Note:
This is a translation of the ESK recommendation entitled
“Leitlinien für die Konditionierung von radioaktiven Abfällen mit vernachlässigbarer Wärmeentwicklung”.
In case of discrepancies between the English translation and the German original, the original shall prevail.

E S K

RECOMMENDATION of the Nuclear Waste Management Commission (ESK)

Guidelines for the conditioning of radioactive waste with negligible heat generation

CONTENTS

1 General

1.1 Scope of the guidelines

The guidelines apply to the conditioning of radioactive waste with negligible heat generation. For the purpose of these guidelines, this is defined as all radioactive waste with the exception of spent fuel and vitrified radioactive waste from reprocessing in canisters. The 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.

The objective of these guidelines is to summarise both the requirements for the conditioning facilities (design and operation) and the requirements for the waste forms or waste packages to be produced. The requirements for the waste forms and waste packages to be produced result from the boundary conditions for storage, disposal and transport.

For already existing conditioning facilities, these guidelines shall be applied by analogy.

1.2 Fundamental safety functions

When conditioning radioactive waste with negligible heat generation,

1 any unnecessary radiation exposure or contamination of man and the environment shall be avoided (§ 8(1) of the Radiation Protection Act (Strahlenschutzgesetz – StrlSchG) [1]), and

2 any exposure or contamination of man and the environment shall be kept as low as possible even where values are below the authorised limits, taking due account of the state of the art in science and technology and of the conditions of each individual case (§ 8(2) StrlSchG [1]).

The planning of structural or other engineered protection measures against design basis accidents is to be based on the requirements of § 104 in conjunction with § 194 of the Radiation Protection Ordinance (Strahlenschutzverordnung – StrlSchV) [2].

Based on this, the following fundamental safety functions are derived for the conditioning facilities and the waste packages produced with them:

- confinement of radioactive material,
- avoidance of unnecessary exposure, limitation and control of occupational and public exposures,

where applicable, for special waste also

- maintaining subcriticality

as well as the following derived requirements:

- shielding of ionising radiation,
- design and implementation of installations in compliance with the requirements for operation and maintenance,
- safety-oriented organisation 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.

There are additional requirements, not dealt with here, as regards liability, protection against disruptive actions or other third-party intervention and, in the individual case, the control of fissile material under international agreements.

1.3 Definitions

The terms used in these guidelines are defined as follows:

- **Operating manual**
  Collective term for all documents that describe the operational processes and the measures to be taken in the event of incidents and accidents. These may be operating instructions, radiation protection instructions, operating rules and/or operating regulations or other operating documents.

- **Delta waste**
  Radioactive waste with negligible heat generation that is not suitable for emplacement in the Konrad repository due to its nuclide inventory and/or chemical composition or the time of its generation.

- **Waste management concept**
  According to [3], a waste management concept shall describe the technical and organisational provisions for the collection and recording of all types of radioactive residues and the intended paths of non-detrimental utilisation; for radioactive waste, the intended technical and organisational provisions for the collection and recording as well as for treatment and packaging up to waste packages suitable for disposal shall be described. A concept shall be drawn up as part of the operating documentation, updated in case of changes and submitted to the competent supervisory authority. Currently common terms for such concepts are e.g. waste and residue concept, qualification concept or post-qualification concept.

- **Conditioning**
  Treatment of radioactive waste, if necessary pre-treated, to qualified waste forms and their packaging in containers with the objective of storage and disposal. Conditioning may be carried out in more than one stage and during different time periods via intermediate products and in different conditioning facilities. Conditioning is carried out by means of procedures whose application has been approved in accordance with § 3(2) of the Nuclear Waste Management Ordinance (Atomrechtliche Entsorgungsverordnung – AtEV) [4].

- **Conditioning facility**
  - ***Autonomous conditioning facility***
    Self-contained system(s) for processing radioactive raw waste, which may have been pre-treated, into waste forms or for carrying out individual process steps within the scope of conditioning in independent buildings with a dedicated licence (e.g. external conditioning facility, residue treatment centre).

  - ***Mobile conditioning facility***
    Self-contained system with defined interfaces which is used for processing radioactive raw waste, which may have been pre-treated, into waste forms or for carrying out individual process steps within the scope of conditioning and which is set up specifically for the respective conditioning campaign in a nuclear installation or facility and removed again at the end of the campaign (e.g. mobile drying facility).

  - ***Stationary conditioning facility***
    Self-contained system with defined interfaces which is used for processing radioactive raw waste, which may have been pre-treated, into waste forms or for carrying out individual process steps within the scope of conditioning and which is permanently installed in a nuclear installation or facility (e.g. stationary high-efficiency compactor).

