

The deluge sprinkler systems protect the transformers. Operative firefighting activities are difficult to conduct at the transformer area because of tight spaces, the size of the transformers, protective bunker, and high voltages. The safety significance of the systems is high because they extinguish the fire at the transformer area to prevent its spread to turbine building and diesel building. One system protects the main transformers and auxiliary transformers. The nozzles of the system have bulbs that break at high temperature. The piping from the nozzles to the valve station is filled with pressurized air, and the breaking of the bulb gives an alarm to the fire alarm system. The system is automatically actuated when differential- or bucholz-relay opens a magnetic valve in addition to bulb break to allow for water to flow. This is done to ensure the transformer is disconnected when it gets in contact with water. The system can also be actuated manually. The other system is used to cool down the backup transformer and prevent its combustion in case of fire at the main transformer. This system is actuated manually. [45]

In addition to these most noteworthy sprinkler systems, the plant also has sprinkler systems in different areas that were deemed important to protect. There are sprinkler systems in backup emergency feed water pumping station, laboratory building , containment spray pumping station, emergency diesel building, IC building, CT-transformer rooms, seawater pumping station, controlled area waste rooms, and PCP-area. [46]

CO_2 gas extinguishing systems are used in cable rooms where manual firefighting is challenging and where water based extinguishing systems are not suitable. There are in total 8 subsystems, 4 per plant unit (EDG building, two in control building, auxiliary building). Each subsystem protects 1-4 rooms. The system is actuated via fire detection from two separate fire detectors, or one manual fire alarm button. The subsystem protecting EDG oil tanks can be actuated only manually. Delayed launch, warning lights, and warning bells are used to ensure personnel safety. Ventilation is stopped. The system can also be actuated via the actuation button at the gas cylinders. In this case there is no delay, and the ventilation is not stopped automatically. [47]

Fire protection of final disposal facility for low and intermediate level radioactive waste (VLJ) is heavily dependent on operative fire protection. The cavernous facility has feed piping for CO_2 protecting the maintenance waste storages and firefighting water for hydrants protecting the access tunnel and adjacent rooms. Both are operated by the fire brigade with tank trucks from outside the facility. [41]

A 3.2.2.3. Management of harmful effects and consequential hazards

The fire suppression systems are not qualified against seismic events. Seismic walkdowns have been used to assess possible consequences of an earthquake.

The erroneous actuation of fire suppression systems doesn’t pose a risk to nuclear safety.

The erroneous actuation of fire suppression systems in EDG building would prevent the protected emergency diesel generator from working. Also, the erroneous function of the deluge sprinkler systems could cause the loss of the protected CT-transformer and in addition the transformer in the adjacent area.

A risk for reactor pressure vessel brittle break was identified in the case of pipe break in the line feeding all the extinguishing systems in the containment. With a large break, the reactor pit could be flooded. The pipe was modified to include a motor operated valve with a constricted bypass line. In normal operation, only the bypass line is open. This guarantees enough capacity for the fire hydrants inside the containment and an emergency shower. The main pipeline valve will be opened if the sprinkler systems inside the containment are needed. [42]

A 3.2.2.4. Alternative/temporary provisions

The alternative provisions when active fire protection systems are disabled is described in a fire brigade guide [23].

If primary fire water pumping station water reservoir is too low, the secondary pumping station is in standby. If the pumps don’t work at required capacity, the fire brigade prepares adequate pumping capacity with operative arsenal. The fire water pumps shall be fixed without delay.

For turbine generator water spray extinguishing system, when one subsystem is out of use, operational readiness shall be prepared for the covered area. If all the subsystems for one turbine generator are out of use, the readiness shall be prepared with hoses directly from secondary firefighting water pumping station. The system shall be fixed without delay. These provisions only apply to plant states where the turbine is operational. During outages the system can be disabled.

Operational readiness is prepared also in the case of one turbine hall sprinkler system subsystem being out of use. If the entire water spray or sprinkler system in the turbine hall is out of use for either plant unit there shall be an extra fire brigade shift (0+3) working in addition to normal operational readiness. The extra shift is on call in the turbine hall.

For main transformer area system being out of use, the operational readiness is prepared with hoses on the ground level and turbine hall roof. These provisions only apply when the transformer is operational.

For the cable sprinkler systems, following provisions apply: one subsystem out of use requires operational readiness to be prepared; one subsystem out of use inside the containment requires portable CO_2-extinguishers to be taken to the location; two subsystems out of use require an extra fire brigade shift (0+3) patrolling the area, and the repair shall be done without delay.

For the CO_2 system and EDG building fire suppression system being out of use, operational readiness shall be prepared.

If the water extinguishing systems in the cable rooms below MCR are out of use, the location shall be provided with portable CO_2-extinguishers.

The regulatory authority (STUK) shall be informed of these systems being disabled or faulty.

A 3.2.3. Administrative and organisational fire protection issues

A 3.2.3.1. Overview of firefighting strategies, administrative arrangements and assurance

Figure 10. Loviisa plant fire brigade trucks (image source: Fortum)

<u>Firefighting strategies</u>

The plant fire brigade has a start time of 60 seconds. The fire brigade has to be able to reach all facilities at plant within six (6) minutes from the alarm. In case of fire and accident situations, the plant fire brigade starts the extinguishing or rescue operations and commands the operations until offsite fire brigades reach the accident location.

Operative procedure also describes the fire brigade actions in 14 most probable mission types. The relevant ones in the scope of this report are:

- fire
- fire in electrical rooms
- fire alarm
- fire detector fault indication

- loss prevention – chemical leak
- loss prevention – hydrogen leak
- loss prevention – oil leak.

In case of fire the plant fire brigade starts rescue and extinguishing operations with manpower of 1+3 (Fire Lieutenant and three Firemen). Two security personnel are also assigned to help if the fire is inside plant area. The Fire Lieutenant established a command post at a location of their choosing and informs the MCR and Alarm Centre. Alarm Centre signals for fire alarm at the plant in informs the emergency response centre according to guide [23]. Alarm Centre also guides the first units of Regional Emergency Services to report at the location. The units arriving later are kept as a reserve near the main gate until a task is assigned.

Criteria for deploying onsite and offsite firefighting resources are defined in fire protection instruction and operative instruction of the security control room/alarm center operator.

At the fire location the Fire Lieutenant:

- performs a quick recon
- makes sure that the active fire protection systems at the location are actuated
- identifies occupational safety hazards (voltages, smoke diving, radiation protection)
- assesses the situation, defines the plan of operations and orders for offsite resources to be called
- orders the first actions for extinguishing and rescue operations
- orders the tasks to limit the spread of fire and smoke removal if the fire can't be extinguished
- founds command post and orders task for the security organization
- keeps MCR and designated duty rescue officer of the Regional Emergency Services informed of the situation
- after Regional Emergency Services have arrived, gives briefing of the situation to designated duty rescue officer of the Regional Emergency Services. [48]

In electrical room fires the Fire Lieutenant asks MCR to de-energize relevant equipment, if it's possible to identify, before starting extinguishing operations. [48]

In other types of missions, the basic structure of actions is the same. The Fire Lieutenant has an important role early on in assessing the situation and identifying the needed actions. The communication with MCR and the Regional Emergency Services is paramount. [48]

Fire protection of final disposal facility for low and intermediate level radioactive waste (VLJ) is heavily dependent on operative fire protection. The cavernous facility has feed piping for both CO_2 and firefighting water for hydrants that are operated by the fire brigade. Smoke removal is the main safety concern to allow for evacuation and operative firefighting. [41]

Firefighting strategies are complemented with fire pre-plans which covers all areas and fire groups within the plant. Fire pre-plans are essential part of firefighting strategies. Plans are integrated to be part of active and operative fire protection and also part of change management. Fire pre-plans consist of the following features;

- area maps
- explanations of icons and maps
- target specific maps
- target specific specification card/instructions
- target specific chemical card/instructions.

All of the above documents are kept up to date. Plans are in paper format but also in fire departments mobile devices and in electrical database. The target maps are also identical with graphical user interface of the fire detection system.

After every mission the pre-fire plans are evaluated and deviations and improvement proposals reported if needed [49].

Administrative arrangements

Plant fire brigade operative procedure [48] defines which locations or mission types require fire truck with a water tank to be taken on a mission. These are in the plant area:

- every time there is an actual fire alarm,
- main transformer area,
- EDG building,
- emergency backup feedwater building.

Fire brigade moves to the location with emergency driving.

The units of the Regional Emergency Services that are situated closest to the NPP have dosimeters in their vehicles by default. This also applies to the nearest voluntary fire brigades. Other units have dosimeters distributed to them at the command post. [48]

Upon arrival to the site, all external personnel that take part in extinguishing or rescue operations at the plant must be listed in a document specified in [48]. The superior of a unit is responsible for listing the unit and ensuring that all members have dosimeters. The unit may not leave the plant area before handing the list and dosimeters over to a radiation protecting engineer and the engineer giving permission to leave.

The fire brigade uses authority communications network (VIRVE) for communication between itself and the MCR. Secondary options are Dect-phone system or GSM phones. All offsite fire brigades use authority communications network (VIRVE). Tables for communication groups and call signs are presented in a classified guide [50].

When there is an apparent risk of fire or other accident, e.g, hydrogen leak or faulty machinery, the fire brigade can be ordered to enhanced readiness with an order from the Head of Nuclear Security unit, Fire Chief, Fire and Security Captain or Fire

Lieutenant. In these situations, the shift is in immediate start readiness and all normal work activities are discontinued. [48]

Assurance

The maintenance and inspections of operational fire protection equipment and vehicles are done according to plant fire brigade service procedure [51] and procedure for Fire Lieutenant tasks and responsibilities [30].

Active fire protection system reliability is ensured with scheduled checks and testing. The required tests from plant safety point of view are defined in plant Operational Limits and Conditions (OLC, TTKE in Finnish). OLC determines the test interval and refers to testing procedures. Testing procedures included in Fire Protection manual as documents of F-03-series. The OLC requirements cover fire water pumps, fixed extinguishing systems, fire hydrants and portable fire extinguishers. Some of the tests are done during outages and the OLC requires a written confirmation that fire protection systems are in the correct configuration before the plant can move to startup phase. [52] [53]

Active fire protection systems are also all part of plants aging management procedures and part of regular evaluation.

A 3.2.3.2. Firefighting capabilities, responsibilities, organisation and documentation onsite and offsite

Firefighting capabilities

The plant has professional full time fire brigade (6 shifts) were in each shift there is minimum one Fire and Security Lieutenant and three Firefighters. The fire brigade has a start time of 60 seconds. The fire brigade has to be able to reach all facilities at plant within six (6) minutes from the alarm. This requirement is yearly successfully demonstrated with each six (6) shifts. The fire brigade is supported by security officers/fireman in each shift.

As a basic training to apply to the plant's fire brigade, Firefighters are required to have a national firefighter qualification, so the fire brigade only hires professional firefighters. Fire and Security Lieutenant must have completed a firefighter's degree, and in addition, fire sub officer's degree is required. The firefighter education lasts 1.5 years, the fire sub officers education takes one year.

Professional education for firefighter and fire sub officers is provided by the National Emergency Services Academy. In addition, the Rescue Academy of Capital city trains firefighters for the needs of its Rescue Service. Plant fire brigade has also hired firefighters who has educated themselves there.

At least two years of work experience at an offsite fire and rescue department is required after graduation in order to apply for open firefighter positions. When a new firefighter or fire and security lieutenant is added, there is a 10–12-month induction training period at the plant. The purpose of the induction training is to qualify a Firefighter to work in the fire brigade of the plant. The training focuses especially on aspects related to the plant special environment and systems. Topics of induction training are:

- Fire protection and rescue operations
- Smoke and chemical diving
- Working at heights
- Rescue swimmer
- Paramedic operations
- Maintaining the control of fire safety
- Workplace-specific basic training
- Laws, regulations, and guidelines concerning the fire brigade of the plant
- General plant knowledge, such as radiological environment
- Plant layout
- Knowledge and management of fire protection systems
- Fire and rescue equipment/equipment and other equipment.

At the plant, refresher training is based on the basic training program for fire brigade, in which refresher intervals are defined for the subjects to be trained. Trainers are plant fire officers, Fire and Security Lieutenant, Security unit personnel or other persons outside the Security unit. National guidelines and legislation become obligations for the Firefighters and Fire and Security Lieutenants qualification. This especially applies to rescue diving (smoke and chemical diving), for which the plant also has its own guidelines. The plant fire brigade conducts its refresher training in addition to the training and exercises organized in the plant, for example, at the National Emergency Services Academy where fire brigade personnel can exercise themselves in real environment, such as real fires.

An implementation plan has been drawn up for all trainings and exercises, which serves as an aid to training planning. Schedules, responsible persons, and minimum requirements for the contents of the trainings are presented in the plan. All held trainings are reported comprehensively, the fire officers of the fire brigade oversee the reporting and implementation. In practice, the trainings are carried out either on training days or weekly exercises. On the training days, extensive exercises that require special preparations are carried out outside of work shifts. The weekly exercises are carried out in shifts.

Offsite fire brigades are familiarized with the hazards of the plant trough comprehensive training and co-operation with Regional Emergency Services. Emergency exercises and co-operation exercises with fire and rescue authority are held annually. Valid training plans are held up to date.

Security aspects are taken into consideration when planning fire protection measures.

<u>Responsibilities</u>

The fire brigade is responsible for the following topics:

- Testing, evaluation and supervision of fire suppression and sprinkler systems

- Issuing hot work permits both in work management system and in the field before starting hot work. In addition, they give permission to stop the hot works and check that all fire prevention arrangements are in order after the hot works
- Issuing fire load permits
- Management of fire compartment integrity
- Evaluation and approving of the fire protection issues and aspects in plant modifications and maintenance
- Design of fire protection instructions and requirements
- Aging management of fire protection systems
- Maintenance of fire extinguishers
- Conducting periodical fire safety inspections at the plant
- Providing fire protection training to plant personnel
- Service and maintenance of operational equipment used by the fire brigade
- Lead the preventive measures in case of fire, industrial accidents or acute illness, leaks of oil or hazardous chemicals and in other accidents at the plant
- Situation management in case of fire and accident situations, in co-operation with Regional Emergency Services and other relevant authorities
- The fire brigade and the Regional Emergency Services has an agreement on how the plant's fire brigade participates in rescue operations in the vicinity of the site area.

In case of fire and accident situations, the plant fire brigade starts the extinguishing or rescue operations and leads the operations until Regional Emergency Services assume the leading responsibilities as dictated by the Rescue Act. The shift manager of the plant has the responsibility for radiation protection. By default, the Fire and Security Lieutenant is the responsible for rescue operations. The responsibility can be shifted to Head of Nuclear Security unit, Security Chief, Fire Chief, Fire and Security Captain, or Station Officer with a separate command if necessary. The responsibility is then shifted to designated duty rescue officer of the Regional Emergency Services when they are ready to assume the lead. The Fortum leader of rescue operations has the following tasks:

- Define the main tasks and their correct sequence of actions.
- Found area command center and secure communications to MCR and designated duty rescue officer of the Regional Emergency Services.
- Make sure that the active fire protection systems at the location are actuated.
- Lead the rescue operations in co-operation with the MCR.
- Ensure occupational safety (voltages, smoke diving, radiation protection).
- Notify Central Alarm Centre of the directions to be given to offsite fire brigades.
- After Regional Emergency Services have arrived, move to area command center to help lead rescue activities. [23]

The internal and external communications for fire and accident situations are instructed in a separate guide. [54]

The procedures are described in more detail in plant fire brigade instructions:

- Fire Lieutenant tasks and responsibilities [30]
- Plant fire brigade operative procedure [48]
- Plant fire brigade service procedure, [51]

- Plant waste disposal facility fire protection plan [55]
- Rescue operations and first aid for personal injuries in RCA [56]
- Smoke and chemical diving at Loviisa NPP. [57]

<u>Organization</u>

The plant has professional full time fire brigade (6 shifts) were in each shift there is minimum one Fire and Security Lieutenant and three Firefighters. The fire brigade is supported by specifically trained security officers/fireman in each shift. Fire brigade is part of Nuclear Security unit. Fire protection and fire brigade are headed by Fire Chief/Fire Protection Manager. Deputy head of fire brigade is Fire and Security Captain. One Fire Lieutenant at a time is chosen to function as Station Officer and is responsible of guide and procedure development, training planning, maintenance and testing planning and in various projects.

