European Nuclear Safety Regulators Group

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‘Fire Protection’
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National Presentation of Sweden

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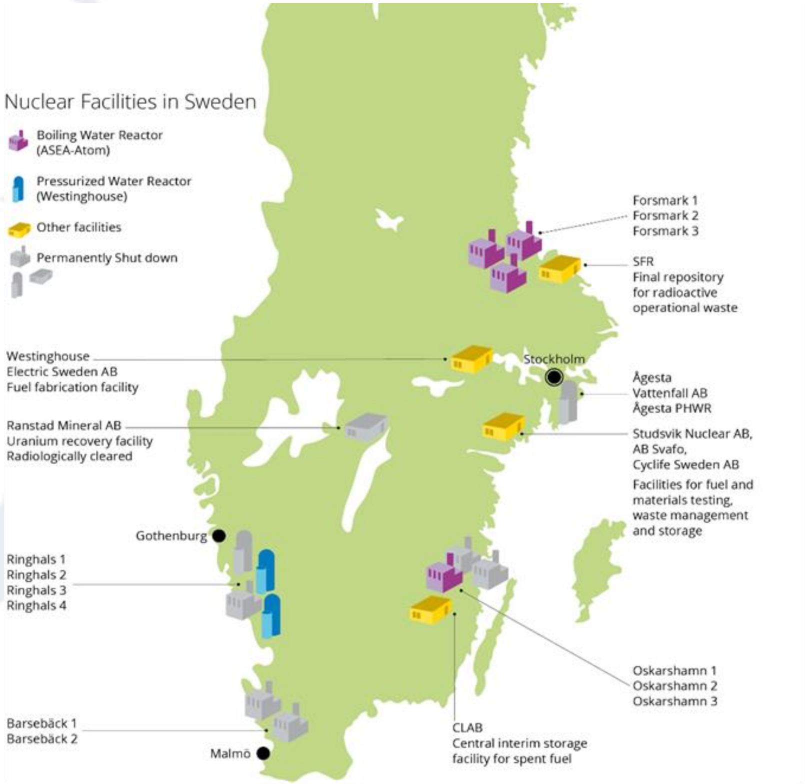
National Presentation Outline

ENSREG European Nuclear Safety Regulators Group

Nuclear installations in Sweden



National Presentation Outline

Installations included in the Swedish national report are:

- Forsmark 2 (BWR)
- Oskarshamn 3 (BWR)
- Ringhals 3 (PWR)
- Westinghouse Fuel factory
- Clab, the Central Interim Storage Facility for Spent Nuclear Fuel

National Presentation Outline

Installations excluded in the Swedish national report:

- There are presently no research reactors operating in Sweden.
- No plants under decommissioning are included in the scope of this NAR. All fuel has been removed from the sites and they therefore represent a much lower radiological risk to the public and the environment compared to the facilities that are included.
- The SKB final repository of low- and intermediate level waste (SFR) represent a much lower risk to the public and the environment, compared to the facilities that are included.

National Presentation Outline

National regulatory requirements and standards

The Swedish legal framework consist of the legally binding acts, ordinances and regulations. With reference to its legal mandate SSM issues legally binding regulations for nuclear facilities in its Code of Statutes, SSMFS.

Regulations may include non-binding general advice, which give strong recommendations on how to implement specific requirements.

The regulations are also supported by non-binding guidance documents provided for comprehension of the implications of the regulations, with explanations and examples of application.

With regard to fire safety, the nuclear facilities in Sweden have to comply with specific nuclear regulations as well as conventional (non-nuclear) fire protection regulations.

Authorities that set fire requirements

- Swedish Radiation Safety Authority
- Boverket, (The Swedish National Board of Housing, Building and Planning) building regulations (not the least for compartmentation)
- The following requirements are also important regarding segregation of items important to safety from fire loads:
  - Civil Protection Act
  - Civil Protection Ordinance
  - Flammable and explosive goods act
  - Work Environment Act
  - Work Environment Ordinance

Fire analyses and risk assessments (both deterministic and probabilistic) are carried out at intervals that are in accordance with current laws and regulations.

Also requirements from insurance companies and licensees own ambition.