2 Waste management process

The waste management process for radioactive material classified as waste with negligible heat generation comprises all measures starting with the generation of the raw waste, through conditioning and storage to the package suitable for disposal and its emplacement in a disposal facility, taking into account the respective responsibilities (e.g. conditioning service provider, storage facility operator). The overall waste management process is to be laid down in a waste management concept by the waste producer from the generation of the raw waste to its delivery to the disposal facility in accordance with the applicable regulations [3, 5]. The required conditioning includes all steps for the production of waste packages by treatment and packaging of radioactive waste; this also includes steps to be performed in the disposal procedure with regard to the waste characterisation. The requirements concerning the description of the characteristics relevant for storage and disposal apply to all types of waste and also to large components.

In the case of radioactive waste that cannot be emplaced in the Konrad repository due to its radiological and/or material characteristics or due to the time of its generation (delta waste), conditioning shall be designed such

as to acquire and record any data needed for characterisation according to qualified processes and to enable conditioning is carried such that long-term stability for storage is achieved as well as flexibility for the later production of disposal packages. Conditioning may be carried out according to the Konrad waste acceptance criteria.

For radioactive waste with negligible heat production, which is foreseen to de disposed of in the Konrad repository, the waste management process is terminated upon emplacement of the waste package in the Konrad repository. This case is explicitly described in the subsequent chapters of these guidelines unless other specific cases are addressed as noted.

The measures for the qualification of waste that has not yet been finally qualified for a disposal facility are also to be described in the waste management concept.

At regular intervals, the waste producer also has to review the waste management process on the basis of feedback from experience and the current state of the art.

3 Requirements for qualified processes, waste forms, waste containers and large components

3.1 Product control

Product control serves to prove compliance with the waste acceptance criteria of waste packages for disposal and represents an essential task within the framework of radioactive waste management by the waste producer. It basically consists of a process qualification (prior to conditioning), controls accompanying the conditioning and a corresponding documentation. Process qualification comprises the proof that by subjecting to a conditioning process, waste packages can be produced with characteristics within the permissible ranges [6].

Within the scope of process qualification, the respective work and inspection steps to be carried out are determined by the waste producer or the conditioner on the basis of the documented characteristics of the waste to be conditioned and checked by the respective authority(ies). In addition to the general suitability of the conditioning process for the production of a waste package that meets the waste acceptance criteria for disposal, e.g. the following aspects are to be checked:

- determination of the operating parameters and their permissible tolerance for individual conditioning steps (e.g. the drying temperature as well as the conditions for identifying the end point of drying) and their documentation,
- suitability of the respective method for checking the waste form or waste package characteristics as well as the scope of the required analyses,
- general review of the procedures, e.g. for calibration or performance of recurrent tests, and
- review of the above-mentioned parameters also at suppliers.

In addition to the requirements relevant for disposal, the respective licences of the waste producers or storage facility operators may result in further requirements regarding the characteristics of the waste forms or packages, compliance with which must be demonstrated within the framework of product control. This requires organisational and administrative procedures that define the areas of responsibility, tasks and activities of those involved.
Specifications on the performance of product control with regard to disposal and storage exist on the basis of the Nuclear Waste Management Ordinance [4], the waste acceptance criteria and the product control requirements for the Konrad repository [6–8], the guideline on the control of radioactive residues and radioactive waste [3] and, where applicable, the acceptance criteria of the storage facilities. The parties involved in product control are the regulator of the waste producer, the division of the federal company for radioactive waste disposal (Bundesgesellschaft für Endlagerung – BGE) entrusted with the performance of sovereign product control-relevant tasks for the Konrad repository, the regulator of the storage facility, the consulted experts of these authorities, the waste producer and, if applicable, service companies contracted by the waste producer.

The product control flow chart with corresponding explanation according to the authorised requirements for product control and extended by material aspect [3, 8] is presented in Annex 1 to these guidelines. Product control for radioactive waste is carried out in accordance with this flow chart. Deviations require the approval of the competent authorities and the BGE.

For the qualification of conditioning processes, the measures of the waste producers, the conditioners and the operators of storage and disposal facilities are to be considered in accordance with the requirements laid down by the competent authorities, taking into account the assessments, accompanying controls and inspections by independent experts. Taking into account the general suitability of the raw waste and the containers for the planned conditioning, these measures include the determination of process parameters relevant for the product quality and their recording with the inspection steps required in the qualified process by the conditioner.

Verification of compliance with the Konrad waste acceptance criteria [6] is mainly performed by applying either campaign-specific or campaign-independent process qualification. Product control through random checks, however, only plays a minor role, so that these will not be considered further in these guidelines. According to the product control requirements for the Konrad repository [7, 8], the individual work and inspection steps for a campaign-independent process qualification are to be described by the applicant in a manual. In general, however, the applicant applies for a campaign-specific process qualification by submitting a detailed schedule of processing and inspection steps (“Ablaufplan”). Since its introduction in 1988, this approach with listing of the work and inspection steps naming the persons responsible has generally proven successful also for storage. Experience has shown that compliance with the requirements from disposal, storage and regulatory oversight for waste campaigns can be ensured by such campaign-specific process qualification.