The head of Nuclear Security unit commands the unit and is the superior of Fire Chief. Head of Nuclear Security Unit has the overall responsibility of fire protection of the plant and is the owner of the fire protection systems. Fire protection manager is the system manager for fire protection systems and passive fire protection arrangements, security engineering manager is the system manager for fire detection system. The Nuclear Security unit also employs Safety and Emergency Engineers who are responsible for coordination of training programs, development of emergency planning, and different task related to fire and rescue activities. Risk Engineer is responsible, among other tasks, for development of fire protection arrangements. Environmental, Health and Safety Expert is responsible of the processes related to chemicals and is the designated ATEX-responsible. [58]

<u>Documentation</u>

Fortum has a guide [59]that defines the set of guides that have to be kept up to date and where the guides are available. This includes the following documents:

- Floor maps of detectors
- Emergency operating procedures (EOP) and abnormal operating procedures (AOP)
- Maintance instructions
- Fire brigade instructions
- UK/UJ-piping pi-diagrams
- Emergency plan
- Instructions for general procedures
- Protection orders
- Fire Brigade equipment inspection records
- Fire Brigade equipment instruction manual
- Pressurized air filling station usage log
- Portable fire extinguisher maintenance log
- Pressurized air equipment maintenance and inspection log
- Maintenance log for equipment for working at heights
- Training programmes, planning and follow-up documentation
- Security instructions
- Fire reports.

The procedures alluded to in the previous chapters are described in more detail in plant fire brigade instructions that include:

- Fire Lieutenant tasks and responsabilities [30]
- Plant fire brigade operative procedure [48]
- Plant fire brigade service procedure [51]
- Plant waste disposal facility fire protection plan [55]
- Rescue operations and first aid for personal injuries in RCA [56]
- Smoke and chemical diving at Loviisa NPP [57]

Tables for communication groups and call signs are presented in a classified guide [50].

A 3.2.3.3. Specific provisions, e.g. loss of access

Plant has valid and prepared plan for situations where for example the access route to the plant is not available. Report has been prepared together with fire and rescue authority.

A 3.2.4 Licensee's experience of the implementation of the active fire protection

A 3.2.4.1 Overview of strengths and weaknesses

The plant has highly trained and experienced full time professional fire brigade with wide responsibilities related to plant´s fire protection and fire safety activities. Strength has been supported with WANO Peer Review evaluation.

The power plant has established in cooperation with the authorities (Radiation and Nuclear Safety Authority, Rescue Authority, Police Department) offsite muster point in the area of the nearest city.

Offsite muster point includes facilities suitable for organizing the situation, protective equipment (including dosimeters and iodine tablet) as well as the materials needed to orientate the radiation hazard assistant and employee. If needed, both the power plant's emergency organization and the authorities go to offsite muster point before entering the operational area and when leaving the operational area. Measurement and cleaning measures are carried out in the offsite muster point for evacuated personnel, emergency organization, authorities and radiation hazard assistants. There is also possible to carry out vehicle cleaning procedures in the area. Power plant and Rescue Authority are responsible for the operation of offsite muster point. Rescue Authority leads operations in the offsite muster point. Utilizing facilities, functions, equipment, know-how and resources in cooperation guarantees the best possible result in terms of handling the situation.

A 3.2.4.2 Lessons learned from events, reviews fire safety related missions, etc.

Strong design and recent modification performance of fire protection has been good, Emergency Preparedness area demonstrates excellent performance, as does Fire Protection with a fully staffed fire brigade. The general plant status is good, and management of combustible materials, and housekeeping have improved during the previous years. In addition, the Emergency Response organization and facilities is excellent. These have been identified during e.g. the latest WANO Peer Review.

Active fire protection in the plant is in good condition. This is supported also the system specific aging management reports. Plant is quite extensively protected with active fire protection system. The detection system is reliable, comprehensive and in good condition with modern graphical user interface.

Active fire protection is clearly divided to operative fire protection and to fire protection systems with comprehensive documentation for each areas.

Based on the latest peer review missions and other reviews also the management of combustible materials are in good level. The current procedures provide systematic and disciplined procedures for management and control of the issue.

The plant has utilized mission and peer reviews to identify and define improvement actions especially in the areas of combustible material management and analysis.

A 3.2.4.3 Overview of actions and implementation status

Improvement actions related to active fire protection are listed also in the fire safety analysis section of the report (section A 2.1.5 Periodic review and management of changes).

A 3.2.5 Regulator’s assessment of the active fire protection

A 3.2.5.1 Overview of strengths and weaknesses in the active fire protection

The scope of active fire protection arrangements at the plant is sufficient to complement the deficiencies in structural fire protection. The plant fire brigade is highly trained and at readiness 24/7. Training with regional emergency services is done regularly. Fire suppression systems cover high fire risk areas excluding electrical cabinet rooms. Fire alarm system covers the entire plant.

Challenges for upcoming years are aging management of active fire protections systems. Original piping of firefighting water distribution system has had some leakages, which have been repaired. The aging management system of the plant covers all active fire protection systems.

A 3.2.5.2 "Lessons learned from inspection and assessment on the active fire protection as part of its regulatory oversight"

STUK has inspected the operations of plant fire brigade during outages as part of periodic inspection programme.

Periodic fire protection inspections are held every two years.

B NPP units Olkiluoto 1 and 2

B 3.2.1. Fire detection and alarm provisions

B 3.2.1.1. Design approach

The fire alarm system covers all plant rooms. The system is divided into parts following the redundancies of safety systems (A,B,C,D), where local central units inside a redundancy are interconnected and connected to the master central unit in the MCR. Each detector, push button, control unit etc. has an individual address, so that the origin of a signal can be located.

The MCR has a desktop with graphic user interface (UI) to visualize all the information from fire alarm system and to easily conduct operating actions. The info system desktops with graphic UI in Plant Fire Station, alarm center and other plant unit's MCR are also interconnected via local network. However, the system can only be operated from the MCR. [60]

The fire alarm system also covers the final disposal facility for low and intermediate level radioactive wastes (VLJ). The alarm from VLJ is transmitted to OL1/2 MCRs. [61]

B 3.2.1.2. Types, main characteristics and performance expectations

The system gives out fire alarm and informs where the alarm originates. The system also transmits information about the actuation of extinguishing systems. The central units and control panels are backed up by batteries with 72 h capacity to function without external power source.

The system uses a variety of fire detectors. These include combined smoke and heat detectors, photoelectric smoke detectors, laser smoke detectors, heat detectors, heat increase rate detectors, beam detectors and push buttons. Detectors are chosen based on the ambient conditions and the type of fire load in the room. [60]

Plant's CCTV system is also connected to fire alarm system and can be operated with fire alarm system control panel. [33]

The system is used to actuate gas extinguishing system in the cable spaces below MCR. [60]

In VLJ, the system controls ventilation and over-pressurization of staircase. [61]

B 3.2.1.3. Alternative/temporary provisions

If equipment is deemed to be out of order, the actions to get them operational shall be started without delay.

If fire detectors, detector groups or loops are disconnected, or their operation is otherwise disturbed, there shall be inspection round in the affected rooms or locations. The default frequency for the rounds is three hours, unless otherwise agreed upon with the plant fire brigade. If there are multiple detectors in a room, the disconnection of one detector doesn't trigger the rounds.

If a fire group is disconnected, the manual call points are still operational. If the call points in the area are also out of operation, it shall be marked at the locations and informed to plant personnel. [35]

B 3.2.2. Fire suppression provisions

B 3.2.2.1. Design approach

Active fire protection supplements the passive fire protection that is based on layout design, fire compartmentation, and fireproof materials.

Fire suppression systems at the plant include fire-fighting water system and different types of fire extinguishing systems. Fire-fighting water system provides fire-fighting water to extinguishing systems and fire hydrants.

Rooms and locations where risk of ignition is high, or which contain significant amounts of fire load are protected with automatic or manually actuated extinguishing systems. Following locations are protected with water extinguishing systems:

- important cable rooms
- turbine cellar
- turbines
- high-pressure turbine steam valves
- generator bearings
- turbine oil room and oil pipe channel
- feed water pumps
- startup transformers
- main transformers and auxiliary transformers
- fire-fighting water pumping stations
- EDG*
- auxiliaxy desalination boilers.

Following locations are protected with gas extinguishing system:

- EDG*
- waste building bitumen station
- waste building waste storage
- waste building bitumen storage
- cable rooms below MCR
- space below elevated MCR floor. [33]

*EDGs' fire suppression systems are currently being changed from gas extinguishing system to water-based system one-by-one.

B 3.2.2.2. Types, main characteristics and performance expectations

The fire-fighting water system (861) is designed to distribute fire fighting water to all consumers, both to fixed fire extinguishing systems and operational firefighting at all plant locations. The system consists of the following subsystems:

- Fire-fighting water supply system
- Supply pipework for fire-fighting water within the buildings
- Sprinkler system for the turbine oil system
- Fire hydrants with riser pipes
- Empty riser pipes for the pumps of the fire brigade
- Water monitors for the turbine hall

In the fire-fighting water supply system there are two pump stations with their own water tanks at the plant. Each pump station has one electric and two diesel pumps. Each pump can fulfil the needed capacity alone. In addition, there are two moveable fire water pump containers and back up water tanks that can be used in operative firefighting or to feed water into plant pools in accident conditions. Normal firefighting water capacity is 2000 m^3 + 2000 m^3, so that even when a tank is out for maintenance there is a minimum of 2000 m^3 of water available. Tanks have volumes of 2500 m^3 + 3000 m^3, but the minimum reserved for firefighting is 2000 m^3 per tank. Backup water tanks have a volume of 250 m^3 + 250 m^3. Fire water is also used as domestic water at the plant. [62]

Fire water pipes inside the buildings are designed as ring mains, where, in case of a leak, the leak can be isolated, and water supplied to needed location through the other branch. Water pipes are supported with anchoring with seismic resistance. [62]

Indoor fire hydrants which are normally located in the vicinity of staircases. Each fire hydrant includes valves, 10-30 m of hose on a reel, steel pipes and sheet steel cabinet. The outer walls of plant building also have fire hydrants for operative firefighting. The hydrants are situated at maximum 75 m distance from each other. [62]

Two of the three reactor building staircases and the turbine hall roof are equipped with dry riser pipes. Dry riser pipes can also be used to supply water into fuel pools in the reactor building. [62]

The deluge sprinkler system for the turbine generator covers the turbines, oil tank room, oil pipe channel, reheater steam valves and generator bearings. The system has six deluge valves that are actuated automatically or manually. Detector line temperature bulbs breaking actuates the system. It can also be actuated from the valve station or MCR. Pipes leading from the valve to the protected location are empty with open nozzles. [63]

The turbine hall is protected with five water monitors. Four of these water monitors cover and protect the turbine area and one is for the generator and exciter. These monitors are manually operated by fire brigade. There is an own valve station for each water monitor. Fire brigade can supply foam-water solution from a foam trailer via foam valves and couplings. [62]

The necessary routine testing of the systems is defined in TVO fire protection manual. An inspection firm specially accepted by TUKES carries out a yearly or biannual system review depending on the system. [62]

The sprinkler system is designed to extinguish fires with fixed extinguishing systems in important plant locations with high amounts of fire load. System is also designed to prevent fires from spreading to adjacent locations. The system is divided into five subsystems:

- Turbine building sprinklers
- Cable room sprinklers
- EDG room sprinklers
- Heat boiler and fire-fighting water pumping station sprinklers.
- 9.EDG sprinklers.

The sprinkler subsystems are wet systems with closed nozzles actuated with independent and automatic actuation via temperature bulbs, with the exception of the older fire-fighting water pumping station system which has deluge valve with dry pipes and open nozzles. The latter subsystem is actuated either automatically or manually. The system also includes the extinguishing systems for startup transformers, main transformers and auxiliary transformers, and high activity waste storage (KAJ), which are operated only manually. Each system actuation transmits a signal to MCR with the exception of KAJ-storage system and older fire-fighting water pumping station system.

One subsystem covers turbine building levels below the turbine and generator, including the feed water pump room.

Sprinklers cover cable rooms, cable tunnels, and cable shafts. The subsystem is divided by redundant safety trains (AC and BD) behind two valves. In the cable rooms with height under 3,5 m, the nozzles are placed at the ceiling. In the rooms higher than that, there is a fast-acting deluge valve at the ceiling level which feeds 5-6 open nozzles that are placed at different heights. These high cable rooms have cables of two redundancies, with each redundancy at one wall. The nozzles are placed in a way that they create a “wall of water” between the redundancies when the system is actuated.

OL1/2 plant units have an ongoing project to modernize EDGs. The EDGs are renewed one at a time and at the same time, the extinguishing system is switched from CO2 gas extinguishing system to sprinkler system. At the time of writing this report, four of the eight EDGs have been modernized. The new EDG sprinkler systems cover the EDG room and the adjacent diesel day tank room, anteroom, and the valve stations of sprinkler covering EDG room. There is a normal wet pipe sprinkler system in the other areas and a dry closed nozzle deluge valve system in the EDG room. The EDG room system thus requires both the deluge valve actuation (via fire detection from two detectors or manual actuation) and temperature bulb breaking to function. As prerequisite for the modernization, TVO installed ninth EDG, which is used to replace each of the original EDGs during their renewal. 9.EDG also has a sprinkler system which covers the EDG room, diesel tank room, cable rooms, fire protection and heat exchanger room, and staircase. The system has a dry closed nozzle deluge valve system in the EDG room and wet pipe regular sprinkler in other protected areas. The EDG room system thus requires both the deluge valve actuation (via fire detection from two detectors or manual actuation) and temperature bulb breaking to function. [64]

The CO_2 gas extinguishing system is designed to extinguish fires in waste building and EDGs. System is also designed to prevent fires from spreading to adjacent locations. The system is actuated automatically with high temperature in the waste building and can also be actuated manually. Fire dampers are closed automatically. Automatic actuation is delayed by 45 s. For the EDG rooms, the system is actuated manually after ventilation has been switched off. [65]

Gas extinguishing system is used to extinguish gases in the cable rooms below MCR and cable space below elevated MCR floor. Both subsystems can be actuated either automatically or manually. Automatic actuation is designed with a single fault criterion (N+1), so that the failure of any single active component doesn't prevent automatic actuation. One subsystem uses Clean Agent FS49C2 (halotron) gas as the extinguishing agent. Automatic actuation for this subsystem is done via smoke detection from one detector which is not part of the fire alarm system but is part of the extinguishing system. The other subsystem uses Novec 1230 gas. This subsystem requires fire detection from two detectors for automatic actuation. The system actuation sends a signal to the fire alarm system interfaces in the MCR. The fire dampers are automatically closed upon actuation. [66]

VLJ has two water tanks with total volume of 25 m^3 as part of the firefighting water system. The system supplies water to the sprinkler system, which is used to extinguish fire in pipe and cable shaft of VLJ. [67] [68]

The CO_2 gas extinguishing system is designed to extinguish fires in VLJ silos of intermediate-activity waste (KAJ) and low-activity waste (MAJ). The system consists of piping and the extinguishing agent is supplied from a tank truck. [69]

B 3.2.2.3. Management of harmful effects and consequential hazards

Pipe break in the firefighting water system doesn't affect plant safety.

Firefighting water system and the distribution network inside plant buildings are classified as seismic class S1. Seismic stability of two diesel-powered pumps and fuel tank in fire-fighting water pumping station 2 were improved in a plant modification project. After this project all the pumps and the fuel tank fulfill the requirements of seismic class S1. The other active fire protection systems are classified as S2B.

The spurious actuation of the sprinkler system in the turbine building may cause flooding and thus M-isolation at the plant.

B 3.2.2.4. Alternative/temporary provisions

Fire water distribution pipes form a loop line, where, in case of possible pipe break, the section can be isolated, and water fed to intended location through other leg of piping. There shall be a plan drawn up if parts of the piping are isolated. The fire brigade arranges more extinguishing equipment or alternate fire water connection to the location, if deemed necessary. For example, in the case of disconnection of normal water connection to reactor building fire hydrants, the dry riser pipes shall be filled with pressurized water. [35]

For the two fire water pump stations, only one pump in total can be out for maintenance at the same time. If another pump is then disconnected for whatever reason, the other pumping station will be put online. [35]

If a sprinkler system is disconnected for more than three hours, the covered area shall be equipped with compensatory extinguishing equipment and the area shall be monitored with technical equipment or fire safety inspection rounds every three hours. If fire detectors are disconnected simultaneously, the rounds shall be performed every two hours. If the equipment is disconnected for over 24 hours, a written memo of the required compensatory measures shall be drawn up and attached to the work order. [35]

Gas extinguishing systems are actuated by smoke detectors of the fire alarm system. If there is maintenance work that may cause the triggering of the smoke detectors (hot work, dust-inducing work, etc.) in the area, the detectors must be disconnected. If the system is disconnected or the amount or pressure of extinguishing agent falls under preset limit value, the covered area shall be equipped with compensatory extinguishing equipment and the area shall be monitored with fire safety inspection rounds every three hours. If fire detectors are disconnected simultaneously, the rounds shall be performed every two hours. Inspection rounds in the area below MCR are performed by MCR personnel, who have the right to open the door of the room. [35]

CO2 gas extinguishing system in diesel generator rooms is manually operated, so normally it’s not disconnected during works. In the bitumen workshop the system is automatic and will sometimes be disconnected for personnel safety reasons. It’s not allowed to do bitumen works when the system is not operational. If the system or parts of it are disconnected, the covered area shall be equipped with compensatory extinguishing equipment and the area shall be monitored with fire safety inspection rounds every three hours. If fire detectors are disconnected simultaneously, the rounds shall be performed every two hours. [35]

B 3.2.3. Administrative and organisational fire protection issues

The operative fire protection consists of a combination of the onsite power plant fire brigade, the plant personnel, and the offsite fire brigade. Initial fires or small fires can be extinguished by the plant personnel using portable fire extinguishers and/or hydrants. For further firefighting operation the onside power plant fire brigade and the offside fire brigade is intended.