NPPs

Requirements development

"Statens Vattenfallsverk" and the Swedish Fire Defense Association (SBF) formed in 1971 a committee with relevant parties including responsible authorities, vendors, owners, relevant insurance companies and future operators.

The committee reviewed current building and fire legislation in combination with identified NRC requirements. The results were incorporated in the guidance document SBF-72.

National requirements on fire hazards and fire prevention and protection at nuclear facilities have then regularly been revisited to ensure that operational experience and lessons learned from events, new knowledge, R&D and latest international standards are appropriately considered.

The latest reports following such reviews are the SSM report 2010:10 (Overview of national and international requirements regarding fire protection on nuclear power plants and how these are applied in the Swedish nuclear power industry) and the National Fire Safety Forum NBSG, NBSG report 84#01 (Design and development of nuclear power plants' fire protection), published in May 2023.

The nuclear facility vendors have over the years implemented operational experience, new knowledge, etc. in the design and operation, and developed principles for fire prevention emphasizing material properties, layout, effective detection and response, redundancy, separation, diversification.

These principles and applied standards are defined and referenced in the Safety Analyses Reports (SAR) for each facility.

Insurers activities

- Nuclear insurance representatives perform inspections on regular basis leading to some recommendations which is base for continuous dialog / improvements.

Fire safety analysis (FSA)
(cf TS 02.1)

NPP

NPPs
Deterministic FSA

- The main objective for DFSA is to demonstrate that a postulated fire does not jeopardize safety functions and barriers needed to bring and maintain the reactor in a safe shutdown condition.
- Key assumptions for DFSA can be summarized as:
  - Postulated Initiating Event (PIE) fire is defined as a postulated fire in a fire compartment.
  - LOOP is assumed as a consequential failure (following scram and turbine trip).
  - Single failure is assumed.
  - Only safety grade SSCs are credited to mitigate the event.
  - No operator actions are credited to mitigate the event within 30 minutes.
- Different approach on credit for manual and automatic fire suppression between NPP´s, described in the NAR.

Fire safety analysis (FSA)
(cf TS 02.1)

NPP

NPPs

Fire phenomena analysis

This analyzing method is suitable for showing fire barrier effectiveness or other local consequences of fire, such as fire spread or heat radiation on specific components. The method is mainly used as an alternative for e.g. large compartments or control rooms etc. where several subdivisions are present in the same compartments.

When performing fire phenomena analyses it is of key importance to be aware of the limitations and uncertainties of models used. It is equally important to use a methodology that is robust and quality assured.

For this reason, whenever a fire phenomenon analysis shall be performed the methodology and applied models are based on recommendations in a report produced by Lund University, “Guide on quality assurance in fire safety analysis work for Swedish nuclear power plants”. The guide was produced by request from the Swedish licensees through the National Fire Safety Forum NBSG, where all Swedish nuclear power plants are represented along with SKB (Swedish Nuclear Fuel and Waste Management Company) and SSM (Swedish Radiation Safety Authority). This guide provides suggested methodology for fire phenomena analyses and describes what to keep in mind when choosing the proper model for the analysis.

For the quantification of direct fire effects such as temperature, pressure, soot and smoke production these are dependent on user input data. This illustrates the necessity of using reliable input data based on experience from previous fires. Experience from NUREG-6850 and OECD Fire Data base must be utilized when applicable. Soot and smoke production should be chosen based on what materials are burning as such might differ between analyses.

Fire safety analysis (FSA)
(cf TS 02.1)

NPP

NPPs

FIRE PSA

- The Fire-PSA is performed as PSA Level 1 and PSA Level 2 for all operating modes.

Contribution of Fire PSA

- Contribution of Fire to the total Core Damage Frequency (CDF) varies between different NPP´s.

For PWR: Fire contributes with about 33% of CDF.

Most penalising scenarios: This is considered sensitive and classified information

For PWR a few cases contribute with 99% of the 33% mentioned above. These are highlighted as mentioned on the thematic workshop as the worst fire spread cases.

Independent Core Cooling System installed has contributed to a total reduced risk level / CDF, also for fire scenarios.
ICCS is designed to withstand severe external hazards beyond design basis.