The characteristics of the waste forms and packages are to be recorded and documented at an early stage in view of the increasing risk of information loss over time [9].

3.2 Waste forms and packages

The waste acceptance criteria and the product control requirements for the Konrad repository [6–8] result in safety-relevant requirements for waste packages that relate to the radioactive inventory, to chemical, physical and biological characteristics of the waste forms and to the packaging of the waste. Characteristics relevant for disposal derived from these requirements relate to the radioactive waste, the waste forms and the waste containers/packaging.

The following characteristics have been identified as relevant for disposal [7]:

- total activity of the waste package,
- activity of relevant radionuclides,
- dose rate at the surface and at 1 m and 2 m distance,
- surface contamination of the waste package,
- composition of the raw waste,
- quality of the fixing agent,
- quality of the waste container,
- quantitative ratio: waste/fixing agent/water/aggregates,
- homogeneity,
- mass of the waste package, waste forms or inner shieldings,
- solidification and product condition,
- water content and residual moisture,
- thermal behaviour, and
- stackability and handling properties.

For waste containing fissile material, the fissile material content and the local distribution of the fissile material in the waste volume are to be specified additionally. Related requirements are specified in the waste acceptance criteria for disposal and the product control requirements for the Konrad repository [6, 7].

Basically, these characteristics are also relevant for storage. For this purpose, proof can be furnished that a substantial part of the requirements for the storage of radioactive waste is fulfilled if it has been conditioned in a manner suitable for disposal in accordance with a procedure approved by the BGE within the framework of process qualification (§ 3(2) AtEV [4]). Likewise, proofs already furnished that waste requirements for storage have been met can be used for disposal qualification.

For storage, waste forms and waste containers have to be chemically/physically sufficiently stable throughout the period of storage until their disposal. This is to be ensured by suitable conditioning processes. In addition, conditioning has to ensure the suitability of the packages for disposal at the time of disposal.

An indication of insufficient stability of the waste form is, for example, gas formation due to digestion, fermentation or corrosion processes. Gas formation which cannot be ruled out, must be controlled during conditioning and limited to a degree that is technologically achievable and that does not raise any safety concern. For this reason, appropriate treatment processes, such as drying of the waste are to be conducted prior to storage. The assessment of the gas formation rate during storage with a view to obtaining waste form

characteristics relevant for storage and disposal is to be based on the state-of-the-art conditioning technology (see Annex 2).

By producing chemically/physically stable waste forms in qualified containers suitable for disposal and by their comprehensive documentation and in the context of inspections and, if necessary, maintenance measures during storage (see [9]), it can be assumed that the waste packages can be safely handled also after storage until they are emplaced in the repository.

For packages with waste forms where significant pressure build-up resulting from gas formation cannot be excluded even in case of proper conditioning, pressure relief measures are to be provided, as far as there are no requirements regarding the leak-tightness of the waste containers. To prevent pressure build-up of more than 0.2 bar [7] in inner containers with pressure relief that are cemented into waste packages, cementing must be carried out in such a way that sufficient discharge of the formed gases through the pores of the grouting compound from the inner container is demonstrably ensured. For example, the results of tests to determine the gas permeability of the grouting compound and of studies on kinetic parameters of gas-forming reactions in waste forms can be used to assess the suitability of the cementing procedure for inner containers with pressure relief. On the basis of the results, additional conditioning activities, such as the creation of a sufficiently large cross-sectional area, may be derived with the objective of preventing pressure build-up in cemented inner containers with pressure relief.

Furthermore, the compatibility between waste, fixing agent or waste matrix and container materials is to be taken into account. For cement products, those compositions are to be avoided that lead to shrinking of the product with gap formation between product and container wall or with formation of cracks in the product, or that lead to a volume increase of the product due to phase transformations up to the destruction of the waste container. Reactions between waste form and the waste container, as it was observed e.g. in connection with containers made of austenitic material after filling with chloride-containing material, are to be prevented by means of adequate conditioning. The same applies to a potential reaction between residues of organic solvents and the coating material of the inner wall of the container.

To verify properties of waste forms in a traceable manner, in a first step the origin and characteristics of the raw waste is to be recorded and documented. On the basis of the available knowledge from process qualification by the BGE, the waste forms to be produced are then to be assessed regarding their suitability for storage. If for storage only partial performance of treatment steps of the qualified conditioning process is provided, the intermediate products are to be assessed regarding their suitability for storage.

3.3 Waste containers

Qualified waste containers must be certified for storage and ideally also for disposal. The requirements are specified in the respective acceptance criteria of the storage facilities as well as in the waste acceptance criteria and the product control requirements for the Konrad repository [6, 7]. Moreover, the requirements under transport legislation according to the applicable dangerous goods regulations [10–13] are also mandatory. If storage takes place in waste containers that are not qualified according to transport regulations, transport requirements have to be fulfilled after an additional later packaging step, e.g. by means of an additional

qualified outer packaging. The design of the waste containers has to be such that their handling is also ensured during and after storage. The boundary conditions on which the qualification certificates are based and which have an impact on conditioning are to be observed.