B 3.2.3.1. Overview of firefighting strategies, administrative arrangements and assurance

<u>Firefighting strategies</u>

The operative fire protection shall be provided by a combination of plant personnel, the onsite power plant fire brigade, and the offsite fire brigade. On the plant site there is a full-time fire brigade which is always in 5-minute preparedness. The fire brigade shift manpower is 1+6 (Fire Sub-officer + six Firemen). The minimum required manpower for rescue and extinguishing operations is 1+3. The fire brigade personal is qualified and appropriately furnished for firefighting capabilities.

Portable fire extinguishers are located throughout plant buildings, intended to provide plant personnel with a means of extinguishing small, incipient stage fires. The selection of the type of portable extinguisher provided in each location is a function of the type of combustibles present. For further firefighting operation the onside power plant fire brigade and the offside fire brigade is intended.

With fire alarms from fire detectors or fixed extinguishing systems the location or covered area is always inspected, even if the alarm is no longer active. Fire brigade moves to the location with emergency driving. At the location, Fire Sub-officer gives out tasks. First task is quick recon. To support the recon, detailed firefighting schemes, localization drawings of detectors, and smoke removal card index are available at the fire trucks. [70] Based on the recon, Fire Sub-officer assesses the situation and decides on calling for offsite resources. The assessment of needed offsite resources can be done by Fire Sub-officer or alarm center. [71]The Fire Sub-officer asks central alarm center to call for aid via public-safety answering point. The Regional Emergency Services have a predefined plan for strength of the response, which is then followed according to the situation. [70]

The recon includes checking for voltage levels from the firefighting scheme. The Fire Sub-officer also contacts the MCR to verify the alarm and the voltage level. Fire brigade secures the adjacent rooms before MCR confirms that the electrical room is de-energized. The firemen enter the rooms with high voltage levels with respirators. Electrical equipment is extinguished using portable CO_2 extinguishers if possible. If the fire is too big to extinguish with portable extinguishers, water mist is used. [72]

Smoke diving is done according to Ministry of the Interior guide on rescue diving (SM 48/2007) and internal TVO guide on rescue diving [73] [70]

Fire Sub-officer reports to designated duty rescue officer of the Regional Emergency Services and gives a briefing on the situation while the officer is on the way to the plant. The officer may order the Fire Sub-officer to function as the commander of rescue operations until they arrive at the site. The transfer of command to Regional Emergency Services has to be done clearly via authority communications network (VIRVE). [70]

There are separate instructions on procedures for oil spill control (101236) and protection against chemical leak (144731). [70]

<u>Administrative arrangements</u>

TVO plant fire brigade response for different missions is defined in [70]. The personal protective gear is also defined in the same guide.

Upon arrival to the site, all external personnel that take part in extinguishing or rescue operations at the plant must be listed in a document specified in instructions for offsite fire brigades [74]. The document is handed over to the plant gate. At the same time, the fire brigade personnel get their dosimeters and DECT-phones from the security personnel at the gate. When leaving the area, the dosimeters are returned at the gate.

Main communication method is the authority communications network VIRVE. Dect-phones are used inside the plant and otherwise as secondary communication method and in non-emergency situations. If the VIRVE devices are not functional, the fire brigade shift (min. 1+3) is on call at the fire station. [70]. Communication call signs are specified in the instructions. [74]

Central alarm center alarms the off-duty officers of plant fire brigade. The officers decide whether off-duty shifts have to be called in. [71]

In wide-ranging fire or radiation accidents the Fire Chief reserves a contact person between emergency organization and fire brigade. [70]

For fires inside a plant unit, the Fire Sub-officer orders evacuation through Shift Supervisor, who makes the announcement via PA-system. [70]

The MCRs of OL1/2 have instructions on how to de-energize rooms with voltage levels of over 1,0 kV. In addition to this, the rooms are marked on firefighting schemes, and localization drawings of detectors. Water based extinguishers are forbidden in rooms with voltage levels of over 1 kV before de-energization. The guide on operations in electrical rooms defines the safe distances for water-based extinguishers in rooms witj lower voltage levels. [72]

TVO has a separate guide on damage limitation in fire situations [75]. This includes removal of firefighting water.

After an operation, Fire Sub-officer writes a report of the operation according to appendix 1 of guide [76].

<u>Assurance</u>

Active fire protection system reliability is ensured with scheduled checks and testing, and preventative maintenance. Plant fire brigade is responsible for periodical inspections and testing being done at required intervals. The intervals for different measures are presented in guide [77]. The instructions for inspections and testing are part of the fire protection manual and listed in [77]. System maintenance is done by maintenance units. In addition to measures done by TVO, the active fire protection systems are periodically tested by an inspection body.

Fire brigade equipment and vehicles are inspected and maintained according to guide [78].

B 3.2.3.2. Firefighting capabilities, responsibilities, organisation and documentation onsite and offsite

Firefighting capabilities

The plant has professional full time fire brigade (5 shifts) were in each shift there is one Fire and Security Sub-officer and six Firefighters. The minimum required manpower for rescue and extinguishing operations is 1+3 with a 5-minute start time. [70]

Plant fire brigade has the following vehicles for operative action:

- fire truck
- light rescue truck
- two maintenance vans
- security truck

Other fire brigade equipment includes:

- oil spill response trailer
- oil spill response equipment container
- foam trailer
- portable high-power fan
- boat and trailer
- oil container booms and related equipment at sea water inlet channel and in two locations in the nearby archipelago
- portable firefighting water pump containers 1850 l/min (2 pcs) and 3500 l/min (2 pcs).

Training program for fire brigade shifts is devised biannually. Station Officer is responsible for the training plan. Compulsory training to be completed each year are:

- smoke diving 3 pcs
- chemical diving/response 2 pcs
- surface rescue 2 pcs (one in winter conditions)
- working at heights 2 pcs.

Training plan is completed with other required training related to preventing fires, operative firefighting and emergency response. [70]

Plant fire brigade organizes three joint exercises with Regional Emergency Services a year. At least one of the exercises is related to OL1/2 and one to OL3. Joint exercises' execution and feedback are reported for learning purposes such as developing procedures and fire brigade cooperation. STUK can participate in training planning and execution as an observer. In addition to joint exercises, there are other education opportunities and guided tours at the plant for Regional Emergency Services' officers. [70]

Operative personnel are responsible for their personal gear being ready to use and that required communications equipment is functional. The working shift always carries TL-dosimeters with them. For entering the RCA, the Firemen have RAD-radiation dose meters in the fire truck and rescue truck. [70]

Figure 11. TVO plant fire brigade and Regional Emergency services joint major accident exercise in 2019. (image source: Tapani Karjanlahti/TVO)

<u>Responsibilities</u>

The plant fire brigade has the following responsibilities:

- accident prevention
- rescue operations
- fire safety measures related to operations and maintenance
- maintaining readiness and capability for initiating fire protection operations
- writing guides and instructions on fire safety matters and training plant personnel
- acquisition of needed fire protection equipment and its maintenance together with other units
- periodic inspections and testing of fire protection systems under OLC. [70]

The plant fire brigade also has a responsibility to oversee all things related to fire safety, and related to this, to perform fire safety inspections described in sections B 3.1.2. Overview of arrangements for management and control of fire load and ignition sourcesand B 3.3.1. Prevention of fire spreading (barriers) The detailed responsibilities of each member of the fire brigade are described in [70].

In case of fire and accident situations, the plant fire brigade starts the extinguishing or rescue operations and leads the operations until Regional Emergency Services assume the leading responsibilities as dictated by the Rescue Act. The responsible leader in the early stages of the situation is the Fire Sub-officer of plant fire brigade.

The responsibility is then shifted to Designated Duty Rescue Officer of the Regional Emergency Services when they are ready to assume the lead. TVO plant fire brigade is prepared to conduct operations independently for 30 minutes before the Regional Emergency Services are assumed to arrive at the site. [70]

If the rescue operations are related to a situation that is declared to be an alert (wrt. emergency preparedness), the Emergency Manager oversees operations and plant fire brigade operates under their command until the Regional Emergency Services assume the lead. Emergency Manager remains in charge of matters related to nuclear safety. [70]

At the Olkiluoto site, TVO fire brigade operates as the first responder unit according to partnership pact with the Regional Emergency Services. [70]

Organisation

Olkiluoto plant fire brigade consists of TVO fire personnel and Securitas Oyj Fire Sub-officers and Firemen. TVO has subcontracted the operative personnel working the shifts from Securitas. The fire brigade shift manpower is 1+6 (Fire Sub-officer + six Firemen). The minimum required manpower for rescue and extinguishing operations is 1+3.

Plant fire brigade officers are employed directly by TVO. Fire brigade officers are Fire Chief, Executive Fire Officers, and Station Officer. Fire Chief is the head of plant fire brigade. The three Executive Fire Officers have divided tasks so that the one is mainly responsible for OL3, one for OL1/2 and Posiva spent fuel final repository, and the third for the system maintenance. The fire brigade shift works under Station Officer. Fire brigade also has four System Managers that work under the Executive Fire Officer responsible for system maintenance. [70]

Documentation

TVO has a comprehensive fire protection manual that consists of fire safety guides, plant fire brigade instructions and system maintenance and testing instructions. [79]The fire protection manual consists of 4 series of guides:

- Fire safety
- Plant fire brigade
- Fire protection systems
- Plant specific guides.

The guide [79] defines where each binder of guides is physically available. This guide is revised at an interval of three years. The fire protection manual is also updated whenever there is a change in fire protection arrangements or fire brigade procedures.

Detailed firefighting schemes and localization drawings of detectors have been prepared for each building for extinguishing and rescue operations. Schemes include all relevant information for extinguishing operations. Firefighting schemes are not distributed outside of the site, but they are readily available in emergency situations for offsite fire brigades at the site. Smoke removal card index is available to control smoke removal. [70]

A guide [74] on general information on extinguishing and rescue operations at the Olkiluoto site has been devised and distributed to nearby fire brigades. This guide includes maps of the site. [70]

B 3.2.3.3. Specific provisions, e.g. loss of access

Generally, there are at least two rescue and attack routes to buildings.

Access routes to the plant for offsite resources are defined in annexes to guide [74]. From the main gate, there are two routes to enter the plant area. Leading to the main gate there is only one road.

B 3.2.4 Licensee’s experience of the implementation of the active fire protection

In system responsibility analyses and equipment liability reports, the condition of the systems and potential authority regulations and findings have been assessed. Based on SR analyses, numerous improvements have been implemented in the systems, related to e.g., aging phenomena, etc.

B 3.2.4.1 Overview of strengths and weaknesses

Strengths:

- Overall modernization of multiple active fire protection systems to meet new standards.
- 24/7 professional plant fire brigade on site.

Weakness:

- Some old CO2-gas systems are still operational. The old system design basis doesn’t fulfill today’s industrial standards.

B 3.2.4.2 Lessons learned from events, reviews fire safety related missions, etc.

The process of utilizing operating experiences and WANO missions is described in more detail in section B 2.1.6 Licensee’s experience of fire safety analyses.

Many of the improvements performed earlier years are based on PRA-analyses and user experiences (internal and external).

B 3.2.4.3 Overview of actions and implementation status

Multiple modifications are implemented and about ten are ongoing/planned.

Several fire protection systems have been renewed e.g. EDG's CO2 gas extinguishing systems have been converted to sprinklers (5 of 9 EDG's), the sprinkler systems in the cable rooms below the control rooms have been changed to Novec gas extinguishing systems, sprinkler systems of the cable tunnels have been renewed and modernized according to the fire analyses.

Several changes related to the accident at Fukushima have been made at the facilities. Changes related to fire protection include, for example, mobile fire pump stations, a dry riser line for supplying fire water to the reactor and fuel pools, earthquake classification changes and related improvement measures to the supports.

B 3.2.5. Regulator’s assessment of the active fire protection

B 3.2.5.1. Overview of strengths and weaknesses in the active fire protection

The level of active fire protection arrangements at the plant is sufficient to fulfill fire safety requirements. The aging of the systems is assessed and managed systematically, and improvements have been made based on the findings.

Plant fire brigade is trained and capable to perform fire and rescue operations. Training with regional emergency services is done regularly.

There have been non-conformances observed in the plant fire brigade regarding the conduct of compensatory fire protection practices during the isolation of fire protection systems. Plant fire brigade has also had some challenges in finding enough staff.

B 3.2.5.2. "Lessons learned from inspection and assessment on the active fire protection as part of its regulatory oversight"

Periodic fire protection inspections are held every two years.

STUK has inspected the operations of plant fire brigade during outages as part of periodic inspection programme. The lesson from the case of non-conformances in compensatory fire protection measures is that even with detailed instructions, the human factor issue is to perform the tasks accordingly and to understand the safety meaning of the compensatory measures.

C NPP unit Olkiluoto 3

C 3.2.1. Fire detection and alarm provisions

C 3.2.1.1 Design approach

The Fire Alarm System serves to detect fires at an early stage and to report fire locations toa central operating station in the MCR, as well as to actuate in certain cases appropriate fire protection equipment (fire dampers and fire suppression systems). The necessity for automatic actuation of fire protection equipment is defined within the fire hazard analysis. The system covers each fire compartment in the plant.

The system consists of the local central units, with the corresponding power supply, which are connected via primary circuits. Each central unit covers one building or redundancy. Fire detector groups (loops) are connected to the local central units. The master central unit is located by the MCR. The master central unit consists of a main processing unit equipped with the necessary interfaces to the other local central units, to the corresponding operating panels, to the Info System and to other systems. There are Info Systems with graphic UI also in Plant Fire Station and alarm center of OL3 and OL1/2.

The alarm status (fire, malfunction) of the loop elements (e.g. fire detector etc.) is displayed on the central operating panel and at the terminal of the Info System (at least in the MCR) and on its local operating panel of the central unit. [80]

C 3.2.1.2 Types, main characteristics and performance expectations

The tasks of the Fire Alarm System are:

- Rapid detection of the beginning of a fire,
- Location of the area of the fire source,
- Triggering of an alarm (especially in the MCR),
- Indication of malfunctioning signals,
- Information about the location of the fire and other information related to the location,
- Power supply of fire damper (230 V AC),
- Generally, actuation/indication of fire protection equipment (fire dampers, smoke removal dampers, smoke doors, fire suppression systems, fans).

The fire detectors are either manual call points or automatic fire detectors. The system uses a variety of automatic fire detectors. These include combined smoke and heat detectors, photoelectric smoke detectors, optical line detectors, flame detectors, heat detectors, heat increase rate detectors, air sampling detectors, duct detectors and CO gas detectors. Detector type is chosen based on the location and its ambient conditions. Choosing of the detectors is described in more detail in system description [80].

The system gets indication of actuated sprinkler, spray deluge and gas extinguishing systems.

Protected rescue routes are over-pressured with a signal from fire alarm system. In NI the fans are started automatically, but in TI it’s done manually. Their air intake and smoke extraction dampers are opened automatically. The position of the dampers is visible in the terminal of the Info-System in the MCR.

The Fire Alarm System is designed as S1 system. Postulated external hazards shall not affect the functions of the system.

During loss of normal power supply in one division the corresponding local central units of the Fire Alarm System will be supplied from emergency (diesel) power distribution boards with interruption during diesel start. Because even the diesel busbars may be interrupted for a short time during diesel start, a small separate UPS system (battery buffered) with at least 10 minutes capacity is installed for the power supply of the fire dampers and for the smoke exhaust dampers.

For the detection parts of the Fire Alarm System (incl. control of dedicated fixed fire-fighting installations) a separate UPS system (battery buffered) per master central unit or per local central unit with a capacity for 72 hours in normal operation mode and for half an hour in alarm mode is installed.