NPPs
Strategy for the location of the detectors

Basic design for fire alarm per the Swedish Fire Protection Association standard / rule SBF 110 (previously RUS 110)

The fire detection and alarm system shall be comprehensive such that all compartments in the plant shall be provided with automatic fire detection.

In addition, the following design approach of the alarm system coverage can be described with the following three principles:

1. Areas of importance for reactor safety are monitored by detectors connected to the A- and B-side of the fire alarm central respectively. This guarantees continuous fire and smoke detection, even in the event of failure of one Fire Alarm Central (FAC).

2. Other areas considered important are monitored by two FAC from the same side, A or B side.

3. Remaining areas are monitored by one FAC from either side.

The technology used for fire detectors are: Heat detectors, optical smoke detectors, flame detectors (IR-type and UV-type depending on application), High sensitivity aspirating smoke detectors (laser-optical type), Line smoke detectors and ionization smoke detectors.

NPPs
Characteristics of detectors

The detectors are constantly exposed to environmental effects such as dust, radiation, humidity and changes in temperature. A permit-based maintenance schedule states when detectors need replacing in order to avoid failures due to ageing detectors.

All fire detectors are continuously supervised - the fire alarm system continuously checks that the fire detectors are responding. In case a fire detector is not responding, a failure message is triggered.

When fire is indicated to the FAC the Programmable Logical Control (PLC) automatically control appropriate functions in the fire protection system. Examples of functions controlled by the PLC are:

- Normal ventilation stop and emergency ventilation activation
- Start of overpressure fan in stairwells
- Activation of fire suppression systems
- Closure of fire dampers and recirculation dampers

NPPs

Strategy for the selection of the location of the fire extinguishing systems and their characteristics

Areas with high fire load and potential risk of fire should be equipped with suppression systems designed to suppress or control fires until manual firefighting is possible.

The main design approach is that compartments with fire load exceeding 200 MJ/m^2 surrounding areas should be provided with fire suppression system.

Extinguishing agents vary depending on the rooms they cover. Agents used are water, foam, inert gas and powder. Some of these agents only occur in fixed systems and some are solely for manual firefighting.

Fire protection systems can also be added for other reasons, such as asset protection or in few cases to minimize the risk of fire spread between subdivisions.

NPPs
Methods for determining suitable fire barriers

- The design principles applied by the reactor designer provides the basis for fire barriers.
- Furthermore, some plants have improved over time from original design.
- Any plant modifications in general must not compromise the above.
- The determination of robust and adequate fire barrier separation is demonstrated in the Safe Shutdown Analysis.

Compensatory fire protection measures in cases where the use of ‘state-of-the-art’ compartmentation is not (fully) possible (e.g. when modern regulations have to be followed for older installations)

- Fire protection systems can also be added for other reasons, such as asset protection or in few cases to minimize the risk of fire spread between subdivisions. For the same reason Forsmark 2 is equipped with an oxygen reduction system.
- Shielding.
- Cable enclosures.
- Distance separation in combination with minimized transient fire load.
- In few cases shielding combined with smoke extraction is a possibility.

NPPs

Maintenance of fire dampers

- The required testing and testing frequency of fire dampers is governed by the Technical Specification where also the test procedure is referred. Practically this includes to verify that fire dampers are actuated by the fire alarm system. Examination, inspection and maintenance are addressed within the maintenance program.
- Modern motor operated fire dampers are self-testing with an interval, typical 48 hours. In case of deviation these self-tests triggers an alarm in the fire alarm system.
- Exchange program depending on facility where needed.
- Experiences of testing shows a very high reliability.

TS 01.3 and TS 04

NPP

NPPs

Significant improvements resulting from PSR/PSA, OPEX, updated regulations and insurers requests, and potential updates since the NAR production

Fire load management.

- Efforts to minimize fire loads and arrangements for the control of fire loads are part of daily operation.
- OPEX related improvements is the implementation of fire extinguishers for metal fires (After the titanium fire in France)
- Installation of sprinkler on main and step down transformers
- PWR has installed oil encapsuling system for reactor coolant pumps.
- Mapping of gas cylinders to avoid explosion risk in case of fire and facilitate for manual firefighting intervention.
- Inspections of electrical equipment in ATEX areas according to *“SS-EN 60079-17” and ”IEC 60079-17, Fifth edition, 2013 - Explosive atmospheres - Part 17: Electrical installations inspection and maintenance”* validating that the correct installation and equipment in order to decrease explosion risk.
- Thermography of switch gear and electrical cabinets to find hot spots / possible fire initiators.