3.4 Documentation of storage and disposal packages

Within the scope of conditioning, the relevant data on the waste forms and waste packages as well as on the waste origin are to be documented. Specifications on the data to be documented are laid down in the annex to the Nuclear Waste Management Ordinance [4]. Specifications on the documentation of radioactive waste are contained in the guideline on the control of radioactive residues and radioactive waste [3]. Information on the structure and content of a waste package documentation are exemplary given in the technical acceptance criteria of the Gorleben waste storage facility [14] as well as in the waste acceptance criteria for disposal and the requirements for product control for the Konrad repository [6–8].

The documentation of the waste forms and waste packages for storage is to be performed in accordance with the existing requirements for future disposal and shall include all information required at this time in order to create the necessary documentation for later disposal. For the storage of waste that has not yet been conditioned until being suitable for disposal, such as intermediate products, documentation is to be performed accordingly, taking into account the requirements specified in the respective storage licence. Particularly in the case of an interruption of conditioning to a waste package, all previously created documents on treatment and characterisation are to be compiled. The required documents are to be specified within the framework of the respective process qualifications. The scope of the declaration of radionuclides and material components shall be oriented towards the waste acceptance criteria and the product control requirements for the Konrad repository [6–8].

In addition to the collection of data relevant for disposal and for the proof of product control measures performed, the documentation shall include proofs that storage requirements have been met. These may be e.g. further data on radionuclides with higher volatility or additional proofs on the permission to use the respective packaging.

The waste package documentation may be performed for each package or together for several packages of one conditioning campaign. In this respect, at least the issues stated below should be documented as follows:

- data sheet with information on waste form group, waste container classification, compliance with limit values, radionuclide inventories and material composition,
- records on process qualification performed and approval of conditioning campaign,
- records on the accompanying controls performed by experts on site,
- records on the review of the documentation and statements of the competent authorities (to be completed after review and statement),
- description of the origin and composition of the raw or pre-treated (if applicable) waste,

- description of the conditioning process, e.g. by means of operational data collection, including any deviations occurred and special occurrences as well as the accompanying controls performed,

- compilation of the analysis and measurement data (activity, gas and material analyses, dose rates, contaminations),

- description of activity calculation / activity determination and declaration of the activities of the disposal-relevant radionuclides and the overall inventory and other radionuclides for storage,

- description of the material composition of the waste package with data from the material and the container list [6, 8],

- description of the waste container with information on the qualification of the respective container types for storage and, if applicable, disposal (e.g. test certificate granted by the BGE) as well as transport including evidence of long-term durability and corrosion resistance for sheet steel (drums, containers), manufacturing certificates and proofs of compliance as requested in the operating instructions, and

- further documents such as drum lists, transport documents, reception reports of the conditioning facility, etc.

For the creation of a waste package documentation, general documentation quality requirements regarding clearness and completeness are to be observed. Access to and readability of the documentation must be ensured for the entire period of storage until emplacement in a disposal facility (see [9]).

3.5 Large components

In addition to the prompt conditioning of radioactive waste, in specific cases, large components (e.g. steam generators, reactor pressure vessels) are stored prior to their subsequent conditioning as radioactive waste or their clearance. The storage of these large components is regulated in [9]. In analogy to chapters 2 and 3.1 to 3.4 of these guidelines, it is to be ensured that

- a waste management concept is drawn up, and

- all relevant characteristics of the large components are determined and documented in a timely manner.

4 Design requirements for conditioning facilities

A conditioning facility must be designed such that the conditioning objective can be achieved safely and reliably. An essential prerequisite for this is the selection of a suitable conditioning process with the optimal operating parameters in each case (e.g. pressure, temperature, throughput, etc.). When selecting the

conditioning process, all relevant factors are to be taken into account, including the safety-relevant waste characteristics and the amount of secondary waste that may be generated.

Already during the planning stage of the conditioning facility it is to be ensured that

- operational and occupational safety is ensured under all circumstances,
- the operation of the facility, including maintenance and inspections, does not cause unnecessary exposure to the operating personnel and the environment,
- the facility can easily be decontaminated, and
- dismantling and disposal of the facility will not become unnecessarily complicated.

When designing the facility, an analysis is to be carried out of all incidents and accidents to be assumed. As far as possible, it is to be ensured that the facility is automatically transferred to a safe state in the event of operational incidents. Passive safety systems shall be preferred to the extent possible. In any case, it is to be ensured that the fundamental safety functions are reliably met in the event of any assumable incident or accident. This can be achieved by structural as well as administrative (e.g. quantity limitation) measures.

The suitability of the chosen conditioning process and the conditioning facility is to be demonstrated.