C 3.2.1.3 Alternative/temporary provisions

Immediate corrective maintenance is provided for the case of failure of the central units, of important sub-assemblies, modules or of terminal equipment. For this purpose, a sufficient number of spare and wear parts is permanently kept in stock. Administrative replacement measures are regulated in the operating manual.

In case of an evacuation of the MCR the standby operating panel in the RSS will be activated and takes over the full function of the Fire Alarm System of OL3. [80]

If fire detectors, detector groups or loops are disconnected, or their operation is otherwise disturbed, there shall be inspection round in the affected rooms or locations. The default frequency for the rounds is three hours, unless otherwise agreed upon with the plant fire brigade. If there are multiple detectors in a room, the disconnection of one detector doesn’t trigger the rounds.

If a fire group is disconnected, the manual call points are still operational. If the call points in the area are also out of operation, it shall be marked at the locations and informed to plant personnel. [35]

C 3.2.2. Fire suppression provisions

C 3.2.2.1 Design approach

The fire-fighting water system supplies fire water to the nuclear island for fire-fighting purposes. The system is independent from any external water supply and provides water to the outdoor pillar hydrants, indoor wall hydrants, and fixed water-based fire-extinguishing systems. The fire-fighting water system consists of the fire-fighting water supply which includes the fire water distribution within the facility, and manual fire-extinguishing systems like indoor wall hydrants and additional hose connections. Standpipes and indoor wall hydrant cabinets shall be provided to ensure that all locations can be protected by at least one hose stream.

Fixed, automatic or manually actuated fire extinguishing systems are intended for extinguishing of fires with rapid propagation or areas where manual firefighting is limited. In certain instances, the fire alarm system is linked to the systems. These extinguishing systems include spray deluge systems, wet-pipe sprinkler systems, gas extinguishing systems, manual indoor wall hydrant cabinets, and wall-mounted and wheeled portable extinguishers. In addition to the mitigation capabilities of the fixed automatic extinguishing systems, a fire brigade has been trained to provide prompt and effective response of plant fires using readily available portable fire extinguishers, indoor wall hydrant cabinets, and outdoor pillar hydrants.

The robust structural and layout design and the choice to only have flame-retardant non-corrosive (FRNC) cables have rendered fixed fire extinguishing systems unnecessary in the cable rooms of the plant. [15]

C 3.2.2.2 Types, main characteristics and performance expectations

The fire-fighting water supply system provides fire water to all outdoor pillar hydrants, all fixed water-based fire-extinguishing systems and indoor wall hydrants of the nuclear island. The fire-fighting water supply system is designed with a main loop, which is considered the fire-fighting water technical ring thus providing two independent flow paths within the fire-fighting technical ring. Isolation valves are placed in the fire-fighting water technical ring and in the pipes that branch off from the technical ring to allow portions to be isolated without interrupting the flow of the entire fire-fighting water system. The fire-fighting water system is maintained under pressure by a pressurization system in the range of 8 bar to 10 bar during stand-by conditions.

The main portion of the fire water distribution system which provides the Reactor Building, the Reactor Building Annulus, the Safeguard Buildings, and the Fuel Building consists of a series of three concentric rings installed around the center of the Reactor Building. The outer ring is routed through all four Safeguard Buildings and the Fuel Building, the middle ring is located inside the Reactor Building Annulus and the inner ring inside the reactor building containment. There are two redundant connections between the fire-fighting water technical ring and the outer ring of the fire water distribution system, and between the outer ring and the middle ring.

Three types of fixed fire-extinguishing systems are installed in various locations within nuclear island (NI) buildings. These fixed fire-extinguishing systems include wet-pipe sprinkler systems, spray deluge systems, and a gas extinguishing system.

Spray deluge systems are installed in areas requiring protection against rapidly growing and spreading fires, such as fires on combustible or flammable liquids. These systems are fixed fire-extinguishing systems with permanent piping and open nozzles, intended to distribute large amounts of water through a large area in a reasonably short period of time. Spray deluge systems are installed to provide proper protection for main oil tanks of EDGs and SBO-Diesels, and reactor coolant pumps (RCP). A deluge valve is installed in the water supply pipe for each system. The spray deluge systems only operate when the system is actuated manually from the main control room or locally to prevent adverse impacts caused by spurious action. This is acceptable because the MCR is permanently occupied, fires are detected immediately after ignition, spurious alarms can be identified by the number of detectors that have been actuated, and cameras supervise the RCP areas. The deluge valve is automatically closed after the spray deluge system has been fully operational for period of 10 minutes, which concludes the fire-extinguishing procedure. However, further operation of the spray deluge system is possible. [15]

Wet-pipe sprinkler systems are installed in Emergency Diesel Generator Buildings 1 to 4 (EDG) and the Station Black Out Diesel Buildings 1 and 4 (SBO-Diesel). Individual wet-pipe sprinkler systems are installed in each Emergency Diesel Generator Building providing protection of the generator room, the service tank room, and the auxiliary room in the basement story. The systems are actuated with temperature bulb. The sprinkler systems protecting the diesel generators are physically separated from those protecting the SBO-diesel generators. A failure of one sprinkler system will not lead to a loss of the remaining sprinkler systems. Each area protected by a sprinkler system is limited to one redundancy. The operation of the sprinkler systems are indicated via pressure switch signal to fire alarm system and thus to MCR. [81]

Fixed gas extinguishing systems are typically installed in areas where electrical or electronic circuits exist, and the use of other extinguishing agents could cause extensive damage to equipment. A fixed gas extinguishing system is installed in the cable floor of the main control room box, which is located in the building complex of Safeguard Building 2 and 3. The system uses Novec 1230 fluid as the extinguishing agent. During normal operating conditions, the fixed gas extinguishing system is in stand-by mode, pressurized up to the control head. The fixed gas extinguishing system can be actuated manually using a pull ring located at the discharge station. The discharge station is installed as close as possible but outside of the purge area (just outside the MCR). The release of the manual pull ring activates the pneumatic valve at the control head, which immediately introduces the extinguishing agent into the piping network. The cylinders are protected against unauthorized actuation via enclosure.

As the extinguishing agent reaches the specially designed discharge nozzles it is distributed uniformly throughout the entire purge area. The necessary extinguishing concentration is reached within 10 seconds after actuation, which concludes the fire-extinguishing procedure. All alarm and operation signals of the system will be transmitted to the fire alarm system. [15]

In the turbine island (TI) there are also various extinguishing systems intended for extinguishing of fires with rapid propagation or areas where manual firefighting is limited.

The turbine oil room and the main turbine oil pipe duct, which is running parallel to the turbine generator set, are equipped with automatically operated spray deluge systems. The spray deluge system is normally, in stand by condition, filled with demineralized water and kept under pressure up to the spray deluge valve. Upon actuation, water flows through the deluge valve station to the open nozzles. The spray deluge systems are be triggered by local controls from fire detection and manually from the MCR. The spray deluge systems will be turned off automatically after 10 minutes extinguishing time to limit the total water quantity during the extinguishing process. [82] Leaking oil in the main turbine oil pipe duct will be drained to the turbine oil room. [83]

The floors below the turbine are equipped with flood wide wet pipe sprinkler systems. The sprinkler system also includes ducting structures which belong sterically to turbine building. Main feedwater pumps are also protected with wet pipe sprinkler system. The sprinklers are actuated individually via temperature breaking the glass bulb at the nozzle. Actuation of the system open the wet alarm valve which transmits actuation signal to MCR via local control panel. [84]

The generator transformers, auxiliary transformers, and offsite system transformers are equipped with an automatically or manually operated spray deluge system. The system is actuated automatically by transformer self-protection system. If a deluge valve station is actuated manually at valve, a signal is sent to the transformer self-protection system to trip the transformer before water flooding. The spray deluge system is normally, in stand by condition, filled with demineralized water and kept under pressure up to the spray deluge valve. Upon actuation, water flows through the deluge valve station to the open nozzles. After extinguishing the fire, the system must be shut down manually. [82]

C 3.2.2.3 Management of harmful effects and consequential hazards

System reliability is ensured with scheduled checks and testing. The required tests from plant safety point of view are defined in plant Technical Specifications (OLC, TTKE in Finnish). The TTKE requirements cover fire water pumps, fixed extinguishing systems, fire hydrants and portable fire extinguishers at NI. TTKE determines the test interval and refers to testing procedures. Some of the tests are done during outages. Testing procedures for TI systems are defined in the fire protection manual. [85]

The fire-fighting water supply connection system belongs to seismic class S2. [86]

The fire-fighting water system in the NI belongs to seismic class S2A in the main buildings of the NI housing safety systems. The building isolation valves of the containment are monitored from MCR and maintained in closed position in system stand-by to prevent flooding in case of pipe break or incidental actuation. They are by-passed by open DN15 valves to ensure system pressurization in stand-by conditions. In the event of fire, the building isolation valves are opened from MCR to allow active firefighting. [87]

The spray deluge systems at NI are seismically classified as S2A. The systems only operate when the system is actuated manually from the MCR to prevent adverse impacts caused by spurious action. The deluge valve is automatically closed after the spray deluge system has been fully operational for period of 10 minutes. To prevent flooding after a pipe rupture, isolation valves are installed in the connection lines. The spray deluge systems are designed and located such, that their rupture or inadvertent operation will not inadmissibly impair the structures, systems, and components important to safety. Every extinguishing area is limited to one redundancy area. The fire alarm system, which provides the release system of the spray deluge stations is backed up by the emergency diesel and batteries. In the EDG and SBO oil tank rooms, there is a catchment basin sufficiently large to accommodate the amount of fire water dispatched in 10 minutes and the oil in the tank. This way the oil-water mixture will not spread out of the room. [88]

The sprinkler systems at EDG are seismically classified as S2A. The systems are designed and located such, that their rupture or inadvertent operation will not inadmissibly impair the structures, systems, and components important to safety. The diesel buildings are divisional separated, so in the event of flooding in building part or failure actuation there will be no inadmissible effect on plant safety. The removal of fire-fighting water discharged from fixed fire-extinguishing systems is provided by the drainage system in the affected room. However, the total volume of water supplied by the sprinkler system may exceed the total capacity of the drainage system. To prevent flooding after a pipe rupture, isolation valves are installed in the connection lines. [89]

The fixed gas extinguishing system belongs to seismic class S2A in order to avoid consequential damages on seismic class S1 equipment. [90] The system is designed and located such, that the rupture or inadvertent operation will not inadmissibly impair the structures, systems, and components important to safety. [15]

The spray deluge system at TI is seismically classified as S2. The fire-fighting control system 30SGY, which provides the release signals to the spray deluge stations is backed up by batteries. [82]

The sprinkler system at TI is seismically classified as S2. To prevent flooding after a pipe rupture or spurious actuation, separation / isolation valves are installed in the connection lines inside the building complex. The separation / isolation valves are placed inside the buildings. These valves are normally open and will be manually closed. The systems are designed and located to ensure that their rupture or spurious or inadvertent operation does not inadmissibly impair the structures, systems and components important to safety.

C 3.2.2.4 Alternative/temporary provisions

Fire water distribution pipes form a loop line, where, in case of possible pipe break, the section can be isolated, and water fed to intended location through other leg of piping. There shall be a plan drawn up if parts of the piping are isolated. The fire brigade arranges more extinguishing equipment or alternate fire water connection to the location, if deemed necessary. [35]

For the two fire water pump stations, only one pump in total can be out for maintenance at the same time. If another pump is then disconnected for whatever reason, the other pumping station will be put online. [35]

If a sprinkler system is disconnected for more than three hours, the covered area shall be equipped with compensatory extinguishing equipment and the area shall be monitored with technical equipment or fire safety inspection rounds every three hours. If fire detectors are disconnected simultaneously, the rounds shall be performed every two hours. If the equipment is disconnected for over 24 hours, a written memo of the required compensatory measures shall be drawn up and attached to the work order. [35]

For the spray deluge systems, the temporary provisions are compensatory extinguishing equipment and for RCP areas the use of CCTV. For EDG and SBO buildings CCTV isn't required. [35]

Deficiencies in the gas extinguishing system are accounted for with extra manual extinguishing equipment. [35]

C 3.2.3 Administrative and organizational fire protection issues

Olkiluoto 3 plant is situated at the same site as Olkiluoto 1 and 2 and is serviced by the same plant fire brigade. Administrative and organizational fire protection issues are described in section B 3.2.3. Administrative and organisational fire protection issues. This chapter only includes procedures and instructions that are unique to OL3.

C 3.2.3.1 Overview of firefighting strategies, administrative arrangements and assurance

Firefighting strategies

There is a specific guide for extinguishing and rescue operations OL3 pipe and cable tunnels. The tunnels are long, and some may contain cables with voltages of over 1 kV. Main thing to consider is turning off ventilation and starting to extinguish only after smoke extraction is started. Smoke is extracted with the fan that is stored in the fire truck. [91]

Administrative arrangements

The MCR of OL3 doesn't have specific instructions on how to de-energize rooms with voltage levels of over 1 kV. The rooms are marked on firefighting schemes. MCR will de-energize the equipment with voltage over 1 kV. [72]

Assurance

Fire protection arrangements are provided ensuring safe plant operation. To ensure the availability, reliability, and functionality of these fire protection arrangements appropriate procedures are established describing the periodical inspection and testing of the fire protection arrangements. Periodical inspection program of fire protection arrangements [92] includes the descriptions of inspections and references to the Nuclear Test Manual (many documents). Nuclear Test Manual covers the active fire protection systems. The inspection programs described in the periodical inspection program are:

- Inspection of fire loads
- Inspection of fire compartments
- Inspection of access/escape routes and attack routes for the fire brigade
- Inspection of fire insulations.

The inspections referred are listed below:

- Fire detection and alarm system
- Fire-fighting water system
- Fire extinguishing systems
- Fire venting and smoke extraction
- Fire dampers
- Fire-fighting and rescue equipment
- Protective apparatus
- Emergency lighting
- Communication system.

C 3.2.3.2 Firefighting capabilities, responsibilities, organisation and documentation onsite and offsite

Firefighting capabilities

See section B 3.2.3. Administrative and organisational fire protection issues

Responsibilities

See section B 3.2.3. Administrative and organisational fire protection issues

Organization

See section B 3.2.3. Administrative and organisational fire protection issues

Documentation

OL3 firefighting scheme [93] contains followings information:

- plant site and its immediate surroundings
- the actual power plant area in detail (buildings, outdoor fire hydrants, entrances to buildings)
- building layouts with markings of fire compartments, fire hydrants, equipment for initial extinguishing, access routes for the fire brigades, escape routes, smoke extraction equipment, overpressure ventilation etc.
- compartments protected by fire-extinguishing systems, valve stations and the manual actuation locations of the systems.

Plant specific instructions for OL3 include:

- Extinguishing and rescue operations in cable and pipe tunnels of OL3 [91]
- Fire brigade procedure in an alarm from OL3 RCA [94]
- OL3 transformer extinguishing instructions [95].

Periodical inspection program for fire protection arrangements of OL3 is documented in [92].

C 3.2.3.3. Specific provisions, e.g. loss of access

See section B 3.2.3. Administrative and organisational fire protection issues

C 3.2.4. Licensee's experience of the implementation of the active fire protection

Licensee's safety assessments for active fire protection systems [96] [97] have been done. These provide the most relevant information about the systems and references to important documents related to the systems, such as system descriptions. The most important user experiences can be found in the system analysis of the active fire protection systems [98] and in the fire protection systems' equipment liability report [99].

All commissioning tests of phase A of the commissioning have been completed for the fire protection systems and smoke confinement system. There are only A phase tests for systems. The systems are ready and implemented. The systems do not deviate from the plans and fully meet the requirements.

Deviations to Finnish building code have been discussed and agreed upon with the local building authority and STUK. No deviations related to active fire protection systems were found. [100] [101]

C 3.2.4.1 Overview of strengths and weaknesses

Strengths:

- High safety culture (continuous monitoring)

Weaknesses:

- Authority communications network (TETRA) does not exist at plant
- Basic position of firefighting water supply system containment isolation valves is closed position. In the event of fire, the building isolation valves are opened from MCR to allow active firefighting.

C 3.2.4.2 Lessons learned from events, reviews fire safety related missions, etc.

Changing the characteristics of some fire detectors due to room conditions.

Sprinkler systems in EDG/SBO diesels have been modified due to several unnecessary fire alarms. Fire pump tests caused pressure hammers to the fire water network. After the modification the unnecessary fire alarms have ended.

C 3.2.4.3 Overview of actions and implementation status

Most significant events are related to the cable replacement works of the smoke extraction system 30SAG. Original cables with a 30-minute fire resistance have had to be replaced with cables with a 90-minute fire resistance according to regulations. With the cable changes made, the correct operation of the 30SAG system can be ensured in a fire situation for the entire required 90 minutes.

