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AGING MANAGEMENT FOR RESIDUAL MATERIAL TREATMENT CENTERS, INTERIM STORAGE FACILITIES AND RADIOACTIVE WASTE CONTAINERS

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ABSTRACT

Since decommissioning of nuclear power plants (NPP) takes about 15 to 20 years or even longer and a final storage in Germany may start operation in the 2050s, aging may also become a relevant problem for safety-relevant technical facilities in residual material treatment centers (RMTC) and interim storage facilities (ISF).

In this paper, the development of harmonized aging management (AM) requirements and guidelines in Germany for RMTC, ISF and radioactive waste containers is outlined. The practical implementation of general AM requirements and guidelines and the current status is also shown in this paper based on several examples. Based on the experience and lessons learned during the past years of AM implementation, an outlook on potential advancements of the past and current practice is given in this paper.

Radioactive waste containers are stored in German ISF since the early 1970s and many older containers are already bloated due to internal chemical reactions or show corrosion and coating damage. Some examples of the dominant damage mechanisms and the remedial actions to control them are shown in this paper.

INTRODUCTION

AM concepts and procedures are well-established and practiced for German NPP since the early 2000s, especially after the first release of the harmonized AM standard KTA 1403 in 2010 (current: KTA (2022)). In the past 20 years, the developed AM concepts and procedures proved to be practical and suitable for NPP in operation and decommissioning regarding monitoring and detecting of systematic failures, fatigue of safety-relevant technical facilities and providing a comprehensive database on operating experience.

Since more and more NPP in Germany started to be decommissioned in the past years, more RMTC and ISF had to be built to process and store decommissioning waste. RMTC and ISF are important parts of the radioactive waste flow where radioactive waste is processed or stored, see Figure 1. Therefore, safety-relevant technical facilities have to ensure safe confinement of radioactive materials, protection of the environment and personnel from contamination and for high-active waste also subcriticality.

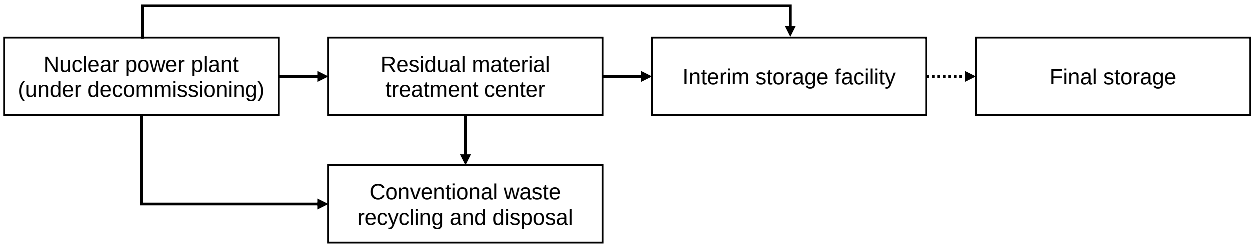

Figure 1. Schematic decommissioning waste flow diagram

AM for RMTC, ISF, and radioactive waste containers plays a crucial role in ensuring the long-term safety and efficiency of nuclear waste disposal. Radioactive waste, originating from various sources such as NPP, medical institutions, and industrial processes, must be stored and processed safely over extended periods. During this time, material processing infrastructure, storage facilities and waste containers are subjected to various aging processes. These processes can cause material fatigue, corrosion, and structural changes that may increase the risk of leaks, contamination, or other safety-related incidents.

Effective AM involves monitoring, assessing, and performing timely maintenance of the processing and storage infrastructure as well as the waste containers. Preventive measures have to be taken to maintain the functionality of the facilities and the integrity of the waste containers over the required decades of operation and storage, and in some cases, even centuries. Sustainable AM not only ensures environmental protection and human health but also helps meet regulatory requirements and minimize risks in handling highly radioactive materials.

DEVELOPMENT OF AGING MANAGEMENT STANDARDS IN GERMANY

In the early 2000s, there was no specific AM standard for RMTC, ISF and waste containers in Germany. At that time, there were recommendations of the Reactor Safety Commission (RSK) and a standard of the Nuclear Safety Standards Commission (KTA) on monitoring programs for dry interim storage of spent fuel assemblies as well as medium and low active waste, see RSK (2001), RSK (2002) and KTA (2020).

The focus for a harmonized AM standard in Germany was initially on NPP. Activities of the IAEA in the late 1990s on international standardization of AM (e. g. IAEA (1999)) lead to activities of the RSK which aimed to the definition of requirements for a harmonized standard of AM for German NPP, see also RSK (2004). On proposal by the Ministry of the Environment Baden-Württemberg, the KTA started in 2005 to develop a standard for AM which was binding for German NPP. In 2010, the first issue of the KTA 1403 standard (current: KTA (2022)) was released.

After the first release of the KTA 1403 standard, the Nuclear Waste Management Commission (ESK) started to include specific AM requirements for RMTC, ISF and waste containers in their recommendations, see ESK (2020), ESK (2021), ESK (2022) and ESK (2023). Additional AM requirements for the transport of radioactive materials were recently published by the Bundesanstalt für Materialforschung und -prüfung (BAM), see BAM (2022).