5 Requirements for buildings of conditioning facilities

The structural parts of autonomous conditioning facilities are to be built in accordance with the respective building codes of the *Länder* and in accordance with the generally recognised engineering rules. Additional design requirements result from the safety analyses of the specified normal operation until the end of the scheduled operating life as well as of anticipated accidents:

- For the design of the building, the intended duration of use is to be considered with regard to durability and functional performance of the building materials.
- The floor in the area of the conditioning facility shall have an adequate compressive strength and wear resistance.
- The base plate must be appropriately designed for driving on with transport vehicles and for the loads.
- Walls, floors and, if necessary, ceilings of the installation rooms of conditioning facilities must be easy to decontaminate.
- When handling liquid radioactive waste, suitable leakage collecting systems are to be provided.
- The structural design also has to consider impact loads during transport processes unless these are excluded by other measures. Crane loads and loads of other heavy plant components, e.g. shieldings, and

special loads from internal hazards (Chapter 9.1) and external hazards (Chapter 9.2) are also to be taken into account.

- The materials used for the building must generally be *non-combustible* (building material class A according to DIN 4102, Part 1 [15]). If *non-combustible* building materials are not available for reasons of the intended use (e.g. decontamination coatings), use can be made of *flame-retardant* building materials (building material class B1 according to DIN 4102, Part 2 [15]) (Chapter 6.2).

- The design of the building shall be such as to ensure stability for the load case fire in accordance with DIN 4102, Part 2 to 4 [15].

- The building is to be equipped with grounding and lightning protection systems in accordance with the conventional rules and regulations. More stringent requirements only have to be considered where monitoring and protection functions may be affected; in this case, additional lightning protection measures are to be taken.

- The top edge of the floor has to be above the water level for the 100-year flood, otherwise structural measures are to be taken to prevent the ingress of water. Temporary measures are to be provided for the 10,000-year flood. When determining the design water level, the state of the art in science and technology is to be taken into account.

- For the determination of the type of the seismic design it is to be examined on a plant-specific basis whether postulated damage caused by earthquake may lead to exposure due to the release of radioactive substances into the environment exceeding the planning levels of § 104 StrlSchV. If this is the case, the structural parts at the location where the conditioning facilities are installed are to be designed against earthquakes in accordance with nuclear safety standard KTA 2201, Part 1 [16].

For the installation and handling of mobile or stationary conditioning facilities and containers in existing nuclear installations or facilities, sufficient floor and working spaces must be available that meet the above requirements mutatis mutandis.

6 Requirements for the technical infrastructure

For stationary conditioning facilities in existing nuclear installations or facilities, the interfaces with regard to technology, operation, fire protection, radiation protection and to the organisational structure with the corresponding responsibilities are to be assessed and adjusted if necessary. These interfaces are to be assessed for mobile conditioning facilities before each start-up.

For autonomous conditioning facilities, the necessary technical auxiliary systems are to be designed and described, taking into account the requirements stated below.

6.1 Radiation protection systems and equipment

For autonomous conditioning facilities, this includes radiation monitoring within the facility (local dose rate, room air, contamination) and environmental radiation monitoring (discharges, local dose rate at the fence).

A radiation monitoring concept is to be drawn up that specifies the required measuring equipment.

6.2 Fire protection and fire protection equipment, explosion protection

For buildings in which conditioning facilities are operated, a fire protection concept is to be prepared or the existing fire protection concept is to be adapted and updated, if necessary. This concept describes the individual measures of preventive fire protection by structural and engineered measures, of organisational (operational) fire protection and of fire suppression. The individual components and their interconnection are to be described with regard to the radiological protection objectives, taking into account the facility operation, the fire risk and the expected extent of damage. .

For the operation of the conditioning facility, measures are to be established for avoiding of fire loads and ignition sources, for timely fire detection and for effective fire fighting. If the formation of explosive gas mixtures is to be postulated, adequate preventive measures are to be taken. Furthermore, the necessity of fire water supply and fire water retention is to be determined in the design stage.

6.3 Lifting and transport equipment

The technical design of the lifting equipment used for handling the waste or waste packages is based on the results of the analysis of events during specified normal operation and in the event of accidents. They must comply with the general safety regulations and requirements. The lifting and transport equipment must be designed as to handle the waste or waste packages safely. For this purpose, regular maintenance and inspections are to be carried out. If the lifting and transport equipment is not used for a longer period of time, these regular measures can be replaced by tests prior to return to service. If, in the event of failure of lifting or transport equipment, there is a risk of exposure from internal exposure exceeding 1 mSv or from external exposure exceeding 5 mSv, additional measures are to be taken.

6.4 Supply and disposal systems

For autonomous conditioning facilities, this includes auxiliary systems such as

- ventilation systems,
- water supply and waste water systems, and
- other systems (e.g. fuel gas supply, counter gas supply, nitrogen supply, compressed air supply, breathing air and emergency breathing air supply).

