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# Topical Peer Review II Country Review Workshop
# 'Fire Protection'
# 30 September – 3 October 2024

## National Presentation of Germany


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**Candidate installations**
(TS 01.1)

# National Presentation Outline

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|---|---|
| **1. Nuclear Power Plants (NPP):** | *Konvoi-type PWR (meanwhile in decommissioning, (non-defueled)* |
| **2. Research Reactors (RR):** | *FRM II pool type research reactor with 20 $MW_{th}$*<br>*FR MZ, Mark II, with 0.1 $MW_{th}$* |
| **3. Fuel cycle facilities:** | *UAG uranium enrichment facility*<br>*BFL fuel fabrication facility* |
| **4. Dedicated spent fuel storage:** | *BZB Biblis*<br>*ZLN Rubenow* |
| **5. Waste:** | *AZB1 & AZB2 Biblis radioactive waste storage facilities*<br>*ZLN Storage facility North* |
| **6. Decommissioning:** | *WAK and VEK Karlsruhe reprocessing and vitrification plant (in decommissioning)* |

**Candidate installations**
**(TS 01.1)**

# Insurers activities

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- **NPPs**
  - Covered by the **Nuclear Financial Security Ordinance**, no separate fire insurance

- **RR and WAK/VEK Karlsruhe**
  - Public Institutions **self-insured**

- **FCF**
  - The fuel cycle facilities properties are insured. The insurers **audit** the plant site regularly.
  - The inspections (insurance survey) include fire protection topics in the areas of structural, technical and organizational fire protection.
  - A **report** with a risk assessment is subsequently drawn up and **recommendations** are made if necessary.

- **Waste Storage Facilities**
  - **Comprehensive risk assessments** (in particular, checking fire protection concepts, alarm plans, reporting chains, etc., checking existing fire loads)
  - **Regular site inspections** with detailed inspection reports (including specifications and recommendations with dates for implementation)
  - Determination of criteria for testing electrical systems (test intervals, external inspectors or trained in-house staff, in accordance with VdS guidelines, **recommended use of thermal imaging cameras**, etc.)
  - **Reporting obligations** in the event of so-called increased risk (welding work on site, new fire loads, etc.)

# Related Regulations

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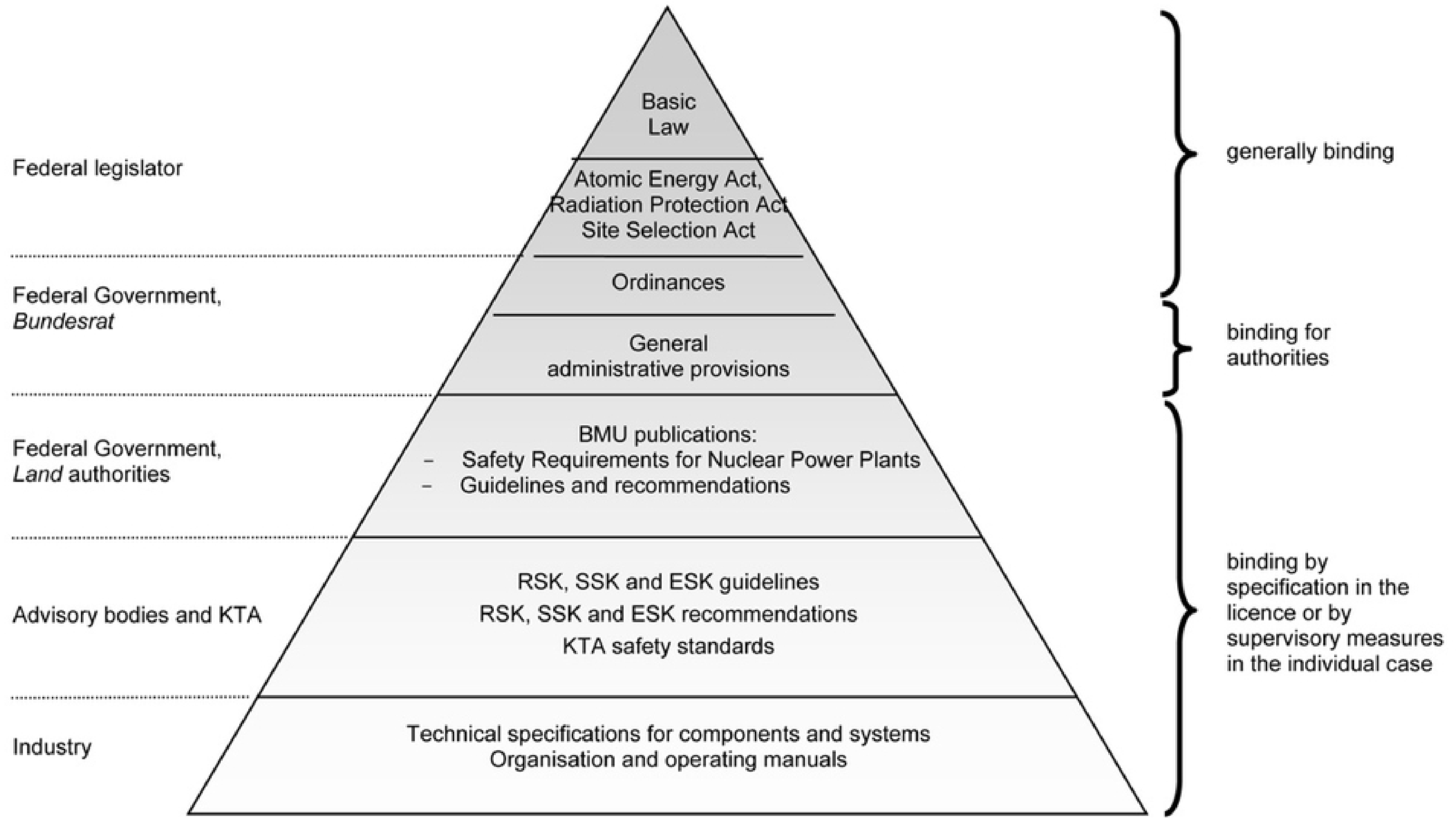
## German regulatory pyramid




