ENSREG
European Nuclear Safety Regulators Group

Topical Peer Review II

Fire protection at nuclear installations

Topic of interest:

General Methodologies for Deterministic FSA

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Fire safety analysis

General methodologies for deterministic fire safety analysis

Aspects to be discussed

1. Objectives and scope of the deterministic fire safety analysis

2. Deterministic fire safety analysis: Types, methodologies, standards, guidelines, and assumptions

3. State-of-the-art understanding of fire-induced phenomena

Expected outcome of discussion

- Overview and a broad understanding of different approaches for deterministic fire safety analysis, in particular objectives, assumptions, regulatory requirements, standards, and their interactions.
- Better insights from national approaches to share experience and identify potential good practices or challenges

General methodologies for deterministic fire safety analysis

1. Objectives and scope of deterministic fire safety analysis

- *Ensuring the fulfilment of the safety functions under the conditions of a postulated fire has been the main objective of the fire safety analyses in nuclear installations. The TPR technical specification requested to detail the type and scope of fire safety analyses, key assumptions and methodologies, phenomena and main results*.
- Objectives of DFSA need to be clearly defined on general level and supported also on specific level. The general objectives described in the NARs are nuclear safety, personnel safety and property safety. There are also some further more detailed objectives provided, e.g.:
  - Need to perform DFSA to meet requirement
  - Support SSC Equipment environmental qualification
  - Support development of fire safety SSC functional performance requirements and environmental qualification.
- Scope of DFSA is expected to be full scope, i.e. covering all sources, operating states and fires initiated anywhere. A graded approach is generally applied to focus DFSA on most risk important areas (sources of radioactivity, operating states and fire areas)

General methodologies for deterministic fire safety analysis

1. Objectives and scope of deterministic fire safety analysis - **Approaches reported in NARs:**

High Level Objectives

- ✓ Focus on Nuclear/Radiation safety
- ✓ Worker safety
- ✓ Asset safety
- ✓ In principle in all NARs

Many specific objectives are mentioned, some examples

- ✓ Input to fundamental safety function SSCs equipment qualification
- ✓ Show that the plant can be shutdown safely in case of fire
- ✓ ISFS: Fire simulations have been used to justify the performance-based fire safety design of the expansion of the ISFS facility.
- ✓ 1) Compliance with the nuclear protection goals, 2) Compliance with the conventional non-nuclear fire protection goals

Any comment regarding focus of objectives for different types of installations?
How is DFSA integrated with broader safety analysis efforts? Are the fire-specific objectives harmonized with other safety objectives?
Can you comment on the relation between objectives for design analysis and verifying analyses (specifically for fire events)?

General methodologies for deterministic fire safety analysis

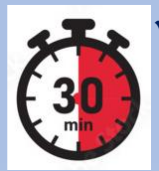
1. Objectives and scope of deterministic fire safety analysis - **Approaches reported in NARs:**

Scope high level

- ✓ All sources of radioactivity
- ✓ Operating states
- ✓ Fire events
  - ✓ Internal fires
  - ✓ External fires
  - ✓ Combination of fire with other events
- ✓ Graded approach

Scope Details in approach

- ✓ Depending on hazard potential
- ✓ Fire risk assessments are prepared for buildings important from the point of view of nuclear safety and to the extent provided for by the Fire Protection Act
- ✓ Natural fires, fire in the SFS and explosion of technical gases are among the postulated initiating events'
- ✓ Explicit requirements for certain combinations.



Any general comment on the scope issue? Does the scope of DFSA sufficiently cover all potential fire risks in various nuclear facilities? Are there areas where the scope might be too broad or too narrow?
Is it important to have specific guidance to support graded approach or better to leave to the individual organizations to argue ?

Fire safety analysis

General methodologies for deterministic fire safety analysis

2. Deterministic fire safety analysis: Types, methodologies, standards, guidelines, and assumptions

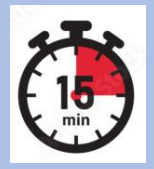
- *Understanding the different approaches to fire safety analysis, from conservative to realistic, during the different operational conditions of the installation, (e.g. in NPPs under power or shutdown conditions), the phenomena that are considered in the analysis, the assumptions made, etc. is crucial for developing effective strategies that balance safety and operational efficiency.*
- *Furthermore, it is relevant to have an overview of general methodologies for the understanding of how the various methods interact and support the overall objectives with deterministic safety analysis.*
- *Depending on the facility type, the type and amount of nuclear material in the facility, the spectrum of initiating events, etc., different methodologies can be applied for the Fire Safety Analyses. The different objectives and scope of those methodologies and their respective application can be shared and discussed.*

General methodologies for deterministic fire safety analysis

2. Deterministic fire safety analysis: Types, methodologies, standards, guidelines, and assumptions

Approaches reported in NARs: Types of analyses

- ✓ Deterministic Fire Safety Analysis (DFSA)/Fire Hazard Analysis (FHA), acronyms used exchangeable
- ✓ Safe Shutdown Fire Analysis (SSFA)
- ✓ Some specifics
  - ✓ Control room fire analysis
  - ✓ In France, Fire Risks Management Case DMRI, part of SAR



What are the benefits and drawbacks of each approach?

Some particularities with DMRI? Any general comment / observation?