The auxiliary systems are to be designed and described with regard to their tasks under consideration of §§ 99 to 103 StrlSchV [2] and conventional rules and regulations.

The ventilation system is used for controlled aeration and deaeration of the building and/or special sections of the building. The following requirements are to be taken into account when designing the ventilation system:

- supply of outside air to the rooms,
- maintaining permissible room air conditions,
- maintaining specified room negative pressures relative to the outside atmosphere,
- maintaining a directional flow between different rooms,
- filtering of possibly contaminated exhaust air and controlled discharge of the cleaned exhaust air,
- preventing the accumulation of harmful gases, vapours and airborne aerosols in the indoor air, and
- heating of the building.

6.5 Electrical systems and equipment

For autonomous conditioning facilities, this includes auxiliary systems such as

- energy supply, emergency power,
- instrumentation and control, and information technology,
- communication systems,
- grounding, lightning protection and electromagnetic compatibility, and
- lighting.

The auxiliary systems are to be designed and described with regard to their tasks under consideration of conventional rules and regulations.

7 Requirements for the operation of the conditioning facility

7.1 Operating principles

The conditioning facility shall be operated in such a manner that the necessary precautions against damage have been taken according to the state of the art in science and technology. In particular, the following plant states are to be considered:

- for new conditioning facilities before start-up: all procedures for reaching the normal plant operating state for the first time (commissioning),

- normal operation and operational incidents,
- control of accidents and elimination of their consequences.

The entire operation is to be structured appropriately to ensure that operational processes can be carried out safely. For this purpose, the following requirements are to be met:

- all operational processes shall be clearly described and the qualifications of the operating personnel required for them specified,
- all installations necessary for safe performance of operation shall be specified,
- the results of operation shall be systematically evaluated and used for the continuous improvement of the operational processes.

In particular, the necessary administrative prerequisites related to personnel, organisation and safety are to be established and proof of compliance is to be furnished. Competencies and responsibilities are to be clearly defined.

For the operational processes as well as the management of accidents and elimination of their consequences, clear instructions are to be laid down in an operating manual (see Chapter 7.4). In particular, the following is to be described:

- acceptance, handling and delivery of radioactive waste, empty containers and individual components as specified,
- the conditioning of the radioactive waste,
- the normal operation of auxiliary systems,
- control measurements of parameters relevant for operation and safety,
- in the case of deviations from normal operation, measures to restore it.

Quality- or safety-relevant events during commissioning, normal operation (in particular during maintenance and inspection) and periodic tests are to be documented (Chapter 11.2). Type and scope of this documentation are to be specified. Safety-relevant events are to be reported in accordance with the provisions of the Nuclear Safety Officer and Reporting Ordinance (Atomrechtliche Sicherheitsbeauftragten- und Meldeverordnung – AtSMV), Appendix 6 [17]. Consequences derived from the evaluation of such events are to be assessed and, where appropriate, incorporated into the operating rules.

7.2 Organisation and management system of the operator

The organisational structure of the operator of the conditioning facility must provide for clearly defined responsibilities, competencies, powers and communication channels. In particular, the interfaces between the operator of the conditioning facility and other organisations involved in the waste management process, e.g. waste producers or operators of storage facilities, are to be defined in clear, unambiguous and comprehensive regulations.

The operator of the conditioning facility must ensure that the necessary personnel and the required skills, abilities and experience will be available throughout the entire operating period in order to be able to carry out all necessary activities properly. If the operator makes use of external support for this, he must always be able to independently assess the resources and qualifications of the contractor for the proper execution of the activities as well as the quality of the result.

The operator of the conditioning facility has to establish a management system and to continuously monitor and develop it. The ultimate goal of the management system should be to achieve, continuously maintain and improve safety.

This requires that the management system

- brings together all requirements necessary for the safe operation of the facility in a coherent approach,
- describes all planned and systematic measures that are required for the implementation of these requirements, and
- ensures that requirements from the areas of occupational safety, environmental protection, plant security, quality assurance, ageing management (long-term availability of individual components) and economic efficiency are not considered separately from the safety requirements, thereby preventing potential negative impacts on safety.

The management system is to be maintained continuously for the entire time needed (design, construction and operation) and must cover normal operation as well as operational incidents, accidents and emergency situations.

The management system identifies those processes that are necessary to achieve the organisational goals, including the provision of means necessary for compliance with all requirements and for task performance. The processes must be carried out and implemented as planned, implementation is to be assessed and continuously improved. The work procedures of each process are to be carried out under controlled conditions and in compliance with the applicable provisions. Instructions, drawings and other aids are to be checked periodically to ensure their suitability and effectiveness.

A task of the management system is to compile the necessary qualifications and experience for all employees who perform safety-related tasks and provide training programmes for development and maintenance of professional knowledge, skills and abilities.