## Selected particular regulations

- Atomic Energy Act
- Radiation Protection Act
- Building Code (of the Länder)
- Occupant Safety regulations

- BMUV: Safety Requirements for NPPs
- Recommendations of the Nuclear Waste Management Commission

- BMUV: Guidelines on PSA for NPPs

- KTA 2101, part 1 to 3 on Fire Protection in NPPs
- DIN 4102 and EN13501 on Fire classification of construction products and building elements

# Nuclear Power Plants, Research Reactors



- **Objectives**
  - **Compliance with the nuclear protection goals ensuring that the fundamental safety functions are achieved**
    - Control of reactivity
    - Cooling of the fuel elements
    - Confinement of radioactive substances
    - Limitation of radiation exposure
  - **Compliance with the conventional non-nuclear fire protection goals**
- **Scope**
  - **Fire hazard analysis (FHA)**
    - Deterministic safety demonstration for design and operation
    - For all plant operating states; as far as applicable for plants in decommissioning
    - Regularly performed and in case of design modifications and changes in operation
    - For RR applying a graded approach depending on the risk

# Nuclear Power Plants, Research Reactors

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- **Scope (contd.)**
  - **Fire PSA**
    - **For demonstrating the balance of the safety concept**
    - Assessment of possible plant transients that may occur due to fire events
    - For all plant operational states, Level 1 (mandatory), Level 2 (voluntarily)
    - In the frame of PSR every 10 years
    - Additionally, in case of findings/needs identified
      (e.g. to demonstrate the benefits of a plant modification)
    - For RRs only for those with a higher risk potential, applying a graded approach

# Nuclear Power Plants, Research Reactors



- **Assumptions FHA**
  - One fire at a time
  - Combinations of fires and other hazards are considered in line with nuclear fire protection standard KTA 2101.1
  - Fire compartment approach as conservative basis
  - No single criterion applied for fire protection systems and equipment; the entire fire protection means must ensure that the protection goals are met
  - A dedicated on-site fire brigade 24/7 is present at NPPs in operation
  - For fuel-free NPPs in decommissioning, core and fuel damage states do not need to be assumed
- **Consideration of fire induced phenomena**
  - Not only thermal effects but also mechanical stability are considered in the design including pressure build-up
  - Potential harmful effects from fire by-products (e.g. smoke, soot, fire extinguishing agents, etc.) and their spreading are considered in the analyses
  - Access and escape route availability and qualification is particularly taken into account