General methodologies for deterministic fire safety analysis

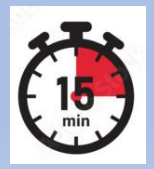
2. Deterministic fire safety analysis: Types, methodologies, standards, guidelines, and assumptions

Approaches reported in NARs: Methodologies

- ✓ DFSA - Fire Containment Approach – conservative
- ✓ DFSA - Fire Influence Approach – less conservative, mainly in case of larger spaces
- ✓ Safe Shutdown Fire Analysis General steps

- ✓ DFSA/FHA general steps:

1. Identification of the equipment important to safety and determination of the location of individual components in fire zones;
2. Fire data collection and modelling
3. Analysis of expected fire development and possible consequences on equipment important to safety;
4. Determination of the required degree of fire resistance of fire barriers;
5. Determination of passive and active fire protection measures;
6. Identification of cases where additional separation or additional protection is required;
7. Assessment of the indirect secondary consequences of the development of fires.



Are / should DFSA methodologies and standards be standardized across all nuclear facilities, or is there a need for facility-specific approaches?
What is really the role of various fire hazard analyses in relation to deterministic safety analysis?

General methodologies for deterministic fire safety analysis

2. Deterministic fire safety analysis: Types, methodologies, standards, guidelines, and assumptions

Approaches reported in NARs: Standards and guidelines

- ✓ WENRA issue E Design Basis and SV internal hazards
- ✓ IAEA SRS No. 8 (FCA, FIA etc) Preparation of Fire Hazard Analyses for Nuclear Power Plants
- ✓ Plus a number of IAEA and other on fire safety in general
- ✓ 10CFR50, Appendix R, Section III.G on safe shutdown analysis
- ✓NUREG-1805 Fire Dynamics Tools (FDTs) – Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Inspection Program
- ✓ EPRI document 3002012980 “Methodology for Seismically Induced Internal Fire and Flood Probabilistic Risk Assessment”.
- ✓ Magic developed by EDF (Pressure effects), MAGIC and Code_Saturne developments and simulations for mechanically ventilated compartment fires
- ✓ Fire Dynamics Simulator Users Guide, Sixth Edition, NIST

Any standard, guideline that you want to recommend over another?
How well do national practices in DFSA align with international standards (e.g., those from the IAEA)? Are there any conflicts or areas for improvement?
Standards and guidelines seem to be have a focus on nuclear power plants? How applicable are the IAEA standards for other types of facilities?

General methodologies for deterministic fire safety analysis

2. Deterministic fire safety analysis: Types, methodologies, standards, guidelines, and assumptions

Approaches reported in NARs: Many assumptions identified, some examples

- ✓ Only one fire can occur at time in the facility, Two or more simultaneous “independent” fires affecting the rooms in the same plant unit or different plant units, is not postulated.
- ✓ Fire is always assumed whatever the nature, quantity, type and configuration of the combustible masses present.
- ✓ all components are assumed to be failed.
- ✓ No credit is taken from automatic / manual fire-extinguishing systems.
- ✓ The most limiting boundary conditions for DFSA according to Guideline ENSI-A01 are applied. These include the following:
  - ✓ Independent single failure
  - ✓ One division under planned maintenance
  - ✓ Total Loss of Offsite Power
  - ✓ Credit for only safety systems within first 10 hours
  - ✓ No credit for operator actions until 30 minutes.

Many assumptions tend to be on the conservative side (?). What about the need for more realism?

Any assumptions that are seen as more important than others?

Differences in assumptions for different objectives and types of facilities?

General methodologies for deterministic fire safety analysis

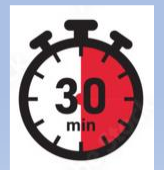
3. State-of the-art understanding of fire-induced phenomena

- *Deterministic fire safety analyses typically postulate failure of equipment. State-of-the-art understanding of fire-induced phenomena has revealed potential failures resulting from different fire phenomena. Some more detailed models and methods allow exploring the degree of deterioration/failure/malfunction of safety components, including*
  - *pressure effects due to fire impairing fire-barriers,*
  - *effects of smoke and soot onto equipment,*
  - *spurious actuation/signals of electric and electronic components,*
  - *high-energy arcing faults (HEAF),*
  - *smouldering fires,*
  - *overpressure impact*
  - *Flooding due to fire extinguishing etc.*
- The handling of phenomena is very much linked to the approaches and related assumptions. Understanding of phenomena is very important for equipment environmental qualification.

General methodologies for deterministic fire safety analysis

3. State-of the-art understanding of fire-induced phenomena - **Approaches reported in NARs**

- ✓ Pressure effects due to fire impairing fire-barriers - only a few NARS mentions this
- ✓ Effects of smoke and soot onto equipment - only a few NARs mentions this
- ✓ Spurious actuation/signals of electric and electronic components - single and MSO common
- ✓ High-energy arcing faults (HEAF) - only a few mentions this
- ✓ Smouldering fires - only a few mentions this
- ✓ Overpressure impact - only a few mentions this
- ✓ Flooding due to fire extinguishing etc. only a few mentions this, but seem to be quite common.



How important is it to consider these phenomena in the analyses for different types of facilities and for the different high level objectives?
Are all relevant fire-related phenomena (e.g., fire spread, smoke generation, heat release) adequately considered in DFSA? Are there phenomena that are often overlooked?