Another significant event can be mentioned the larger 10-year maintenance of the spray deluge system valve centers. In addition to normal inspection and cleaning, these have renewed deluge valves.

Sprinkler systems in EDG/SBO diesels have been modified.

C 3.2.5 Regulator’s assessment of the active fire protection

C 3.2.5.1 Overview of strengths and weaknesses in the active fire protection

Based on the robust passive fire protection arrangements including the separation of safety divisions, the active fire protection arrangements are not as important to radiation and nuclear safety as in older Finnish NPPs. The fire alarm system covers the entire plant. Large concentrations of fire load and other important areas such as

MCR are protected with active fire suppression systems. Generally, cable rooms with FRNC-cables are not protected.

Issues related to plant fire brigade are handled in section B 3.2.5. Regulator's assessment of the active fire protection

C 3.2.5.2 "Lessons learned from inspection and assessment on the active fire protection as part of its regulatory oversight

Internal flooding risks related to firefighting water systems were identified in the inspections and document review during the construction phase of OL3. This led to some changes in the design.

The active fire protection arrangements have been inspected and approved as part of STUK's commissioning inspections.

D Olkiluoto ISFS

D 3.2.1. Fire detection and alarm provisions

D 3.2.1.1 Design approach

The fire alarm system of Olkiluoto ISFS covers all rooms, where the installation of detectors is technically possible.

D 3.2.1.2 Types, main characteristics and performance expectations

The detectors used are generally multi-criteria detectors. Only the storage pool hall and interconnecting personnel tunnel between ISFS and OL1 have optical beam detectors.

The building has its own central unit. When a detector gives an alarm, it's transmitted to the central unit and control panel in ISFS, alarm center, plant fire station and plant gate. The alarm center and plant fire station get the alarm with the address of the detector and the graphic interface also prints out a paper print of the alarm. The alarm is also visible in the graphic desktops of OL1/2 MCRs.

Detectors are looped in a way that one loop only contains detectors and cables from on redundant division's rooms.

Over-pressurization of stairways is controlled by fire alarm system. [39]

D 3.2.1.3 Alternative/temporary provisions

If equipment is deemed to be out of order, the actions to get them operational shall be started without delay.

If fire detectors, detector groups or loops are disconnected, or their operation is otherwise disturbed, there shall be inspection round in the affected rooms or locations. The default frequency for the rounds is three hours, unless otherwise agreed upon with the plant fire brigade. If there are multiple detectors in a room, the disconnection of one detector doesn’t trigger the rounds.

If a fire group is disconnected, the manual call points are still operational. If the call points in the area are also out of operation, it shall be marked at the locations and informed to plant personnel. [35][

D 3.2.2. Fire suppression provisions

D 3.2.2.1 Design approach

The fire suppression in ISFS is done via fixed systems or operative fire protection.

The rooms of ISFS that contain large amount of fire load or where there is an elevated risk of ignition are protected with fixed automatic fire extinguishing systems to ensure rapid extinguishing of fires and to avoid damages and dangerous situations.

Protected rooms are:

- cable tunnels, A-sub (three rooms)
- cable tunnels, C-sub (three rooms)
- elevator shaft and machine room
- sprinkler valve station room
- oil processing room
- interconnecting personnel tunnel. [39]

D 3.2.2.2 Types, main characteristics and performance expectations

Firefighting water is supplied to ISFS via two connecting pipes from firefighting water system of OL1. The firefighting water system provides water to fire hydrants and fixed fire extinguishing systems. Firefighting water can also be supplied from a fire truck.

For the automatic fixed fire extinguishing systems there are four valve stations in total which are situated in the same room. All the systems in ISFS are wet systems with actuation via temperature bulb. The sprinkler nozzles are actuated one at a time. A pressure switch transmits information of system actuation to fire alarm system. [102]

D 3.2.2.3 Management of harmful effects and consequential hazards

Firefighting water is removed via drainage systems. [102]

D 3.2.2.4 Alternative/temporary provisions

If a sprinkler system is disconnected for more than three hours, the covered area shall be equipped with compensatory extinguishing equipment and the area shall be monitored with technical equipment or fire safety inspection rounds every three hours. If fire detectors are disconnected simultaneously, the rounds shall be performed every two hours. If the equipment is disconnected for over 24 hours, a written memo of the required compensatory measures shall be drawn up and attached to the work order. [35]

D 3.2.3 Administrative and organizational fire protection issues

Olkiluoto ISFS facility is situated at the same site as Olkiluoto 1, 2, and 3 and is serviced by the same plant fire brigade. Administrative and organizational fire protection issues are described in section B 3.2.3. Administrative and organisational fire protection issues

D 3.2.4. Licensee’s experience of the implementation of the active fire protection

D 3.2.4.1 Overview of strengths and weaknesses

The task of active fire protection systems is to ensure good operating conditions for the operational activities of the fire brigade and to extinguish fires in locations with large fire loads or an obvious risk of ignition.

D 3.2.4.2 Lessons learned from events, reviews fire safety related missions, etc.

The systems have been kept in good working order by testing them regularly and modernizing them, e.g., a 25-year health assessment has been made for the sprinkler system, as a result of which the nozzles were changed to fast-acting ones.

D 3.2.4.3 Overview of actions and implementation status

Sprinkler nozzles were changed to fast-acting ones.

D 3.2.5 Regulator’s assessment of the active fire protection

D 3.2.5.1 Overview of strengths and weaknesses in the active fire protection

The active fire protection arrangements fulfill their role in the fire protection concept of Olkiluoto ISFS facility.

D 3.2.5.2 "Lessons learned from inspection and assessment on the active fire protection as part of its regulatory oversight

There have been no recent findings related to active fire protection systems.

3.3. Passive fire protection

A NPP units Loviisa 1 and 2

A 3.3.1. Prevention of fire spreading (barriers)

A 3.3.1.1. Design approach

The purpose of passive fire protection and fire compartmentation is to ensure the safety of the facility in case of fire and accident situations. The buildings are divided into fire compartments in order to limit the spread of fire and smoke, ensure exit safety, limit property damage, and enable fire prevention, rescue and fire extinguishing measures. Fire protection features are designed in such a way, that plant safety is ensured even if any fire compartment is destroyed in a fire. The following principles are followed, but not achieved universally:

- Each building is its own entity with relation to fire protection.
- Different levels of a building make up different fire compartments.
- Important redundant systems are situated in different compartments.
- Cable trains are originally separated according to Regulatory Guide 1.75, 1974 and since then according to up-do-date guidance.
- Radiologically controlled area and non-controlled area are generally in different fire compartments.

Special attention is paid to making compartmentation complete and leaving no holes or orifices between compartments. Compartmentation is also considered in ventilation and the penetrations for pipes, cables, and ventilation ducts. [13]

The fire compartmentation has been done according to contemporary requirements. When the laws and decrees have been updated to stricter requirements, they have been applied to plant modifications.

As the original design of the plant was lacking with respect to fire protection, there has been a focus on continuous improvement. Improvements have been made both to safety systems, which improves plant resiliency in fire situations and actual passive and active fire protection. Some of the highest significance modifications were made to passive fire protection. Main example of this is the firewall that was constructed between turbine hall and feedwater tank compartment and the control building.

A 3.3.1.2. Description of fire compartments and/or cells design and key features

The basic requirement for compartments is 60 minutes fire resistance. The safety related equipment is divided into two separate redundant groups. Compartmentation for safety divisions should be at least EI 120 fire resistance, but this isn't achieved everywhere. There are also compartments with high fire load, that have resistance rating EI 180.The fire resistance rating for boundaries between two fire compartments is always chosen based on the higher rated compartments requirement.

The separation between redundances is not complete in following compartments:

- steam generator room
- turbine hall
- feed water tank level
- sea water pumping station
- salt removal station basement
- plant condensate make-up RV-storage tank area
- clean condensate TD-storage tank area
- MCR and cable floor below MCR
- ventilation control room
- remote shutdown station (RSS) and its electrical cabinet room
- SAM-control room

In these rooms, safety system equipment that belongs to redundance 2 has to be protected against possible threats (incl. fire) that could damage equipment from both redundances.

Flammable liquids and gases are stored in their own fire compartments.

All fire doors are type-approved or separately approved by independent inspection and testing company/body. In addition, doors must be approved by persons responsible for fire protection at the plant. The licensee has an up-to-date listing of approved fire door types [103].

Selected steel structures of turbine hall and adjacent control building are protected against fire to prevent collapse of structures. In the worst-case fire scenario, the turbine hall collapse cannot be ruled out. This would lead to loss of original residual heat removal and emergency feed water systems. Independent backup pump stations for residual heat removal and emergency feed water system are installed outside of the turbine building. [16]

A 3.3.1.3. Performance assurance through lifetime

Fire doors are inspected twice a year according to preventive maintenance program and using a specific instruction [104]. Inspection includes checks for general condition of door and possible accessories, thermal insulation of entrance doors, condition of the seals against air or water pressure, and closing and latching. If necessary, maintenance is then carried out. Also, some original plant doors have been replaced with modern doors based on these inspections.

Penetrations are inspected as part of the inspections for structural fire safety. Damaged penetrations are reported and fixed without delay.

The fire compartmentation may not be changed or breached without a work order that includes approval by Fire and Security Lieutenant or their superiors. All fire compartment penetrations must be designed separately, and the fire stop products must be CE-marked, type-approved, or approved based on a separate aptitude evaluation. All works related to compartment structures have to be planned comprehensively. All new fire compartment penetrations must be caried out with separate work orders with a fire permit given by Fire and Security Lieutenant or their superiors. Carrying out installation or modification works on penetrations requires a separate qualification.

When penetrations or doors are opened for maintenance work or plant modifications, there are measures to temporarily close the openings before the work is finished.

To keep the access routes clean, the storage of materials is only allowed in marked storage areas. The procedures for establishing a storage are described in section A 3.1.2. Overview of arrangements for management and control of fire load and ignition sources

Fire protection is part of plants change management processes and design areas. All changes that might have influence in fire protection are evaluated and approved with person responsible for fire protection.

A 3.3.2. Ventilation systems

A 3.3.2.1. Ventilation system design: segregation and isolation provisions (as applicable)

Ventilation systems for fire compartments and the penetrations needed for ventilation ducts have been designed according to fire protection requirements. [13] As a general design principle, the ventilation and air conditioning systems shall not degrade the overall level of fire safety. [105]

Separate buildings have separate ventilation systems. [106]The systems have fire dampers operated by thermal fuses and smoke dampers operated by fire detections system.

A 3.3.2.2. Performance and management requirements under fire conditions

The turbine hall and feed water tank level have smoke ventilation hatches and windows to lower the temperature under the ceiling. Smoke removal increases the working conditions of the fire brigade and lowers the risk of ceiling collapse. Smoke removal windows are operated remotely, and the hatches can be operated remotely or manually, but they are also equipped with thermal fuse for automatic operation. Turbine hall windows and hatches have been designed to remove the smoke from 200 m^2 oil pool fire, so that the visibility on the main turbine level is good enough for efficient extinguishing operations. Windows can’t be used for smoke removal if the wind blows toward the wall where they are situated. [107]

Maintenance building has smoke removal system to remove smoke from storage rooms. This increases the vision of fire personnel. [107]

The fire risks of final disposal facility for low and intermediate level radioactive waste (VLJ) are mitigated by smoke control to allow for evacuation and operative firefighting. The smoke removal system and overpressurization system are controlled by fire alarm system. [41]

A 3.3.3. Licensee’s experience of the implementation of the passive fire protection

A 3.3.3.1 Overview of strengths and weaknesses

The original design of Loviisa NPP was vulnerable to fires due to shortcomings in functional plant layout design, in passive fire protection (unprotected load carrying steel structures and inadequate functional fire compartments), in active fire protection (heavy fire loads), in safety system physical separation and location (turbine building, some process and electric rooms), and in cable routings. Some modifications have been evident based on engineering judgement and case analyses, while others have been strongly influenced by probabilistic fire risk analysis (fire PRA).

As described in the fire safety analysis section several improvement actions have been executed within the plant to improve the passive fire protection.

A 3.3.3.2 Lessons learned from events, reviews fire safety related missions, etc.

Fire events are continuously evaluated by the plant personnel. No major findings have been done during the recent years that would have directly impacted to changes in passive fire protection of the plant.

Comprehensive evaluation of the quality of fire doors have been done in 2017. Based on the evaluation and analysis separate improvement project was established.

Closing, locking or walling up of some fire doors has been done based on their risk importance in the fire PRA.

A 3.3.3.3 Overview of actions and implementation status

Majority on the implemented actions are listed in the fire analysis section of the report. Renewal of fire doors phase one (2018-2022) have be finalized and the next phase is in planning phase.

A 3.3.4. Regulator’s assessment of the passive fire protection

A 3.3.4.1. Overview of strengths and weaknesses in the passive fire protection

The possibility of fires and nuclear accident risks caused by them were not adequately taken into account initially in the functional design and the lay-out design of the Loviisa plant. Therefore, fire compartments were not implemented so that the plant safety functions could be maintained during all postulated fire scenarios. Due to the layout design, physical separation of some plant safety systems is inadequate. Fire compartmentation and cable routings do not meet the standards of today. The plant has unprotected steel structures which increase the risk of collapse in case of fire. Current requirements regarding the structural separation of control room and emergency control room are not fulfilled.

Many improvements have been done to mitigate these deficiencies. These are presented in section 1.3. With regard to passive fire protection, there have been new walls built, some doors closed permanently, protection of load-bearing steel structures, and moving of fire loads to different fire compartments.

With these modifications and the support of active fire protection systems, the level of fire safety has been deemed sufficient based on fire-PRA.

A 3.3.4.2. "Lessons learned from inspection and assessment on the passive fire protection as part of its regulatory oversight"

As a part of STUK implementation decision on regulatory guide YVL B.8, STUK required that Fortum assess fire doors and hatches also taking into account the risk of flooding. This assessment led to renewal program of fire doors that did not meet the current standards.

B NPP units Olkiluoto 1 and 2

B 3.3.1. Prevention of fire spreading (barriers)

B 3.3.1.1. Design approach

The plant is divided into fire zones, which are separated by structures of class EI 60. The fire zones have separate ventilation systems (except ventilation outlet pipe). The fire zones correspond to plant buildings. In addition, the buildings which contain safety systems are separated into two fire zones. The fire zones are further separated into fire compartments. The compartments are described in the following chapter in more detail.

The plant safety systems are separated as pairs of redundant divisions AC and BD. The separation is done with fire resistant construction materials. Inside these compartments the safety systems of the two divisions are separated by distance, by protective structures, or for example by placing the equipment in different cabinets. In addition, some safety systems are placed in their own respective compartments inside the division.

Technical design basis of the plant units' fire protection is based on the following documents:

- Asea-Atom: "Recommendations Regarding Fire Protection in Nuclear Power Plants" issued in 1972, the Swedish Fire Protection
- Finnish industrial guides, decrees, and standards
- YVL-guides
- Nordic Nuclear Insurers pool (NNI) guides. [33]

B 3.3.1.2. Description of fire compartments and/or cells design and key features

The fire zones and compartments of the plant have originally been designed in fire resistance class A 60. It has been deemed to correspond to currently used class of EI 60 in sufficient capacity.

The fire zones at the OL1/2 plants are:

- Reactor building
- Containment
- Turbine building, RCA
- Turbine building, non-RCA
- Auxiliary building, right
- Auxiliary building, left
- Control building, AC-subs
- Control building, BD-subs
- Switchgear building
- Cooling water intake building
- Waste building
- Active repair shop
- Entrance building
- Each detached building.

The control building housing the MCR is mainly divided into two fire zones according to pairs of redundant systems. Also, the two auxiliary buildings follow this same principle with the left auxiliary building housing AC-subs and right auxiliary building housing BD-subs.

The fire compartments in these fire zones are:

- Stairways
- Elevators
- Reactor building AC-subs
- Reactor building BD-subs
- Reactor building, H-rooms
- Containment
- Diesel generator rooms
- Turbine oil tank room
- Group of switchgear rooms
- Group of relay rooms
- Group of transformer rooms
- Group of battery rooms
- Main control room

The containment is its own fire compartment. The separation of subsystems inside is done via distance. The containment atmosphere is also inerted with nitrogen during power operation.

The turbine hall and turbine basement make up one fire compartment.

Generally, there are two escape routes from each compartment. [33]

Finnish regulatory guide YVL B.8 dictates that all fire-doors and hatches at NPPs shall be self-closing and self-bolting.