The documentation of the management system includes at least the following:

- the company's safety philosophy,
- a description of the management system,
- a description of the competencies and responsibilities, their assignment, the decision-making structures and the interaction with the management, the performers and those who have to assess the performance,
- a description of the cooperation with relevant external organisations,
- a description of the processes, including information regarding preparation, review, performance and documentation of the work. In addition, the measures for assessment and, if possible, improvement of the processes and activities are to be described. In doing so, not only the operating experience of the own conditioning facility is to be taken into account, but also from other, comparable conditioning facilities.

The same requirements apply mutatis mutandis to mobile or stationary conditioning facilities operated in existing nuclear installations or facilities. The above regulations may be included in the management system of the existing nuclear installations or facilities. In this context, the interfaces between the conditioning facility and the existing nuclear installation or facility are also to be assessed.

7.3 Commissioning

Prior to commissioning, all conditioning facilities, both autonomous and conditioning facilities in existing nuclear installations or facilities, are to be subjected to commissioning tests. These tests are to be specified in a commissioning programme. They serve to verify that the conditioning facility has been installed so as to meet the requirements for the planned operation.

In this context, the entire handling process is to be tested, also including the radiation protection measures. During this test, any deficiencies in the process that may still exist are identified and the planned procedures adapted and finally defined.

In addition mobile conditioning facilities have to undergo a pre-operational acceptance and functional test after having been reinstalled in order to verify that

- the technical condition, spatial arrangement and interconnection of the facility components and their connection to the corresponding systems of the nuclear installation or facility correspond to the licensed condition,
- all operational processes take place in a functionally correct and fault-free manner,
- the safety-related switching functions (e.g. emergency shutdown, high-temperature shutdown, isolation of the systems, high-temperature alarm, break of the vacuum) are correctly triggered as soon as the specified triggering criteria are met, and

- the radiological protection of the personnel is ensured during operation and maintenance.

7.4 Operating manual, operating instructions

All operational processes and the measures to be taken in the event of incidents and accidents in operating instructions are to be described in specific documents, the collection of which is referred to as “operating manual”. The operating manual has to contain all operational and safety-related instructions, limits and conditions that are required for the operation of the conditioning facility, the management of incidents and accidents as well as the operating regulations that may apply for the conditioning facility. This includes, for example, regulations on personnel organisation, maintenance, radiation protection, guard and access, alarms, fire protection and first aid. In particular, the operating manual has to address any safety-related aspects. This is to ensure that the personnel can initiate and perform the necessary measures during operational processes or in the event of incidents and accidents without any delay and in a reliable manner. In addition, the proceeding for modifications or supplementations of components and procedures is to be specified. Existing operating regulations the existing nuclear installation or facility, in which a mobile conditioning facility is to be operated, shall be taken into account.

For the structure of the operating manual and with respect to general requirements for the layout of the operating manual, nuclear safety standard KTA 1201 [18] may be used as a guide, in particular with regard to compliance with the state of the art and ergonomics as well as to the completeness and clarity of descriptions.

7.5 Technical acceptance criteria of the conditioning facility

Technical acceptance criteria are to be established, taking into account the following aspects:

- procedural design,
- radiation protection design,
- handling design, and
- licensing-related design / conditions of the operating licence.

The technical acceptance criteria must contain at least

- requirements regarding the physical and chemical characteristics of the waste,

- requirements regarding the radiological characteristics of the waste:
  - activity content,
  - nuclide composition,
  - dose rate and surface contamination,

- permissible packaging of the waste,

- required documentation of the waste,

- measures in case of non-compliance with the acceptance criteria.

7.6 Incoming and outgoing inspection

Before accepting waste, it is to be subjected to an incoming inspection. The incoming inspection serves the purpose of verification as follows:

- Identification control: determination whether the waste is in conformance with the declaration.

- Compliance with the technical acceptance criteria of the conditioning facility: verification that the acceptance criteria have been met. This check is usually carried out using the information provided in advance by the deliverer in connection with the identification control.

- Conformity with the declared information of the deliverer: random verification of certain characteristics of the waste, e.g. radiological characteristics, mass, in particular if these are safety-relevant for the processing.

Where waste is received from a neighbouring facility without being transported via public transport routes, certain parts of the controls already carried out at the neighbouring facility may be dispensed with in the incoming inspection.

When waste is delivered, an identification control is to be carried out. This involves establishing that the waste is the waste intended for delivery.

In case of non-compliance with the technical acceptance criteria of the conditioning facility upon delivery – despite prior inspection and confirmation – a concept for further action is to be developed and defined. The concept must specify all precautions and actions to be taken in this case (additional checks to be carried out, e.g. by means of additional measurements, informing the deliverer and, if necessary, returning the waste).

7.7 Monitoring, recurrent tests

The operation of the conditioning facility is to be monitored to ensure compliance with quality-relevant process and product parameters and compliance with safety-relevant parameters and limits in an appropriate manner.