Forsmark specific:

- Following the results of the FHA, vulnerabilities of the plant configuration was identified and actions has been taken to improve the fire protection, including reducing the risk of multiple redundancies being affected. These includes dividing compartments with vital equipment into separated fire cells and reduced oxygen levels in important areas such as electrical relay rooms.

NPPs

Strengths

- High quality of building construction and separation of safety system redundancies.
- Well-trained and well-equipped on-site fire brigade and good co-operation with the municipal rescue service.

- The results from the DSA and the PSA demonstrates high resilience against fire events for all NPP´s. The resilience against fire is a result of the original plant design along with significant improvements done to the plant configuration, such as the physical separation of safety systems.
  In addition to this the independent core cooling system exist for Design Extension Conditions.
  The NPP´s are equipped to handle combination of events and Beyond Design Events.

- National Fire Safety Forum (NBSG) have resources to manage R&D in the field of fire safety and protection. R&D / yearly meetings are held in cooperation with licensees, relevant authorities, external fire brigade, insurance representatives and the universities. NBSG also conduct national and international surveillance to collect and distribute OPEX and fires for non nuclear installations.
- High competence in the country due to mentioned cooperation with University departments in the field of fire safety engineering.

NPPs

Strengths

- RISE Research Institute of Sweden, in the municipality of Borås is a test institute with a large-scale fire laboratory. Their laboratories and test facilities are sometimes used to test fire resilience of components and materials, or determine properties and fire behavior of different materials. Experiments have also been performed regarding potential ageing issues in cables, fire penetrations. etc.

Addressing Areas For Improvements

- Earlier identified weaknesses have been resolved.

- The fire safety and fire protection is continuously self-evaluated and when areas for improvements is identified, further analysis are performed to verify which actions are most appropriate. Actions are taken in a timely manner.
- In case Areas For Improvements are identified for NPP´s they will be appropriately addressed and remedied. Such an example is the enhancement of separation.

Fire safety analysis (FSA)
(cf TS 02.3)

Fuel fabrication facilities

Westinghouse

- The scope of the fire safety analysis with fabrication facility is explicitly to be found with laws regulated by other regulators than SSM.
- The scenarios covered with the FSA are:
  - Hydrogen explosion
  - Release of uranium powder in the event of a fire in the filter bank
  - Methanol fire
  - Ammonia fire and formation of nitrogen dioxide
  - Fire as a result of lightning
  - Fire as a result of crashing aircraft
  - Fire as a result of a falling helicopter
  - Fire in the factory area – ammonia fire
  - Fire in the factory area – methanol fire
  - Fire in the factory area - other cause
  - Fire outside the factory area
- The most penalizing scenario with aspect to fire is a fire within the process HVAC-system that would release UO2-powder to the environment via smoke.

Westinghouse

- **Basis for fire compartmentation design:**
  - **Use of a combination of explicit (prescribed design) regulatory requirements and risk-based performance-based design where functions that are necessary, both for safety reasons and to protect the production, is covered by the compartmentation strategy.**

- **The facility does not have any situations where new requirements states higher demands on the fire compartmentation than as-built. This means there is no need for compensatory measures for fire compartmentation.**

Westinghouse

- Where the HVAC-system service multiple fire compartmentations, and the ventilation channel breaks through a fire compartment, the system is equipped with fire dampers that are activated by smoke and will close automatically.

Westinghouse

- Westinghouse work with continuous improvements throughout the Swedish operations and the global corporation.

  - Examples of improvements made as a result of fire safety analysis to the HVAC-system are:
    - Increased requirements on configuration control implemented for modifications
    - Rubber hoses replaced with metal ones
    - Identify manufacturing equipment with temperatures exceeding 200 degrees Celsius and remove or motivate combustible materials in contact with that.

- An important advantage with the Westinghouse corporation, both local and global organisation, is the sharing of feedback and information up to the highest (international) decision making level. This policy thus guarantees that all operating units can benefit from solutions, mastered at the global level and adapted to local specificities.