AGING MANAGEMENT FOR RESIDUAL MATERIAL TREATMENT CENTERS

Aging Management Requirements For RMTC And ISF

According to ESK (2020), "… conditioning of radioactive waste includes the treatment of radioactive waste, if necessary pre-treated, to produce qualified waste forms and their packaging in containers with the objective of storage and disposal. This radioactive waste originates both from the operation and dismantling of nuclear installations or facilities and from other uses of radioactive substances, e. g. in industry, medicine, research and at the Federal Armed Forces. It is treated either in autonomous conditioning facilities or in mobile or stationary conditioning facilities that are part of a licensed nuclear installation or facility."

According to ESK (2021) and ESK (2023), interim storage covers radioactive waste with negligible heat generation as well as spent fuel and vitrified radioactive waste canisters from reprocessing: "The radioactive waste considered originates from the operation and dismantling of nuclear installations […] or facilities […] as well as from other uses of radioactive material, such as in industry, medicine, research, and at the Federal Armed Forces. It is either stored in central storage facilities, in decentralised storage facilities at the sites of nuclear installations or facilities, in these nuclear installations or facilities themselves, or in public or private collection facilities."

According to ESK (2020) and ESK (2023), conditioning facilities (e. g. RMTC) and ISF have to fulfill the following fundamental safety functions:

- Confinement of radioactive material,
- Avoidance of unnecessary exposure, limitation and control of occupational and public exposures,
- Maintaining subcriticality (where applicable for special waste).

And also, the following derived requirements:

- Shielding of ionizing radiation,
- Design and implementation of installations in compliance with the requirements for operation and maintenance,
- Safety-oriented organization and performance of operation,
- Safe handling, safe transport and safe storage of the radioactive material,
- Design against accidents, and
- As far as required due to the release potential, measures to mitigate the consequences of beyond design basis events.

Regarding AM, the following requirements are defined in ESK (2020), ESK (2021), ESK (2022) and ESK (2023) for conditioning facilities (e. g. RMTC) and ISF:

- Implementation of an integrated management system that includes AM for preventing potential negative impacts on safety,
- Including of the AM program in the safety documentation of the conditioning facility,
- Implementation of a monitoring concept for the management of aging effects during the operational lifetime,
- Regular evaluation of walkdowns, inspections and checks of buildings, technical installations and, if applicable, of the waste stored,
- Regular assessment of internal and external experience feedback.

Practical Implementation Of Aging Management Requirements For RMTC And ISF

During the approval phase for the erection of a RMTC and ISF, a component inspection list is created where all mechanical, structural, electrical and instrumentation and control (I&C) as well as radiation protection components of the facility are listed. In the component inspection list, the safety-relevance of the individual component is defined according to their relevance for fulfilling fundamental safety functions and requirements. The safety-relevant components define the scope of aging-related observation.

The following components are typically considered as safety-relevant for RMTC:

- Mechanical:
    - Exhaust air systems (with filters)
    - Process water piping and tanks
    - Vacuum evaporator system
    - Measurement and control technology
    - Container drying system
    - Bridge crane (with rails)
    - Handling and transport equipment
    - Housings and cabins for processing stations
    - Smoke extraction system
    - Fire water supply
    - Fire flaps
- Structural:
    - Building shell, baseplate and steelwork
    - Internal and external gates and doors
    - Structural anchoring
    - Structural lightning protection
    - Fire doors
    - Wall duct fire sealings
- Electrical and I&C:
    - Uninterruptible power supply
    - Emergency lighting
    - Central alarm system
    - Fire alarm system
- Radiation protection:
    - Dosimeter stations
    - Monitors for whole body contamination, local dose rate, aerosol, exhaust air, wastewater
    - Test sites for filters, wipe tests, components, containers, clearance measurement

The following components are typically considered as safety-relevant for ISF:

- Mechanical:
    - Exhaust air system (with filters)
    - Bridge crane (with rails)
    - Handling and transport equipment
    - Fire flaps
- Structural:
    - Building shell, baseplate and steelwork
    - Internal and external gates and doors
    - Structural anchoring
    - Structural lightning protection
    - Fire doors
- Electrical and I&C:
    - Uninterruptible power supply
    - Emergency lighting
- Radiation protection:
    - Monitors for contamination and local dose rate

   - Test sites for wipe tests
- Waste containers

For the above-mentioned safety-relevant components, an AM system is implemented following the requirements of the ESK recommendations and the KTA 1403 standard. In a so-called “Basis Report”, the following aspects shall be addressed according to KTA (2022):

a) description of the technical and administrative procedures,
b) structure of the knowledge base,
c) pursuing and evaluating aging-related findings:
   ca) state of science and technology,
   cb) experience feedback,
d) aging-management of the technical facilities including auxiliary and operating media:
   da) scope of aging-related observation and classification,
   db) potentially relevant damage mechanisms,
   dc) mitigating measures regarding these damage mechanisms,
   dd) monitoring the effectiveness,
e) aging-management with regard to non-technical aspects:
   ea) personnel,
   eb) documentation,
   ec) information systems and operation management systems.