# Nuclear Power Plants, Research Reactors



- **Assumptions Fire PSA**
  - Combinations of fires and other hazards are considered in line with IAEA SSG-3, SSG-64 and SSG-77
  - All components inside a fire compartment are conservatively assumed to fail
  - For fuel free NPPs in decommissioning, core and fuel damage states do not need to be assumed ➔ no PSA needed
- **Process and results of Fire PSA**
  - Analysis of fire-induced failures of systems and components regarding their effect on the frequency of plant damage states, based on simplifying assumptions
  - Primary focus of Fire PSA is on fire events that lead to event sequences resulting in reactor scram
  - Fire scenarios are identified by a room-specific screening
  - Within decommissioning/dismantling licensing process for a NPP, additional analyses of dismantling-specific fires

Fire safety analysis
(FSA)
(TS 02.1 and 02.2)

# Nuclear Power Plants, Research Reactors

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- **Improvements resulting from fire safety analyses**
  - Further reduction of fire loads
  - Modification of the oil supply to the reactor coolant pump
  - Use of self-medium-operated (steam/water) instead of hydraulically controlled (oil) valves
  - Improvements in cable protection and redundancy separation in several plant areas
  - Additional fire extinguishing systems as compensatory measures in areas where full fire compartmentation not possible
  - No dominant contribution of fire events to CDF/FDF; Fire PSA results confirm high safety level
  - Occasional plant-specific probabilistic fire risk analysis demonstrated a safety increase by a modification of the fire extinguishing valve basic state change from "open" to "closed" regarding flooding from a break of this pipe

# Nuclear Power Plants

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- **Extent of coverage of fire detectors**
  - In rooms important to safety (nuclear and conventional safety goals) and according to German standards (KTA and conventional)
  - Exceptions according to German conventional standards (as an example, fire detectors are often not installed in sanitary facilities and changing rooms)
- **Detector types**
  - Only addressable detectors in use
  - Mostly multi-criteria detectors
  - Other detector types in use depending on purpose
- **Backup energy**
  - Own battery backup according to nuclear and conventional standards
  - Up to 72 h backup time
- **Safety class**
  - German nuclear regulations do not require safety-classes but fulfillment of conventional and nuclear requirements

# Nuclear Power Plants

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- **Criteria for installation of automatic fire suppression systems**
  - If early and reliable fire suppression is important to meet nuclear or conventional safety goals
  - Protection of firefighters in operation is also part of the conventional safety goals; therefore, accessibility is also a criterion for implementation of fixed fire extinguishing systems
- **Criteria for design and selection of extinguishing media**
  - Extinguishing water requirement (100%) results from the stationary extinguishing system with largest design water volume inside or outside building (sprinkler, spraywater, foam extinguishing system) plus a water flow of 1600 l/min, e.g. for field and wall hydrants; total amount of water available at least 3200 l/min (cf. KTA 2101.3, Sect. 6.2)
  - For selection of extinguishing agents inside rooms possible adverse effects have been considered concerning e.g. vulnerability of electrical equipment => use of $CO_2$ or other gases
- **On-site fire brigade**
  - Dedicated, fully qualified on-site fire brigade, at least as long as NPP is not defueled

# Nuclear Power Plants

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- **Methods for determining suitable fire barriers**
  - Compartmentation considers nuclear safety goals for NPPs and conventional safety goals (e.g. safe access and escape, allowing firefighting, etc.).
  - Large local fire loads should be protected according to nuclear fire protection standard KTA 2101
- **Fire resistance of barriers**
  - The standard fire resistance for compartment barriers is 90 min (walls, ceilings, doors, dampers, penetration seals etc.)
  - The necessary fire resistance of fire barriers can be calculated by a conservative procedure according to the informative Annex A of KTA 2101.2
- **Compensatory measures**
  - Few locations with fire influence approach
  - Compensatory measures are protection of electrical cables, automatic suppression systems, etc.