Fire safety analysis (FSA)
(cf TS 02.3)

Spent fuel storage

Clab Central Interim Storage Facility for Spent Nuclear Fuel

- Originally, physical separation between redundant trains in the active fuel pool cooling system was accomplished by ensuring a physical distance of at least one meter between redundant trains in the same room. Analyses have shown that this distance is sufficient as long as no transient fire load is placed between the two trains. Additionally, transient fire loads in those relevant rooms are prevented and controlled by the OLC.
- When spent nuclear fuel is removed from the reactor core at NPPs, it is initially placed in the on-site spent fuel pools at each reactor unit and stored for at least one year before transported to Clab. When transported to Clab the decay heat and the radiation levels are significantly reduced (by time) compared to the levels when originally removed from the reactor core. In Clab the spent fuel is stored in large pools, allowing the ratio of generated heat (effect) and water volume, to be very low.
- If a fire would result in loss of the active fuel pool cooling system, the passive cooling provided by the large water volume in the fuel pools and supported by the air flow in the compartment where the pools are located, will secure the integrity of the spent fuel and ensure that radiation safety is maintained through the event. The sequence of the event is slow. The time available to repair or replace damage equipment provides sufficient margins. It is nearly a week before boiling in the fuel pools may no longer be prevented if no actions are taken, and about 30 days before the water level reach TAF (top of active fuel).
- Spare parts are accessible at site and the maintenance personnel has competence and training to replace equipment and restart the fuel cooling system within 72 h. Additionally, there is always an independent make-up system available at site.

Clab Central Interim Storage Facility for Spent Nuclear Fuel

- PSA scope / contribution of Fire PSA
  - The estimation of fire frequencies is based on NUREG-CR-6850.
  - The consequences that are analyzed in the probabilistic safety analysis are “boiling in the fuel pools” or “exposure/overheating of fuel”.
  - Considering that the sequence of the event is slow, it will take about 30 days before additional water to support the cooling of the spent fuel is required.
    - Therefore, it is assumed that manual actions will succeed and that exposure/overheating of fuel will be prevented with a high degree of confidence.
    - Exposed fuel at Clab is therefore considered a residual risk.

Clab Central Interim Storage Facility for Spent Nuclear Fuel

- There are fire detectors in every room. Location of detectors follows requirement in SBF 110 (Swedish fire protection association).
- Clab has multi-detectors (smoke and heat) and in large spaces (pool areas) sampling detectors.
- The detector condition is continuously monitored by the system.
- The fire alarm systems are battery backed-up and are not affected by loss of external power.
- In case of fire, the fire system automatically close dampers, start sprinklers and overpressure fans in stairwells

Fire suppression (cf TS 03.2.2)

Spent fuel storage

Clab Central Interim Storage Facility for Spent Nuclear Fuel

- Sprinklers are placed in areas where manual firefighting is hard to perform such as cable shaft or where the fire load is high (reference value >200 MJ/m^2) such as areas/room where garbage containers are located.
- Sprinklers are also placed throughout the escape routes from controlled areas.
- All sprinkler systems uses water.

Clab Central Interim Storage Facility for Spent Nuclear Fuel

– Strengths

- The FHA demonstrates a robust design and no radiological consequence to the public following a fire.
- The FHA demonstrates slow progression of relevant event sequences and generous response time. Due to additional regulatory requirements and reviews, the analyses have been developed and refined over the years.
- The facility's routines and safety culture promotes early reporting and response to potential weaknesses.
- Clab´s fire protection safety is considered to be robust both when it comes to radiation safety, personnel safety and property protection.
- The fire load in Clab is generally low and efforts to minimize transient fire load and explicitly in critical areas are part of the everyday operation.
- The fire brigade is familiar with the facility and perform annual training at the site at least 8 times per year.

Clab Central Interim Storage Facility for Spent Nuclear Fuel

Addressing Areas For Improvements

- **Earlier identified weaknesses have been resolved.**
- **The fire safety and fire protection is continuously self-evaluated and when areas for improvements is identified, further analysis are performed to verify which actions are most appropriate. Actions are taken in a timely manner.**
- **In case Areas For Improvements are identified they will be appropriately addressed and remedied. Such an example is the enhancement of separation conducted.**