AGING MANAGEMENT FOR RADIOACTIVE WASTE CONTAINERS

Aging Management Requirements For Radioactive Waste Containers

Radioactive material from operation and decommissioning of NPP in Germany is conditioned and currently stored in on-site ISF within containers with the aim for final storage or the material receives immediate clearance if it is free of activation or contamination.

The storage period of the waste containers in ISF may vary depending on the conditioning state and the beginning of the final storage period from several months to many years or even decades. During the storage period in ISF, the waste containers may undergo detrimental effects both from inside and outside of the containers.

For waste containers, the AM is implemented as a monitoring concept for all storage sites in Germany. Requirements for the monitoring concept are defined in KTA (2020), ESK (2021), ESK (2022) and ESK (2023):

- Visual inspection program for waste container surfaces
- Definition of appropriate inspection intervals, charges and lots depending on the sample size, similar container materials and structural characteristics
- Documentation and assessment of the inspection results and findings
- Consideration of experience feedback and systematic exchange of information

Practical Implementation Of Aging Management Requirements For Radioactive Waste Containers

For the waste containers, a monitoring concept is implemented following the requirements of the ESK recommendations and the KTA 3604 standard. In a site-specific technical report or service instruction, the following aspects are addressed as follows:

- Preassessment of existing waste containers regarding unfavorable or favorable corrosion behavior

- Definition of inspection charges and lots depending on material and structural characteristics
- An inspection lot (i. e. packages to be actually inspected) shall be chosen from each inspection charge.
- The sample size is linked to the current total number of stored containers and is therefore subject to change. The actual sample size is communicated to the authority to the end of every year.
- The chosen inspection charges and lots are assessed by the authority and the technical expert every year.
- Definition of appropriate inspection procedure:
    - Inspection according to four-eyes principle
    - Written documentation of the inspections:
    - Additional documentation in case of findings (finding categorization, location, photos, integrity assessment, possible repair measures and deadlines)
    - Preparation of an annual review for the authority:

Aging-Related Damage Mechanisms Of Radioactive Waste Containers

Since radioactive waste containers are stored in German ISF since the early 1970s, various aging-related damage mechanisms were already found during inspections:

- Corrosion of container surfaces, cover screws and sealings due to mechanical damage of coating, improper coating, unfavorable ambient conditions, internal chemical reactions (or combination)
- Bloating due to internal chemical reactions with gas formation
- Mechanical wear of coatings due to recurrent handling tasks
- Chemical/Radiation-induced aging of elastomeric cover sealings
- Fatigue failure of welds due to recurrent handling tasks

Remedial Actions For Aging-Related Damages Of Radioactive Waste Containers

The following remedial actions are carried out in case of aging-related damages according to KTA (2020):

- Category A (no action required upon detection of the findings):
    - Documentation of the inspection
    - Returning test object to the inspection batch
- Category B (no immediate action required upon detection of the findings):
    - Documentation of the inspection
    - Monitoring the development of the findings, or specifying repair measures including a date for their implementation
    - Possibly, placing the package into a larger drum
    - Determining the cause
    - Checking the stacking capability
    - Transferability check regarding other packages of the same inspection lot, and, if necessary, expanding the extent of tests and inspections
    - Transferability check regarding improvement of handling process
- Category C (immediate action required after detection of the findings):
    - Documentation of the inspection
    - Establishing the cause of the findings, checking for the possibility of a systematic fault

- Transferability check regarding other packages of the same inspection charge, and expanding the extent of inspections
- Transferring the content of the package to another container, reconditioning the content, possibly, placing the package into a larger drum

CONCLUSION

Since more and more NPP in Germany started to be decommissioned in the past years, conditioning and storage infrastructure had to be built up as well. As RMTC and ISF are important parts of the radioactive waste flow, their safety-relevant technical facilities have to ensure safe confinement of radioactive materials, protection of the environment and personnel from contamination and for high-active waste like spent fuel also subcriticality.

Despite AM concepts and their implementation was at first focused on NPP in the past, AM has started to be established for RMTC, ISF and radioactive waste containers at present because their expected operational or storage period may reach several decades. Therefore, aging-relevant damage mechanisms which can be detrimental to ensuring essential safety functions have to be constantly monitored.

AM concepts and procedures are well-established and practiced for German NPP since the early 2000s and proved to be practical and suitable for NPP in operation and decommissioning. Therefore, these concepts and procedures were also applied for conditioning and storage facilities as well.

Radioactive waste containers are stored in German ISF since the early 1970s and monitoring programs are already established since the 1980s. A significant percentage of older waste containers already shows aging-related damage and has outdated documentation which does not comply with current documentation and traceability requirements. Therefore, extensive inspection, repackaging and documentation renewal is currently carried out and will continue in the next years or even decades until a final storage is opened.

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