Fire compartment boundary penetrations are closed with fire stop solutions of equal fire resistance rating to the penetrated boundary. The licensee has an internal guide for the design and installation of penetrations, which includes the list of accepted fire stop products and their approval documentation (ETA, test reports). The design of new penetrations is approved by civil engineering department of the licensee, and when the penetration has a diameter of > 500 mm or is situated in a beam or similar “one dimensional” structure also by STUK. Civil engineering department is also responsible of the process of opening penetrations. The process includes permit to open structure that is given by plant fire brigade. List of open penetrations is managed in TVO network, where relevant parties mark different phases of the process complete. The penetration stays up on the list until the penetration is closed and inspected. [108]

The licensee has defined compensatory measures to be used when fire compartmentation is breached. Penetrations opened for installation work shall be closed with a temporary firestop (fire bags, mineral wool) whenever work is paused. When fire doors or fire dampers are opened, the rooms are monitored with fire alarm system. If the fire alarm system is not in use, there shall be inspection rounds done every two hours. [35]

B 3.3.1.3. Performance assurance through lifetime

If fire load in the plant is increased due to modifications, it shall be checked that the original design basis for compartmentation is not exceeded. Should there be excess, compensatory fire protection arrangements shall be designed and implemented to maintain required level of fire safety.

There shall be no unnecessary fire load inside the fire compartments. If there is a need for transient fire load in a compartment containing safety system equipment, a plan must be formulated to maintain the level of fire safety. [35]

The plant fire brigade does inspection rounds to ensure that fire safety is on an adequate level [38]. The processes are described in more detail in section B 3.1.2. Overview of arrangements for management and control of fire load and ignition sources The inspection protocol includes checks for fire compartmentation. Visual checks are done to all fire compartment structures including doors, hatches, penetrations and “cat-holes”. Doors and hatches are also tested functionally.

To keep the access routes clean, the storage of materials is only allowed in marked storage areas. The procedures for establishing a permanent or temporary storage are described in section B 3.1.2. Overview of arrangements for management and control of fire load and ignition sources

B 3.3.2. Ventilation systems

B 3.3.2.1. Ventilation system design: segregation and isolation provisions (as applicable)

The fire zones have separate ventilation systems (except ventilation outlet pipe). [14] The supply air inlet to a fire protection zone is located at an appropriate distance from exhaust air outlets and fire vents of other fire protection zones to ensure that the risk of external transfer of combustion gases between fire protection zones is kept to a minimum. [14]

The air-pressure in certain staircases is maintained at a level above that of surrounding rooms as a precaution against their becoming filled with smoke in the event of fire in adjacent premises, which would make them less suitable as escape routes and as access routes for firefighting. [14]

Fire dampers in ventilation ducts are provided restrictively and only when the ventilation systems cannot be isolated otherwise. They are tripped by fusible links and in some cases by the fire alarm system. [14]

The plants have a smoke removal system that can be used to clear the burning area of smoke. The system is operated manually by plant fire brigade. The control panels and switches are situated near entrances and fire brigade access routes. Smoke venting can be done by creating under-pressure or gravitationally. Replacement air is inlet via doors and staircases. The system consists of following equipment: smoke removal hatches operated with pressurized air, portable smoke vacuum, smoke removal hatches (with fitting parts) for the portable smoke vacuum, fixed smoke removal fans, smoke removal hatches operated with cable wire, smoke removal hatches operated with motor, and hatches with thermal fuse. The system is installed in following buildings: control building, auxiliary buildings, switchgear building, turbine building, reactor building (non-RCA), waste building, entrance building, outage building, pipe tunnels (OL1 switchgear building-salt removal building-OL2 switchgear building), cable tunnel, and fire station. [33][

VLJ has smoke extraction fans for smoke extraction from the tunnel driveway and smoke removal hatch on top and the pipe and cable shaft. [109]

B 3.3.2.2. Performance and management requirements under fire conditions

Fire dampers that are equipped with thermal fuses close automatically when room temperature rises.

Plastic ventilation ducts are only used leading out from the waste building acid fume hoods. They are sheltered in non-combustible material. Otherwise, the ducts and components are made of non-combustible materials.

The over-pressurization fans of staircases activate from fire detection and the motor-operated fire dampers in the inlet and outlet ducts are automatically closed. The requirement for overpressure is 150 Pa. [110]

If the overpressure systems of staircases are not functioning, the fire damper at the ceiling of that compartment is closed and the one at the lowest level made sure to stay open. [35]

B 3.3.3 Licensee's experience of the implementation of the passive fire protection

B 3.3.3.1 Overview of strengths and weaknesses

Strengths:

- Storing at nuclear plant [32]. Handling of fire load inside the plants with fire load permit process.
- Hot work plan [36]. Inspection rounds of temporary fire compartment penetrations.

Weaknesses:

- In WANO's peer review in 2020, an AFI was published regarding opening fire penetrations. A procedure has been published and implemented to improve the situation.
- Noticed during fire safety self-assessment that doors/hatches in between divisions is not monitored in a systematic way. This weakness was improved identifying the doors/hatches in between divisions and defining the closed position check measures. It was important thing to be assessed, securing that the fire containing principle is valid all the time, if not then compensatory measures come in force: "Fire compartments are completely surrounded by fire resistant walls and ceilings with fire resistant sealing devices for openings and penetrations."

B 3.3.3.2 Lessons learned from events, reviews fire safety related missions, etc.

In WANO's peer review in 2020, an AFI was published regarding opening fire penetrations. A procedure has been published and implemented to improve the situation.

B 3.3.3.3 Overview of actions and implementation status

Multiple modifications are implemented, and some are ongoing/planned:

- Fire door exchanges
- Fire compartment improvements
- Fire penetration improvements.

B 3.3.4 Regulator's assessment of the passive fire protection

B 3.3.4.1 Overview of strengths and weaknesses in the passive fire protection

The possibility of fires and the risks of nuclear power plant accidents arising from fires have been taken into account in the functional and layout design of the Olkiluoto 1/2 plant units. The safety systems are separated from each other as pairs of redundancies.

Aging fire doors and penetrations have been evaluated and renewals have been planned and completed based on the evaluations.

B 3.3.4.2 "Lessons learned from inspection and assessment on the passive fire protection as part of its regulatory oversight"

As a part of STUK implementation decision on regulatory guide YVL B.8, STUK required that TVO assess fire doors and hatches also taking into account the risk of flooding. This assessment led to renewal program of fire doors in order to meet the current industrial standards.

Some challenges have been identified when opening fire penetrations with large amounts of cables. The cables could be damaged when removing the existing fire stop material. This has created some penetrations with combination of two separately approved fire stop products, when the original fire stop product is no longer in use at the plant.

C NPP unit Olkiluoto 3

C 3.3.1 Prevention of fire spreading (barriers)

C 3.3.1.1 Design approach

OL3 NPP is divided into nuclear island (NI) and turbine island (TI), which consists mainly of conventional buildings and is not covered in the following description even though the fire protection principles are similar. The NI is comprised of several interrelated buildings including Reactor Building, Safeguard Buildings, Fuel Building, Access Building, Nuclear Auxiliary Building, Radioactive Waste Processing Building, Emergency Power Generating Buildings and Essential Service Water Pump Buildings. The Reactor Building is situated in the center of NI and is surrounded by the Safeguard Buildings and the Fuel Building. The Access Building, Nuclear Auxiliary Building, and Radioactive Waste Processing Building are physically connected to the aforementioned buildings. The Emergency Power Generating Buildings and Essential Service Water Pump Buildings are located away from other buildings, but there are tunnel connections to them. [15]

The main safety systems intended to achieve safe shut down of the reactor and to remove residual heat from the core are divided into four redundant safety divisions, or trains, that are physically and spatially separated. Each one redundant safety division is contained within one Safeguard Building. This divisional separation is provided for both mechanical and electrical systems. [15]

The principal method used to achieve nuclear safety is the use of the fire containment approach (fire compartments) and the fire influence approach (fire cells). With these approaches, redundant items important to safety are located in separate safety fire compartments or when the overall layout of the facility prohibits the use of the fire containment approach, the fire influence approach is used. [15]

In fire containment approach, each compartment is enclosed with fire barriers sufficient to withstand a fire where all the fire load inside a compartment takes part in combustion. The purpose is to contain the fire and its harmful effects to one fire compartment. In fire influence approach the propagation of fire between two fire cells is limited by limitation of combustible matter, spatial separation, the use of passive fire protection measures such as fire retardant coatings, and fixed automatic fire extinguishing systems. [15]

C 3.3.1.2. Description of fire compartments and/or cells design and key features

OL3 plant unit is divided into fire compartments and fire cells. There are three types of fire compartments and two types of fire cells in NI buildings. The fire compartments are safety fire compartment (SCO), unavailability limitation fire compartment (UCO) and protected rescue route fire compartment (RCO). The fire cells are correspondingly safety fire cell (SCE) and unavailability limitation fire cell (UCE). [15]

Safety fire compartments (SCO) are designed to safeguard the redundant trains responsible for performing safe shutdown operations against a common mode failure. The fire barriers of safety fire compartments have a minimum fire resistance rating of 120 minutes (EI 120-M / REI 120-M). [15]

Protected rescue routes are designed to ensure safe evacuation from the plant in case of fire and to enable effective rescue and extinguishing operations. The RCOs have a minimum EI 60 fire resistance rating. [15]

Unavailability limitation fire compartments (UCO) are designed for further separation to limit fire spread inside the facility, to enable safe escape of the plant personnel and to facilitate prompt response from the fire brigade. The fire barriers of most unavailability limitation fire compartments have a minimum fire resistance rating of 60 minutes (EI 60). The fire load inside an UCO may raise the required fire resistance rating to EI 90 or EI 180. [15]

Fire cells are used in limited instances where the design and layout of systems and equipment prevent certain portions of the facility from being systematically subdivided into fire compartments. Therefore, such areas are subdivided into fire cells to provide systems and components important to safety with protection against the spread of fire. This is accomplished by maintaining adequate spatial separation between the redundancies and/or using protective structures, fire resistant materials, and fire-resistant insulation. Safety fire cells (SCE) are designed to safeguard the redundant trains responsible for performing safe shutdown operations against a common mode failure. Unavailability limitation fire cells (UCE) provided further separation within a safety fire cell (SCE). [15]

Outer walls of buildings have a fire resistance rating of EI-M 120. This also includes the walls between buildings that are adjacent to each other. All load-bearing structures have a rating of at least R 120, which may be raised due to the fire load density in adjacent spaces. All load bearing structures that are also at a fire compartment boundary fulfil the same fire resistance rating EI as R. [15]

Doors, hatches, and penetrations in compartment boundaries are avoided as far as possible. Fire resistance rating of doors is at least half of that of the penetrated structure. Penetrations have the same fire resistance rating as the penetrated structure. The minimum requirement for all Doors, hatches, and penetrations is EI 60.

C 3.3.1.3. Performance assurance through lifetime

If fire load in the plant is increased due to modifications, it shall be checked that the original design basis for compartmentation is not exceeded. Should there be excess, compensatory fire protection arrangements shall be designed and implemented to maintain required level of fire safety.

There shall be no unnecessary fire load inside the fire compartments. If there is a need for transient fire load in a compartment containing safety system equipment, a plan must be formulated to maintain the level of fire safety. [35]

C 3.3.2. Ventilation systems

C 3.3.2.1. Ventilation system design: segregation and isolation provisions (as applicable)

The nuclear island buildings are equipped with ventilation systems which are designed to maintain ambient conditions within acceptable limits to ensure proper operation of equipment and the safety of operating personnel. The ventilation system also functions to protect operating personnel and equipment against risks that may come from within the facility such as fire, smoke, and toxic gases. [111]

The ventilation systems of the rooms that contain equipment of safety related redundant systems are independent of the ventilation of other redundant systems. The ventilation systems are designed to ensure air flow from areas with less radiological activity towards the areas with larger radiological activity. The exhaust air from radiologically controlled area is extracted to environment through the ventilation stack. [15]

The air intake systems are situated in a way that the spread of fire, smoke and any flammable, poisonous, or otherwise hazardous materials is unlikely. If hazardous materials enter the ventilation system, the ducts can be isolated with dampers. [15]

If it is necessary to interconnect several fire compartments by the ventilation system, the ventilation system functions to isolate the individual ventilation system serving the affected fire compartment. [111]. Ventilation ducts that are interconnected but are not equipped with automatic fire dampers meet the applicable fire resistance rating requirements specified in the Finnish Building Codes. The fire rated walls, floors, ceilings, and the fire rated seals are designed in accordance with European Standard or Finnish standards. [15]

The plant has a smoke confinement system, which consists of smoke extraction systems and overpressure ventilation systems. Electrical rooms and fire compartments with high fire loads are equipped with smoke extraction systems that remove smoke and hot gas from the affected fire compartment and cause the compartment to depressurize. This creates a smoke free layer within the affected fire compartment providing improved visibility, which is essential for safe escape, fire brigade response, personnel rescue, and manual firefighting. Protected rescue route fire compartments (RCO) are secured escape routes, and access routes for use by operation or emergency response personnel. The secured escape routes include protected staircases and protected corridors and are equipped with overpressure ventilation systems that generate a slight overpressure inside the RCO providing protection against smoke during rescue or emergency response activities. [15] If the smoke extraction systems of cable-, IC- or electrical rooms are not operational, the fire brigade will perform smoke extraction with portable smoke removal fans. [35]

C 3.3.2.2. Performance and management requirements under fire conditions

Isolation of fire compartments affected by fire is accomplished using automatic fire dampers preventing the air flow generated by the central ventilation system from flowing from and through the affected fire compartment. The fire dampers are usually operated by motor-driven control devices, but each fire damper is also equipped with a thermostatic switch that is preset to operate automatically at a temperature of 70°C [111]. Fire dampers have the same fire resistance class than the penetrated structure. [112]

During normal operating conditions, the electric-actuated insulation dampers which are located in the supply air train and the exhaust air train of the overpressure ventilation system are closed in order to protect the building from external hazards. The regular ventilation is in normal operation mode. Upon detection of a fire, the fire alarm system automatically isolates those fire compartments which are intended to be over-pressured from the regular ventilation by closing the respective fire dampers and simultaneously open the isolation dampers in the supply and exhaust air trains. The fire alarm system also starts the supply air fans automatically. The locations of outdoor air intake openings have been designed to prevent potential contamination of supply air caused by smoke exhaust air or similar environmental conditions. [113]

The power supply for the corresponding air fans and supply/exhaust air damper will be provided by dedicated switchgears of power mains of another division. The power supply of the supply air fans, and supply/exhaust air damper of the ventilation will be controlled by the I&C.

The cable parts of the smoke exhaust damper cables in the same room and in the same fire compartment respectively as of the smoke exhaust dampers have the requirements of electrical function for 30 min during fire.

The MCR, RSS, and other rooms required during accident situations enable plant personnel to perform necessary actions even during an accident/accident conditions.

If the overpressure system of protected rescue routes is not operational, personnel will be evacuated from the building using safe routes guided by public announcement system. [35]

C 3.3.3 Licensee's experience of the implementation of the passive fire protection

C 3.3.3.1 Overview of strengths and weaknesses

The used methods for fire prevention can be seen as strengths in OL3; especially clear instructions for storing at nuclear plant (Doc. 142848) and hot work plan (Doc. 102294).

According to the hot work plan, a permit linked to the work permit is required for opening all fire compartmentalized structures. The plant fire brigade monitors with weekly inspection rounds that the opened fire compartment penetrations are properly blocked with temporary procedures.

Also, extensive structural fire protection is strength in OL3. The methods have been explained in fire hazard analysis and shown in fire compartmentalization report and fire drawings.

Noticed during fire safety self-assessment that doors/hatches in between divisions was not monitored in a systematic way. This weakness was improved identifying the doors/hatches in between divisions and defining the closed position check measures. It was important thing to be assessed, securing that the fire containing principle is valid all the time, if not then compensatory measures come in force: "Fire compartments are completely surrounded by fire resistant walls and ceilings with fire resistant sealing devices for openings and penetrations."

The fire cell concept is applied only in some exceptional cases. It is based on protection against the spreading of fires by means of separation by distance, protective structures, fire resistant materials and/or fire-resistant insulation. Fire cells are used in areas where fire loads cannot be separated by separate compartments; such areas include the interior of the containment and the annulus. Anyhow, these are very limited cases in OL3, and compensatory measures are followed thoroughly. Also, fire cell areas are monitored as a high priority.

Deviations to Finnish building code have been discussed and agreed upon with the local building authority and STUK. The deviations are mainly related to the width and length of exit routes which have sometimes been deviated from for nuclear safety reasons. [100] [101]

C 3.3.3.2 Lessons learned from events, reviews fire safety related missions, etc.

In WANO's peer review in 2020, an AFI was published regarding fire-opening penetrations. A procedure has been published and implemented to improve the situation.