# Nuclear Power Plants

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- **Design of ventilation systems**
  - Ventilation systems are divided among different redundant trains. Typically, each train has its own ventilation system. The separation of different compartments and sub-compartments is ensured by fire dampers.
- **Staircases**
  - Doors of staircases as part of access and escape routes are qualified **"smoke-tight“**; if there are no openings to extract smoke out of the building, KTA 2101.2 (Sec. 8.4) requires overpressure systems to prevent smoke ingress. This is ensured by existing ventilation systems or by dedicated overpressure systems
- **Maintenance of fire dampers**
  - According to conventional requirements fire dampers are inspected and tested every **6 months**; if 2 consecutive damper tests show no findings, the test interval can be extended to 1 year. Practically, fire dampers could also be tested more than once a year, e.g. if remote actuation is part of another test than local actuation
  - Inaccessible dampers were made accessible e.g. by adding large inspection openings in connecting ventilation ducts; **inaccessible dampers do not exist.**
  - Various reportable events related to fire dampers occurred resulting in several **Information Notices** prepared by GRS (cf. Annex A2 of the NAR) and consequential improvements in test procedures, particularly regarding the thermal actuation

# Research Reactors

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- **Extent of coverage of fire detectors**
  - in rooms important to safety (nuclear and conventional safety goals) and according to German standards (KTA and conventional)
  - “practically each room” equipped with automatic fire detectors (both RRs)
- **Detector types**
  - only addressable detectors (FRM II) / up to 10 detectors per line (FR MZ)
  - mostly multi-criteria (FRM II) / mostly optical (FR MZ) detectors
  - other detector types in use depending on purpose (both RRs), e.g. smoke-aspirating-detectors for high radiation areas (FR MZ)
- **Backup energy**
  - own battery backup according to nuclear and conventional standards (both RRs)
  - at least 30 h backup time (FRM II)
- **Safety Class**
  - German Nuclear regulations do not require safety-classes, but fulfillment of conventional and nuclear requirements

# Research Reactors

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- **FR MZ (TRIGA Mark-II)**
  - Fire fighting is by **portable equipment** only
  - According to the outcome of FHA and regular inspections, the need for a fixed fire extinguishing system is not given due to the low risk potential of the reactor
- **FRM II**
  - **Automatic sprinkler systems** are available for certain areas with high fire risk (e.g. storage of radioactive combustible waste). Everywhere else sprinkler systems are to be started **manually by the firefighters**.
  - The systems with safety relevance are designed to withstand earthquakes
  - The main hazard associated with water could be criticality in the dry storage of fuel; this is excluded by a large margin as required by the KTA
  - No automatic sprinkler system is installed in **experimental areas** to protect scientific instruments, but it needs to be triggered manually by the fire brigade
  - Water pumps haveas well as the fire detection and automatic suppression system actuation have an **emergency power supply**

# Research Reactors

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- **Methods for determining suitable fire barriers**
  - The compartmentation considers the **nuclear** safety goals and the **conventional safety goals** (e.g. safe access and escape, allowing firefighting, etc.)
  - In FR MZ redundant trains for core-cooling do not need to be separated because of the failsafe behavior of the RR
- **Fire resistance of barriers**
  - The standard fire resistance for compartment barriers is 90 min (walls, ceilings, doors, dampers, penetration seals etc.)
  - In FR MZ fire doors are used with 30 min fire resistance as according to conventional requirements
  - The necessary fire resistance of fire barriers can be **calculated by a conservative procedure** according to the informative Annex A of KTA 2101.2

# Research Reactors

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- **Design of ventilation systems**
  - In case of fire, smoke extraction out of the controlled areas is basically possible in order to allow for occupant safety and fire fighting and if a controlled extraction path is used
  - FRM II: ventilation systems are divided among different redundant trains; typically, each train has its own ventilation system; separation of different compartments and sub-compartments is ensured by fire dampers
- **Staircases**
  - Doors of staircases as part of access and escape routes are qualified "smoke-tight“; if there are no openings to extract smoke outside the building, KTA 2101.2 (Sec. 8.4) requires overpressure systems to prevent smoke ingress. This is ensured by existing ventilation systems or by dedicated overpressure systems
- **Maintenance of fire dampers**
  - According to conventional requirements fire dampers are inspected and tested **every 6 months**; if 2 consecutive damper tests show no findings, the test interval can be extended to 1 year. Practically, fire damper could also be tested more than once a year, e.g. if remote actuation is part of another test than local actuation
  - Inaccessible dampers were made accessible e.g. by adding large inspection openings in connecting ventilation ducts; **inaccessible dampers do not exist**.
  - Various reportable events related to fire dampers occurred resulting in several Information Notices prepared by GRS (cf. Annex A2 of the NAR) and consequential improvements in test procedures, particularly regarding the thermal actuation