Before OL3 fuel loading TVO performed fire safety self-assessment considering the following topics [114]:

- Identify doors/hatches in between divisions and define measures to proof that the door/hatch is closed
- Evaluate temporary structures (large scaffolding) which may have impact to fire detection/sprinkler system functionality
- Fire detectors positioning requirement fulfillment check
- Reviewed the guideline in case of fire detector failure or blocking
- Reviewed electrical cabinet/room firefighting guideline.

C 3.3.3.3 Overview of actions and implementation status

Closed position check of doors/hatches in between divisions is made in daily bases by nuclear security.

Managing of open penetrations has been improved with a new procedure.

C 3.3.4 Regulator’s assessment of the passive fire protection

C 3.3.4.1. Overview of strengths and weaknesses in the passive fire protection

The passive fire protection arrangements at OL3 fulfill the current STUK regulations. The separation of safety divisions is exemplary.

The separation of MCR and RSS and the separation of safety division cables in annulus and containment is not absolute. The fire cell approach has been followed to ensure the required level of fire safety.

C 3.3.4.2. "Lessons learned from inspection and assessment on the passive fire protection as part of its regulatory oversight"

The passive fire protection arrangements were inspected and approved as part of STUK’s commissioning inspections.

D Olkiluoto ISFS

D 3.3.1 Prevention of fire spreading (barriers)

D 3.3.1.1 Design approach

ISFS safety systems are two-redundant (A, C). The cabling and equipment of the redundancies is separated in different compartments. If one compartment is lost in a fire, then at least one redundancy remains functional. Apart from the safety systems, the compartmentation is realized based on building level and room functions. The RCA and non-RCA rooms are in different fire compartments. [39]

D 3.3.1.2. Description of fire compartments and/or cells design and key features

The heart of the ISFS is the storage hall with spent fuel pools. Other key fire compartments include:

- cable tunnels
- transport corridor
- switchgear room
- electrical room
- control room.

The storage capacity was increased with an expansion project that was completed in 2014.

ISFS fire compartments have a fire resistance rating of EI 60. Only exception are staircases that are used as escape routes. They have a rating of EI 120. The walls and slabs that border fire compartments are made of reinforced concrete.

Load bearing structures have fire resistance rating of R 60, except in the expansion of the storage hall where the design of steel beams has been done using performance-based fire safety design.

Penetration fire stops, fire dampers, fire doors, and fire hatches have the same resistance rating as the penetrated structure. [39]

D 3.3.1.3. Performance assurance through lifetime

The ISFS is managed by the same licensee as the Olkiluoto NPPs. Therefore, the same guides and instructions regarding fire safety apply for all the facilities. The measures for performance assurance through lifetime are described in more detail in section B 3.3.1. Prevention of fire spreading (barriers)

D 3.3.2. Ventilation systems

D 3.3.2.1. Ventilation system design: segregation and isolation provisions (as applicable)

There are separate ventilation systems for RCA and non-RCA. Both ventilation systems have 2 * 100 % inlet and outlet fans.

The duct network is planned in a way that the ducts servicing areas of different redundancies are separated as far as possible.

D 3.3.2.2. Performance and management requirements under fire conditions

Staircases are automatically over-pressurized by over-pressurization fans controlled by fire alarm system. The staircases have smoke extraction hatches in the ceiling with the exception of one staircase in the expansion part of the facility. Smoke extraction hatches in the staircases are operated manually from the inside or outside.

Regular ventilation is not discontinued in case of fire. Some fire dampers are actuated by fire alarm system and others automatically by temperature.

Smoke extraction from tunnels and cable rooms is done by operative firefighting personnel using smoke extraction hatches, doors, and a portable fan. In RCA rooms, smoke removal is preferably done via regular ventilation ducts.

D 3.3.3 Licensee's experience of the implementation of the passive fire protection

D 3.3.3.1 Overview of strengths and weaknesses

The original fire protection concept/philosophy has mainly been found to be good, even though it does not meet the current regulations regarding passive fire protection in all respects.

Regardless of the fire load, cables, switchgear, instruments and devices of different redundancies (A- and C-sub) are placed in different fire compartments. Thus, in a fire that destroys one fire compartment, both of the redundancies verifying each other are not damaged.

D 3.3.3.2 Lessons learned from events, reviews fire safety related missions, etc.

Noticed during fire safety self-assessment that doors/hatches in between divisions is not monitored in a systematic way. This weakness was improved identifying the doors/hatches in between divisions and defining the closed position check measures. Closed position check of doors/hatches in between divisions is made in daily bases by nuclear security.

D 3.3.3.3 Overview of actions and implementation status

Modernization of smoke ventilation hatches was done in 2023.

D 3.3.4 Regulator's assessment of the passive fire protection

D 3.3.4.1. Overview of strengths and weaknesses in the passive fire protection

Safety systems of different redundancies are separated by fire compartmentation.

D 3.3.4.2. "Lessons learned from inspection and assessment on the passive fire protection as part of its regulatory oversight"

TVO used performance-based fire protection design in the expansion the ISFS. STUK evaluated the analyses used to verify load-bearing capacity of steel structures.

3.4. Licensee's experience of the implementation of the fire protection concept

A NPP units Loviisa 1 and 2

Even though the initial functional and lay-out design were not adequate from fire protection perspective, significant amount of efforts have been done to improve and/or compensate the level of fire protection within the plant. A lot of improvements have been implemented during the operating years which have been based on internal or external experiences, assessments and analysis, recommendations from authorities or other reference groups.

The existing fire protection arrangement management system concept [115] has been found to be good and comprehensively taking into consideration different aspects of fire protection and fire safety. The current fire protection arrangement management system has been designed to describe, complement and ensure the implementation of the overall fire protection philosophy and targets.

B NPP units Olkiluoto 1 and 2

The original fire protection concept/philosophy has mainly been found to be good, even though it does not meet the current regulations regarding passive fire protection in all respects. Many improvements have been implemented over the years, which have been based on operating experiences (internal and external), recommendations from authorities or other parties, etc.

C NPP unit Olkiluoto 3

The implementation of the fire protection concept including fire prevention, fire containing, and fire controlling has been done successfully. Meanwhile, during and after commissioning phase it has been noticed that it's slightly difficult to find adequate number of suitable storage places inside the plant. However, this is more issue for layout and maintenance than fire protection since the materials are mostly incombustible.

D Olkiluoto ISFS

The fire protection concept document is actively used on plant structural and operational planning.

3.5. Regulator's assessment of the fire protection concept and conclusions

A NPP units Loviisa 1 and 2

At Loviisa 1/2, the goals for fire protection arrangements and design are defined to prevent ignition of a fire, limit the ignited fire, avoid the risk to safety of personnel, and avoid the negative consequences caused by fire protection systems. The final goal is to avoid negative consequences to nuclear safety as a result of fire.

The possibility of fires and nuclear accident risks caused by them were not adequately taken into account initially in the functional design and the lay-out design of the Loviisa plant. Therefore, fire compartments were not implemented so that the plant safety functions could be maintained during all postulated fire scenarios. For this reason, the significance of active fire protection (fire alarm and extinguishing systems as well as operative firefighting) is important along with structural fire protection arrangements.

An identified weakness is the large amount of fire load, especially PVC/PE-cables.

As a conclusion the continuous improvement of arrangements related to control of fire loads and other administrative arrangements have reduced the risk of occurrence of fires. The deficiencies in passive fire protection are mitigated by extensive use of active fire protection systems and multiple plant modifications.

B NPP units Olkiluoto 1 and 2

In the Olkiluoto 1/2 plant units the defence in depth principle is implemented as restrictions on combustible matter, fire compartmentation by building and by room groups, and active fire protection measures.

The possibility of fires and the risks of nuclear power plant accidents arising from fires have been taken into account in the functional and layout design of the Olkiluoto 1/2 plant units. The safety systems are separated from each other as pairs of redundancies. The active fire protection arrangements support the structural fire protection. Active fire protection systems are maintained constantly and have been improved based on operating experience. The guidance and measures for controlling fire loads and regulating risk-inducing work have been improved continuously.

There are some weaknesses such as the large amount of fire load, especially PVC/PE-cables.

As a conclusion the fire protection concept at the Olkiluoto 1/2 plant units is sufficient to fulfill fire safety requirements.

C NPP unit Olkiluoto 3

Olkiluoto 3 plant has a high-level fire protection concept. The plant is new (commercial operation started 2023), and the contemporary requirements have been taken into account in the design. The plant follows three level defence in depth approach to fire safety. The levels are fire prevention, fire containing and fire controlling.

Layout design, multiple safety divisions and robust fire compartmentation form a basis for fire safety. OL3 has lowered fire risks by using FRNC-cables as far as practically possible. The cables do not sustain a fire without an external fire source. This has enabled leaving out fire suppression systems in the cable rooms. STUK has contracted VTT to do corresponding fire tests and analysis for verifying FRNC-cable concept and structural protection.

The guidance and measures for controlling fire loads and regulating risk-inducing work are in place.

There are some locations, where fire compartmentation between redundancies cannot be fully achieved. In these areas, the fire cell approach has been used. Cables and equipment of different redundancies are separated by distance or protected. A gas extinguishing system is used in the cable space below MCR floor. The fire safety has been verified with functional fire hazard analyses and PRA.

In the construction phase there were deviations identified in design regarding conventional fire safety legislation. Most of the deviations were regarding escape routes, and they have a positive impact on nuclear safety, by limiting the connections between safety divisions. The responsible authority (local building control) has approved the deviations after quadrilateral discussions between local authorities, the licensee, plant supplier and STUK.

D Olkiluoto ISFS

Olkiluoto ISFS facility has been designed according to all relevant regulations. Fire loads have been avoided where possible. The two redundancies of safety systems have been separated in different fire compartments. A fire in one compartment doesn't jeopardize the safety functions. The load bearing capacity of the expansion part of the facility has been designed using performance-based design, that is verified with analyses. The fire alarm system covers the entire facility and the rooms with large fire loads or ignition risks have been protected with fire suppression systems.

3.6 Conclusions on the adequacy of the fire protection concept and its implementation

A NPP units Loviisa 1 and 2

The plant units fulfill the fire safety requirements set in section 15 of STUK regulation Y/1/2018. This has been verified in implementation of YVL B.8 in decisions 18/0010/2015 and 101/0002/2020. In the implementation decisions, the most important non-conformances to guide YVL B.8 were related to contents of fire hazard analyses and structural fire protection. Fire hazard analyses do not have to be done retroactively and the new requirements only apply to modifications. The approval of non-conformances related to structural fire protection is based on active fire protection arrangements mitigating the consequences of fire.

The current level of fire safety is based on the large amount of essential safety improvements on a safety system level and regarding fire protection arrangements. The fire safety has been verified with fire-PRA.

Fire safety is followed in periodic safety reviews. The continuous oversight includes periodic inspection programme, document review and inspections during outages. STUK also has resident inspectors working at the Loviisa site.

B NPP units Olkiluoto 1 and 2

The plant units fulfill the fire safety requirements set in section 15 of STUK regulation Y/1/2018. This has been verified in implementation of YVL B.8 in decisions 48/0010/2014 and 77/0002/2020, 78/0002/2020, 79/0002/2020. In the implementation decisions, the most important non-conformances to guide YVL B.8 were related to contents of fire hazard analyses, structural fire protection, and separation of MCR and RSS. The approval of non-conformances related to structural fire protection is based on active fire protection arrangements mitigating the consequences of fire.

TVO has improved fire protection measures continually and has been proactive in discussions with the regulator. Many fire safety improvements have been done. The fire safety has been verified with fire hazard analyses and PRA.

Fire safety is continuously followed in periodic safety reviews. The continuous oversight includes periodic inspection programme, document review and inspections during outages. STUK also has resident inspectors working at the Olkiluoto site.

C NPP unit Olkiluoto 3

The plant units fulfill the fire safety requirements set in section 15 of STUK regulation Y/1/2018. This has been verified in implementation of YVL B.8 in decisions 20/0002/2016 and 80/0002/2020. The non-conformances approved in the implementation decisions are minor.

Fire protection concept of OL3 follows the defence in depth principle. Measures have been taken to minimize fire loads and ignition sources. The separation of safety divisions is exemplary. Large concentrations of fire load and other important areas such as MCR are protected with fixed fire suppression systems. The fire safety has been verified with functional fire hazard analyses and PRA.

The continuous oversight includes periodic inspection programme, document review and inspections during outages. STUK also has resident inspectors working at the Olkiluoto site. All of the fire protection arrangements were subject to STUK commissioning inspections performed for NPP buildings.

D Olkiluoto ISFS

The facility fulfills the fire safety requirements set in section 15 of STUK regulation Y/1/2018. This has been verified in implementation of guide YVL B.8 in decisions 48/0010/2014 and 77/0002/2020, 78/0002/2020, 79/0002/2020. There are some deviations from guide YVL B.8, but they do not compromise the fire safety of the facility.

There are no outstanding issues regarding fire protection concept of Olkiluoto ISFS facility.

4 Overall Assessment and General Conclusions

Radiation and Nuclear Safety Authority (STUK) supervises radiation and nuclear safety in Finland. The role and authority of STUK is defined in Nuclear Energy Act (990/1987), Radiation Act (859/2018), Act on Radiation and Nuclear Safety Authority in Finland (1164/2022), and Nuclear Energy Decree (161/1988). The Nuclear Energy Act authorizes STUK to issue further regulations on the technical details. STUK has issued five binding regulations by virtue of the Nuclear Energy Act. In addition, STUK has issued regulatory guides (YVL) which are used to comply with the requirements in the regulations. The Finnish regulations comply with IAEA guides and WENRA safety reference levels can generally be considered stringent.

Requirements on internal hazards including fire are issued in Regulation on the Safety of a Nuclear Power Plant (STUK Y/1/2018) and Regulation on the Safety of Disposal of Nuclear Waste (Y/4/2018). Guide YVL B.8 Fire protection at a nuclear facility introduces more in-depth requirements on fire protection arrangements. Issues related to fire safety are covered in numerous other YVL guides also.

STUK regulates safety, security, and safeguards at the Finnish nuclear facilities. STUK oversees how license holders take care of the safety and security of their nuclear facilities, the activities of organizations as well as safety and security of nuclear materials and nuclear and radioactive waste. The regulatory oversight is based on up-to-date guidelines, extensive inspection programmes and regularly performed safety reviews.

In addition to regulation related to nuclear safety, there are conventional fire safety regulation that also binds nuclear facilities. The conventional fire safety legislation is overseen by rescue services and local building control services. There is co-operation between STUK and the local authorities on fire safety issues.

The current licensees in Finland, Fortum and TVO, have operated nuclear power plants for over 40 years. They have extensive knowledge of nuclear safety and fire safety issues. The licensees have responsibility of the safety of their facilities and operate within the Finnish regulatory framework under the oversight of STUK.

All nuclear facilities in Finland comply with the STUK regulations regarding fire safety. The safety of the plants is evaluated at milestones such as operational license approvals and periodic safety reviews, with implementation of updated regulations and guides, and continuously as part of the oversight with document reviews and inspections at the site.

The safety of the facilities is at a sufficient level even though there are non-conformances to guide YVL B.8. The approval of non-conformances related to structural fire protection is based on active fire protection arrangements mitigating the consequences of fire. In the Finnish NPP fleet, one can see the developments in layout design and their effect on plant safety. In Loviisa NPPs, the original design did not adequately consider the possibility of fires and nuclear accident risks caused by them. In Olkiluoto 1 and 2, the layout design was better, but there were still some fire safety deficiencies. Olkiluoto 3 NPP has been designed according to current requirements and there are very few weaknesses in the fire protection arrangements.

The sufficient fire safety level on the older NPPs has been achieved with numerous improvements to safety systems, structural fire protection, and active fire protection arrangements, especially at Loviisa NPP. The core damage frequencies resulting from internal fires, as assessed in fire PRA, would be considerably higher without these improvements.

The strengths identified in Finnish nuclear facilities are the continuous improvement of arrangements related to control of fire loads and other administrative arrangements such as hot work permits, extensive use of active fire protection arrangements where passive fire protection is not sufficient, and the professional onsite fire brigades with wide range of responsibilities. For just OL3, the strengths also include the separation of safety divisions and lowering of fire risk with FRNC-cables.

The weaknesses for the older NPPs are partially insufficient structural separation of safety divisions, large amounts of fire load, and the extent of fire hazard analyses. Also, the human factor cannot be overstated as seen with the shortcomings of TVO fire brigade regarding compensatory fire protection rounds.