# Nuclear Power Plants, Research Reactors

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- **Improvements (including updates of regulations)**
  - Systematic consideration of combinations of hazards in deterministic FHA according to KTA 2101.1 (2015) and Fire PSA in line with IAEA SSG-3 and SSG-64
  - Various plant-specific improvements resulting from regular fire safety analyses and occasionally (see slide with details)
  - Updates of nuclear regulations regarding FHA (e.g. in KTA 2101.1-3, 2015) and Fire PSA (Technical Supplement to PSA Guide on PSA Methods and Data, 2016) based on experience feedback
- **Strengths**
  - Sharing and use of OPEX (in FHA and Fire PSA) not only plant internally, but externally within industry, with regulators, and via national and international reporting systems and databases
    - Fire events and
    - Events with deterioration/failure of fire protection means
  - Possible weaknesses identified by the analyses are directly removed as stated also by the regulator
- **Weaknesses: None identified**

# Decommissioning NPPs, RR

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- **Fire safety concept still fully implemented**
  - Dedicated on-site fire brigade still employed (if applicable)
  - Significant fire loads (e.g. oils from turbine building and main coolant pumps) were taken out
  - Suppression systems for withdrawn fire loads to be shut down
- **Nuclear safety goals**
  - NPPs defueled for decommissioning
  - Safety assessments for potential fires which could mobilize the residual radioactivity
- **Conventional safety goals fully considered**

# Fuel Fabrication and Enrichment Facilities



- **Objectives and scope of fire safety analyses**
  - **Compliance with the nuclear protection goals**
    - Confinement, retention and shielding of radioactive materials
    - Minimisation and control of the discharge of radioactive substances
    - Minimisation and control of exposure and contamination of operating personnel
    - Ensuring subcriticality
    - Prevention of fire and explosion or their early detection and effective control
    - Preventing a release of uranium hexafluoride
    - Design appropriate to operation and maintenance in order to avoid contamination and keeping radiation exposure of operating personnel low
    - Compliance with radiation protection with a view to decommissioning and disposal of the facility
  - **Compliance with the conventional non-nuclear fire protection goals**
    - Prevention of fire development
    - Prevention of fire and smoke spread
    - Allowing for rescue of humans (and animals)
    - Allowing for effective extinguishing operations

# Fuel Fabrication and Enrichment Facilities

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- **Fire Safety Analysis Assumptions**
  - Design: any fire is detected and extinguished at an early stage limiting it to incipient stage
  - Extinguishing fires in the initial phase is ensured by e.g. redundant fire detection and alarm systems and a dedicated 24/7 on-site fire brigade.
  - One fire assumed at a time
  - Combinations of fires and other hazards are considered widely following IAEA SSG-64 and SSG-77
- **Scenarios**
  - Event "fire in a fire sub-compartment" is considered for BFL since such fires cannot be excluded
  - For BFL, event "fire in a fire sub-compartment" is not a design basis accident since the radiological accident effects are covered by other design basis accidents with dose level far below the accident planning level
  - UAG: two penalising scenarios
    - Fire of mineral oil of the closed valve heads of pumps in the container hall
    - Truck fire in the transfer station or in the truck passage in the product storage

# Fuel Fabrication and Enrichment Facilities

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- **Extent of coverage of fire detectors**
  - Full coverage of the technical facilities to fulfill nuclear and conventional safety goals according to German standards (KTA and conventional)
  - BFL: redundant fire detection system installed

- **Backup energy**
  - own battery backup according to nuclear and conventional standards

- **Safety Class**
  - German nuclear regulations do not require safety-classes but fulfillment of conventional and nuclear requirements

# Fuel Fabrication and Enrichment Facilities

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- **BFL**
  - Fire fighting by portable fire extinguishers according to conventional regulations
  - Fire water pipe-line with above-ground hydrants that are connected to the public water supply by two feed-ins
  - Furthermore, there is a fire water well with a suction pump connected to the backup power supply