5 References to NAR

[1] *Ydinenergialaki 990/1987 (Nuclear Energy Act).*

[2] *Säteilylaki 859/2018 (Radiation Act).*

[3] *Laki Säteilyturvakeskuksesta 1164/2022 (Act on Radiation and Nuclear Safety Authority in Finland).*

[4] *Maankäyttö- ja rakennuslaki 132/1999 (Land use and Building Act).*

[5] *Pelastuslaki 379/2011 (Rescue Act).*

[6] *Ympäristöministeriön asetus rakennusten paloturvallisuudesta 848/2017 (Ministry of Environment Decree on Fire Safety of Buildings).*

[7] *Ydinenergia-asetus 161/1988, (Nuclear Energy Decree).*

[8] *Säteilyturvakeskuksen määräys ydinvoimalaitoksen turvalisuudesta STUK Y/1/2018 (Regulation on the Safety of a Nuclear Power Plant).*

[9] *Säteilyturvakeskuksen määräys ydinjätteiden loppusijoituksen turvallisuudesta STUK Y/4/2018 (Regulation on the Safety of Disposal of Nuclear Waste).*

[10] *YVL B.8 Ydinlaitoksen palontorjunta (Fire protection at a nuclear facility).*

[11] *YVL B.1 Ydinvoimalaitoksen turvallisuussuunnittelu (Safety design of a nuclear power plant).*

[12] *YVL A.7 Ydinvoimalaitoksen todennäköisyysperusteinen riskianalyysi ja riskien hallinta (Probabilistic risk assessment and risk management of a nuclear power plant).*

[13] *LO1, LO2, FSAR 09.6.1 Palontorjunnan yleiset suunnitteluperusteet (General design requirements for fire protection).*

[14] *OL1/OL2, FSAR 4 - Design of Systems, Structures and Components.*

[15] *OL3, Fire Hazard Analysis –General Fire Hazard Analysis–, NESP-G/2007/en/1067.*

[16] *LO1, LO2, FSAR 09.6.2 Paloturvallisuusarviot (Fire Safety Analyses).*

[17] *OL1/OL2, Fire PRA part 12, 136895.*

[18] *OL3, PSA Level 1 - Chapter 2 Main Results and Conclusion, NEPS-G/2009/en/1016.*

[19] *OL3, PSA Level 1 Chapter 4.3: Probabilistic Analysis of Accident Sequences, NEPS-G/2009/en/1003.*

[20] *OL3, OL3 - List of strange cables with locations and their protection methods, PEPS-G/2014/en/1031 rev. C.*

[21] "KPA, KPA PRA part 7.1 Fire analysis, 117019".

[22] *LO1, LO2, FSAR 10.2 Turbiinit ja generaattorit, LO1-K852-00479.*

[23] *LO1, LO2, Palosuojelu ja pelastustoiminta, MO-13-00001 (Fire Protection and Rescue Operations).*

[24] *LO1, LO2, Palokuormakirja, LO1-T9109-00032 (Fire load log).*

[25] *LO1, LO2, Kemikaalien hallinta Loviisan voimalaitoksella, MO-06-00014 (Management of chemicals at the Loviisa power plant).*

[26] *LO1, LO2, Loviisan voimalaitoksen varastointimenettelyt, MO-11-00007 (Storage arrangements at Loviisa power plant).*

[27] *LO1, LO2, Tulityösuunnitelma MO-13-00004, (Hot work plan).*

[28] *LO1, LO2, Loviisan voimalaitoksella tehtävät hitsaukset, MO-07-00007 (Welding at Loviisa power plant).*

[29] *LO1, LO2, Räjähdyssuojausasiakirja, LO1-K500-365-00006 (ATEX explosion protection document).*

[30] *LO1, LO2, Suojeluesimiehen tehtävät ja vastuut, F-02-00002 (Task and resposibilities of a Fire Lieutenant).*

[31] *OL1/OL2, FSAR / 9.4 - MINOR ACCIDENTS OR MALFUNCTIONS, 129531.*

[32] *OL1/OL2, Varastointi ydinvoimalaitoksilla ja sen ulkoalueilla, 142848 (Storage in the NPPs and at the site).*

[33] *OL1/OL2, Selvitys laitosyksiköiden OL1 ja OL2 paloturvallisuudesta, 169574 (Report on the fire safety of OL1 and OL2 plant units).*

[34] *VLJ VLJ-FSAR-L.5 - VLJ-LUOLAN SUUNNITTELUPERUSTEET, 119930 (Design basis of the VLJ-cavern).*

[35] *TVO, KORVAAVAT TOIMENPITEET TTKE:N ALAISIA PALOSUOJELUJÄRJESTELMIÄ TAI NIIDEN OSIA OTETTAESSA POIS KÄYTÖSTÄ, 103202 (Compensatory measures when disabling fire protections systems or parts thereof).*

[36] *TVO, TULITYÖSUUNNITELMA, 102294 (Hot work plan).*

[37] *TVO, The use, transport and storage of hazardous materials, 145820.*

[38] *TVO, Paloturvallisuuteen liittyvien tarkastusten yleisohje, 163482 (General guidance on inspections related to fire safety).*

[39] *KPA, KPA-VARASTO - PALOTEKNINEN SUUNNITTELU, 138901 (ISFS fire safety planning).*

[40] *LO1, LO2, FSAR 9.6.3 Paloilmoitinjärjestelmä, MF- järjestelmä, LO1-K852-00713 (Fire alarm system, MF).*

[41] *VLJ, FSAR 11.9.8.7 PALONTORJUNTA, LO1-K852-00779 (Fire protection).*

[42] *LO1, LO2, FSAR 09.6.4 Palovesipumput ja verkosto UJ/UK, LO1-K852-00437 (Firefighting water pump station and pipe network).*

[43] *LO1, LO2, FSAR 9.6.5 Kaapelitilojen vesispray-sammutusjärjestelmä UJ11-16, LO1-K852-00438 (Cable room water spray extinguishing system).*

[44] *LO1, LO2, FSAR 9.6.6 Turbiinisalin sammutusjärjestelmät UJ17, UJ22 ja UJ23, LO1-K852-00600 (Turbine hall extinguishing systems).*

[45] *LO1, LO2, 9.6.7 PÄÄMUUNTAJA-ALUEEN SPRINKLERIJÄRJESTELMÄT UJ24 JA UJ25, LO1-K852-00685 (Main transformer area sprinkler systems).*

[46] *LO1, LO2, FSAR 09.6.8 Muut yksittäiset sammutusjärjestelmät, LO1-K852-00601 (Other extinguishing systems).*

[47] *LO1, LO2, 9.6.9 HIILIDIOKSIDISAMMUTUSJÄRJESTELMÄT UX14...UX17 (LO1) JA UX16, UX18...UX20 (LO2), LO1-K852-497 (CO2 extinguishing systems).*

[48] *LO1, LO2, Tehdaspalokunnan operatiivinen toimintaohje, F-02-00005 (Plant fire brigade operative procedure).*

[49] *LO1, LO2, The definition of fire pre-plan in Loviisa NPP, LO1-L7-00048.*

[50] *LO1, LO2, Viranomaisradioverkon (VIRVE) viestintä, F-02-00021 (Communication via authority communications network (VIRVE)).*

[51] *LO1, LO2, Tehdaspalokunnan palveluohje, F-02-00006 (plant fire brigade service procedure).*

[52] *LO1, LOVIISA 1 TURVALLISUUSTEKNISET KÄYTTÖEHDOT, LO1-K857-00277 (LO1 operational limits and conditions).*

[53] *LO2, LOVIISA 2 TURVALLISUUSTEKNISET KÄYTTÖEHDOT, LO2-K857-00123 (LO2 operational limits and conditions).*

[54] *LO1, LO2, Kriisiviestintä Loviisan voimalaitoksella, MO-03-00010 (Crisis communications at Loviisa power plant).*

[55] *VLJ, Voimalaitosjätteen loppusijoitustilan sammutussuunnitelma, F-02-00017 (Plant waste disposal facility fire protection plan).*

[56] *LO1, LO2, Valvonta-alueella tapahtuneen henkilövahingon hoito ensiaputilanteessa, F-02-00022 (Rescue operations and first aid for personal injuries in RCA).*

[57] *LO1, LO2, Savu- ja kemikaalisukellus Loviisan voimalaitoksella, F-02-00023 (Smoke and chemical diving at Loviisa power plant).*

[58] *LO1, LO2, Yritysturvallisuusyksikön tehtäväkuvaus, HO-01-00007 (Nuclear security unit task description).*

[59] *LO1, LO2, Suojelutoiminnassa ylläpidettävät ohjeet ja asiakirjat, F-02-00003 (Protection guides and documents to be kept up to date).*

[60] *OL1/OL2, 869 - OL1/OL2 - PALOILMOITINJÄRJESTELMÄ – LOPULLINEN TURVALLISUUSSELOSTE, 107978 (Fire alarm system - FSAR).*

[61] *VLJ, L.869 PALOILMOITUSJÄRJESTELMÄ, 104324 (Fire alarm system).*

[62] *OL1/OL2, 861 - OL1/OL2 - FIRE FIGHTING WATER SYSTEM - FINAL SAFETY ANALYSIS REPORT, 106379.*

[63] *OL1/OL2, 861.3 - OL1/OL2 - TURPIINILAITOKSEN KOHDESUOJAUS - LOPULLINEN TURVALLISUUSSELOSTE, 106381 (Turbine plant extingushing system - FSAR).*

[64] *OL1/OL2, 862 - OL1/OL2 - SPRINKLERISUOJAUKSET - LOPULLINEN TURVALLISUUSSELOSTE, 106382 (Sprinkler systems - FSAR).*

[65] *OL1/OL2, 866 – OL1/OL2 – CO2-SAMMUTUSJÄRJESTELMÄ – LOPULLINEN TURVALLISUUSSELOSTE, 106383 (CO2 extinguishing system - FSAR).*

[66] *OL1/OL2, 867 - OL1/OL2 – Kaasusammutusjärjestelmä - lopullinen turvallisuusseloste, 106384 (Gas extinguishing system - FSAR).*

[67] *VLJ, L.861 PALOVESIJÄRJESTELMÄ, 104320 (Firefighting water system).*

[68] *VLJ, L.862 SPRINKLERIJÄRJESTELMÄ, 104321 (Sprinkler system).*

[69] *VLJ, L.866 HIILIDIOKSIDISAMMUTUSJÄRJESTELMÄ, 104322 (CO2 extinguishing system).*

[70] *TVO, TVO:N LAITOSPALOKUNNAN TOIMINTAOHJE, 159342 (TVO plant fire brigade manual).*

[71] *TVO, OLKILUODON HÄLYTYSKESKUKSEN TOIMINTAOHJE ONNETTOMUUSTILANTEISSA, 162904 (Olkiluoto alarm center functions in accident situations).*

[72] *TVO, PALOKUNNAN SAMMUTUSTOIMINTA SÄHKÖTILOISSA, 159348 (Fire brigade extinguishing operations in electrical rooms).*

[73] *TVO, TVO:n palokunnan sisäinen pelastussukellusohje, 131722 (TVO guide on rescue diving).*

[74] *TVO, OPASTUSKANSIO, 163429 (Guidance binder).*

[75] *TVO, Tulipalon aiheuttamien jälkivahinkojen torjunta, 101602 (Damage limitation in fire situations).*

[76] *TVO, TVO laitospalokunnan käyttöpäiväkirja, 159342 (TVO plant fire brigade log book).*

[77] *OL1/OL2, LAITOSTEN SAMMUTUSJÄRJESTELMIEN TARKASTUS- JA HUOLTO-OHJEET, 101307 (Inspection and maintenance instructions for fire extinguishing systems).*

[78] *TVO, TVO laitospalokunnan hälytyskaluston tarkastusohje, 102113 (Inspection guide for plant fire brigade equipment).*

[79] *TVO, Palosuojelukäsikirjan sisältö, ylläpito ja jakelu, 103688 (Fire protection manual: contents, upkeep, and distribution).*

[80] *OL3, Fire Alarm System (30CYE), NGLEO/2004/en/1011.*

[81] *OL3, System Description Fixed Fire Fighting System Sprinkler system 30SGE at Nuclear Island, EZL/2005/en/0007.*

[82] *OL3, System description Spray Deluge System 30SGC in Turbine Island, 421062687.*

[83] *OL3, Fire Protection Concept Turbine Island, 8799777.*

[84] OL3, System description Sprinkler System 30SGE in Turbine Island, 421941258.

[85] OL3, OL3 Technical Specifications Section 4.7, NEPS-F DC 352.

[86] OL3, System Description Fire Fighting Water Supply Connection System 30SGA, EZH/2007/en/0143.

[87] OL3, System Description Fire Fighting Water System 30SGB at Nuclear Island, EZL/2005/en/0006.

[88] OL3, System description Fixed Fire Fighting System Spray Deluge System 30SGC at Nuclear Island, EZL/2005/en/0008.

[89] OL3, System Description Fixed Fire Fighting System Sprinkler system 30SGE at Nuclear Island, EZL/2005/en/0007.

[90] ”OL3, System Description Fixed Fire Fighting System Gas Extinguishing System 30SGJ at Nuclear Island, EZL/2005/en/0009”.

[91] OL3, Sammutus- ja pelastustoiminta Olkiluoto 3 ydinvoimalan putki- ja kaapelitunneleissa, 177395 (Extinguishing and rescue operations in OL3 pipe and cable tunnels).

[92] OL3, Periodical Inspection Program - Fire, NESP-G/2008/en/1226.

[93] OL3, Olkiluoto 3 Fire fighting scheme, NESP-G/2009/en/1154.

[94] OL3, Palokunnan toimintaohje hälytystilanteessa Olkiluoto 3 säteilyvalvonta-alueella, 191591 (Fire brigade procedure in an alarm from OL3 RCA).

[95] OL3, OL3 muuntajien sammutuskohdekortit, 194711 (OL3 transformer extinguishing instructions).

[96] OL3, OL3 - 30SG PALONTORJUNTAJÄRJESTELMÄT (FIRE PROTECTION SYSTEMS) TURVALLISUUSARVIO. FSAR, OL3-00001649483 (Licensee's safety assessment of fire protection systems 30SG).

[97] OL3, OL3 - SAG REAKTORILAITOKSEN SAVUNPOISTOJÄRJESTELMÄ (SMOKE CONFINEMENT SYSTEM). TURVALLISUUSARVIO. FSAR, OL3-0001644100 (Licensee's safety assessment of smoke confinement system SAG in NI).

[98] OL3, System analysis of the active fire protection systems, OL3-0003476485.

[99] OL3, 3PSJ equipment liability report, OL3-0003835123.

[100] OL3, Deviations to the Finnish Building Regulations -Fire Deviation List TI-, 439303888.

[101] OL3, Deviations to the Finnish building code -Fire Deviation List-, NESP-G/2006/en/1498.

[102] KPA, Y.862 - SPRINKLERSUOJAUKSET - LOPULLINEN TURVALLISUUSSELOSTE, 127493 (Sprinkler systems - FSAR).

[103] LO1, LO2, Hyväksytyt palo-ovet Loviisan voimalaitoksella, F-03-00036 (Approved fire door at Loviisa power plant).

[104] LO1, LO2, Osastoivien palo-ovien tarkastus ja huolto, F-03-00034 (Fire door inspection and maintenance).

[105] LO1, LO2, FSAR 03.3 Sisäisiltä uhilta suojautuminen, LO1-K852-00502 (Protection from internal hazards).

[106] LO1. LO2. FSAR 9.4.0-9.4.9.

[107] LO1, LO2, FSAR 09.6.10 Savunpoisto, LO1-K852-00871 (Smoke extraction).

[108] TVO, LÄPIVIENNIT TVO:N KÄYTÖSSÄ OLEVISSA YDINLAITOKSISSA, 160713 (Penetrations at TVO nuclear facilities).

[109] VLJ, L.868 SAVUNPOISTOJÄRJESTELMÄ, 104323 (Smoke extraction system).

[110] OL1/OL2, FSAR 742, 742 - OL1/OL2 - REAKTORIRAKENNUKSEN ILMANVAIHTOJÄRJESTELMÄ -LOPULLINEN TURVALLISUUSSELOSTE, 108406 (Reactor building ventilation system - FSAR).

[111] OL3, Olkiluoto 3 Final Safety Analysis Report, PEPM-G/2010/en/1001.

[112] Suomen rakentamismääräyskokoelma, E7 (Finnish building code).

[113] OL3, System Description, Smoke Confinement System 30SAG, EZL/2005/en/0052.

[114] OL3, OL3 - Paloturvallisuusjärjestelyiden itsearviointi, OL3-0002789197 (Self assessment of fire protection arrangements).

[115] ”LO1, LO2, Loviisan voimalaitoksen palontorjuntajärjestelyjen hallintajärjestelmän asiakirjarakenne, LO1-L7-00046 (Structure for fire protection arrangements' documentation)”.