- **UAG**
  - Fire fighting is by portable fire extinguishers according to conventional regulations
  - The fire truck of the dedicated on-site fire brigade provides 2,000 l of water for the initial attack
  - Additional water supply close to the building via the extinguishing water ring with distributed water hydrants
  - Furthermore, water supply is provided via a fire pond located on site

# Fuel Fabrication and Enrichment Facilities

- **Methods for determining suitable fire barriers**
  - Basically the compartmentation is based on the requirements from the conventional building code
  - By this requirement the compartmentation fulfills the nuclear safety goals and the conventional safety goals (e.g. safe access and escape, allowing firefighting, etc.)
- **Fire resistance of barriers**
  - The standard fire resistance for compartment barriers is 90 min (walls, ceilings, doors, dampers, penetration seals etc.)
  - Structural building elements are assessed according to both DIN 4102 and the European classification DIN EN 13501

# Fuel Fabrication and Enrichment Facilities

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- **BFL**
  - Two ventilation systems for dry conversation plant and other nuclear prod. areas
  - In order to comply with the radiological safety objectives of the, no fire dampers are installed in the exhaust air system at fire compartment penetrations to achieve a sub-atmospheric pressure in case of fire
    - to compensate for this, a redundant fire detection and alarm system is installed in these areas
    - only persons trained in handling fire extinguishers are allowed to work there
    - a dedicated on-site fire brigade is permanently present so that a fire can be extinguished early
    - ventilation system is switched to fire mode, i.e. the supply air is switched off and the exhaust air system runs in reduced mode
- **UAG**
  - The ventilation systems are or will be equipped with fire dampers that are controlled by smoke detectors and fusible links
  - In case of fire
    - ventilation closure of the fire compartment or fire sub-compartment
    - if applicable: mechanical heat and smoke removal
    - if applicable: natural heat and smoke removal (e.g. stairwells, access and escape routes), alternatively: maintaining overpressure of stairwells

# Fuel Fabrication and Enrichment Facilities

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- **Improvements (including updates of regulations)**
  - Improvements resulting from OPEX feedback including Information Notices sharing information and lessons learned from other types of installations
  - Various plant-specific improvements resulted from regular fire brigade exercises and drills and findings from regular fire specific plant walk-downs
  - Root cause analyses revealed potential for improving fire safety
- **Strengths**
  - Regular reviews of fire protection in the frame of PSR every 10 years focussing on fire protection goals
  - Regular fire protection on-site inspections together with nuclear and non-nuclear authorities in charge of fire protection resulting in conclusions with subsequent plant inspections
  - Sharing and use of OPEX, not only plant-internally but also externally within industry, with regulators
    - Fire events and
    - Events with deterioration/failure of fire protection means
- **Weaknesses: None identified**

# Spent Fuel Storage and Waste Facilities



- **Objectives and scope of fire safety analyses**
  - **Compliance with the nuclear protection goals**
    - Preventing fires in the properties and installations
    - Preventing an inadmissible spread of fire
    - Protecting people from the fire hazard
    - Preventing the release of radioactivity in the event or as a result of fire
  - **Determining and assessing fire hazards at regular intervals and in the event of modifications by:**
    - Workplace-specific risk assessments in accordance with the legal and internal regulations
    - Activity-specific risk analyses based on the work permit
    - **only SFF**: Combinations of a fire with another event
      - Combinations which are causally related and occur simultaneously must be analysed
      - Combinations need to be considered exclusively with regard to compliance with the fundamental safety functions

**Fire safety analysis**
(FSA)
(TS 02.4)

# Spent Fuel Storage and Waste Facilities

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- **Fire Safety Analysis Assumptions**
  - Ensuring fire safety is directly related to ensuring nuclear safety and radiation protection => requiring compliance with fire safety standards
- **Scenarios**
  - Design basis accident: fire of a loaded transport vehicle with the entire vehicle fire loads (fuel, cables, paints and hydraulic oil); modelled by temperature impact on the **spent fuel as well as waste containers of 800 °C for 60 min**)
  - Crash of a military aircraft (**only SFF**)
  - Fire in the neighbouring facilities
  - ZLN: **most serious** safety impacts in handling of unsealed radioactive substances **in an area for conditioning** with a high-pressure press with combustible waste treated in addition to non-combustible waste => suppression by the on-site fire brigade supported by off-site forces if necessary
  - ➢ Entirety of preventive, active and passive fire protection means ensures that fires are widely prevented or detected and extinguished already in the incipient stage

# Spent Fuel Storage and Waste Facilities

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- **Extent of coverage of fire detectors**
  - In rooms important to safety (nuclear and conventional safety goals) and according to German standards (KTA and conventional)
  - Exceptions according to German conventional standards
    - as an example, fire detectors are often not in place in sanitary facilities and changing rooms
- **Detector types**
  - Only addressable detectors in use
  - Mostly multi-criteria detectors
  - Other detector types like smoke aspiration detectors depending on purpose
- **Backup energy**
  - Own battery backup according to nuclear and conventional standards
- **Safety class**
  - German nuclear regulations do not require safety-classes but fulfill conventional and nuclear requirements

# Spent Fuel Storage and Waste Facilities

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- **Design of fire suppression features**
  - Installation of portable fire extinguishers
  - Facilities have diesel operated emergency power system for fire safety features
  - Facilities have a robust fire water ring system
  - Facilities employ a dedicated on-site fire brigade (shared with other nuclear facilities on the sites)

- **Remark on spent fuel casks and waste containers**
  - Protected against severe fires (800 °C for 60 min as design fire)
  - Watertight

# Spent Fuel Storage and Waste Facilities

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- **Improvements (including updates of regulations)**
  - Improvements resulting from OPEX feedback including Information Notices sharing information and lessons learned from other types of installations
  - Updates of the fire safety incl. submittal to nuclear supervisory authority for review and approval on case of plant modifications
  - Changes in preventive or defensive fire protection directly result in fire protection concept updates
  - Regular drills and practical exercises using fire protection equipment often result in improvements incorporated into the operational processes
- **Strengths**
  - Regular reviews of fire protection in the frame of PSR every 10 years focussing on fire protection goals (for AZB1/2 the first ones are scheduled for 2025/2028)
  - Regular fire protection on-site inspections together with nuclear and non-nuclear authorities in charge of fire protection
  - Sharing and use of OPEX, not only plant internally but also externally within industry, with regulators
    - Fire events and
    - Events with deterioration/failure of fire protection means
- **Weaknesses: None identified**

# Installation under Decommissioning (not NPPs)

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- **Objectives and scope of fire safety analyses**
  - **Compliance with the non-nuclear fire protection goals**
  - **Compliance with the remaining nuclear protection goals**
    - Protecting the plant personnel and the environment from radiological consequences to be considered in the event of an assumed fire
  - **Types of analyses**
    - Depending on status of the installations (WAK and VEK) considering
      - Fire compartmentation
      - Early fire detection
      - Low quantity of combustibles present
    - ➢ Small fires at dismantling locations are taken into account in the safety assessment; fire spreading across buildings can be excluded due to the distance to other buildings

# Installations under Decommissioning (not NPPs)



- **Fire Safety Analysis Assumptions**
  - WAK: advanced dismantling stage => only minor fire loads in process building
  - VEK: in principle, only use of small quantities combustibles and protection of unavoidable larger quantities by appropriate measures
  - Incipient / small fires are directly extinguished manually
  - Fire spreading to neighbouring buildings or surrounding area is prevented by structural fire protection or sufficient distance
- **Most penalising scenario**
  - Use of electrically operated cutting tools required during dismantling resulting in a fire (60 min at 800 °C)
  - Fire spreading to other buildings is excluded
  - Only releases into the facility are taken into consideration; worst case activity discharge via the exhaust air stack < 5 E+02 Bq - below accident planning levels

# Installations under Decommissioning (not NPPs)

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- **Improvements (including updates of regulations)**
  - Depending on the status of the installation, fire safety updates
  - In case of modifications, effects on fire protection features present must be assessed together with application submittal to the nuclear authority
- **Strengths**
  - Reporting of all plant-internal fires is mandatory
  - Evaluation of experiences from regular exercises and drills result in further improvement of defensive fire protection
  - Extinguishing water retention to protect the environment even for the most penalising fire scenario
- **Weaknesses: None identified**