The monitoring measures are to be designed such that the corrective measures provided for in accordance with the operating manual can be initiated in due time in order to minimise the production of products not complying with the specifications and to avoid exceedance of safety-relevant limits.

It is to be determined by periodic tests whether the conditioning facility, including all associated safety systems and equipment, continues to meet the specified requirements. The type and scope of the tests, their intervals and the inspector are to be specified in a testing schedule. This testing schedule is to be agreed upon with the competent authority. The testing schedule is to be reviewed at regular intervals and updated on the basis of experience feedback.

The frequency of the respective test is to be determined depending on the relevance for the product quality or the safety significance of the components to be tested, taking into account the specific regulations. The results of the recurrent tests must be documented.

8 Radiation protection

In the following, requirements concerning radiation protection in autonomous conditioning facilities are formulated. In the case of mobile or stationary conditioning facilities in nuclear installations or facilities, the requirements refer to the building of the nuclear installation or facility, including the interfaces with the conditioning facility.

8.1 Operational radiation protection

According to § 8 StrlSchG [1], any unnecessary exposure or contamination of man and the environment shall be avoided when operating a conditioning facility. In this context, any exposure or contamination of man and the environment shall be kept as low as possible, even below the respective limits, taking into account all circumstances of the individual case and the state of the art in science and technology. Requirements for the operation of conditioning facilities are derived from this. Further specific requirements result from the required licence for handling (unsealed) radioactive substances.

For the operational organisation of radiation protection, the requirements of Chapter 4, Part 2 StrlSchG [1] are to be observed. According to § 45 StrlSchV [2], the radiation protection executive for the conditioning facility shall ensure that radiation protection instructions are issued. These instructions shall list the protective measures to be observed during operation. This may include, e.g., the establishment of an organisational plan for radiation protection, the control of operational procedures that are essential for radiation protection, the measurements provided for determining the body dose, as well as provisions regarding the prevention, investigation and notification of incidents. The persons working in the conditioning facility must be regularly instructed in accordance with the requirements of § 63 StrlSchV.

Radiation protection areas are to be established for the operation of the conditioning facility in accordance with § 52 StrlSchV. These shall be appropriately delimited and labelled (§ 53 StrlSchV) and access shall be appropriately controlled in accordance with § 55 StrlSchV. Furthermore, exclusion areas are also to be protected in such a way as to prevent uncontrolled access by persons, including the uncontrolled intrusion of any parts of a person’s body. Only justified access to exclusion areas shall be permitted under the control of the radiation protection supervisor or a person appointed by him and having the required qualification (pursuant to § 47 StrlSchV).

In radiation protection areas, the local dose or local dose rate, the concentration of radioactive substances in the air, or the contamination of the workplace shall be measured and documented to the extent necessary for determining the exposure (§ 56 StrlSchV). For the protection of persons and material goods in radiation protection areas with unsealed radioactive substances it shall be ensured that checks for contamination are carried out. If the values for surface contamination pursuant to § 57 StrlSchV are exceeded, measures shall be taken without delay to prevent the further spread of radioactive substances or incorporation. In addition, the

requirements of the Radiation Protection Ordinance (pursuant to § 58) for contamination detection shall be observed when leaving radiation protection areas and when bringing out movable objects. The results of the measurements are to be documented and preserved in accordance with the requirements of the Radiation Protection Ordinance.

The body dose of persons present in the conditioning facility is to be determined and documented in accordance with the requirements of the Radiation Protection Act and the Radiation Protection Ordinance (§§ 64–66). When working in conditioning facilities where unsealed radioactive substances above the exemption limits are handled, the necessary protective measures (e.g. wearing of protective clothing, rules of conduct) shall be taken (§ 70 StrlSchV). The protection of occupationally exposed persons in the conditioning facility against external and internal exposure shall be ensured primarily by structural and technical devices (§ 75 StrlSchV). In order to further optimise radiation protection, it shall also be examined and documented whether the establishment of dose constraints (§ 72 StrlSchV) for occupationally exposed persons is a suitable instrument for this purpose.

According to § 90 StrlSchV, the radiation measuring devices used and kept available shall meet the requirements of the measurement purpose, be tested for their functional performance and serviced at regular intervals. The measuring devices shall be available in sufficient numbers.

8.2 Exposure in the environment during specified normal operation

For the protection of the population and the environment, the local dose at the fence and, pursuant to § 103 StrlSchV, the liquid and gaseous discharges of a conditioning facility are to be monitored and reported to the competent authority at least once a year. The Guideline concerning Emission and Immission Monitoring of Nuclear Installations (REI) [19] is to be applied to conditioning facilities mutatis mutandis.

Compliance with the limits of § 80 StrlSchG [1] and § 99 StrlSchV [2] is to be demonstrated in the licensing procedure on the basis of the general administrative provisions for the determination of expected exposure of members of the general public (§ 100 StrlSchV).

9 Safety analyses

The safety analyses are to be based on an event spectrum that covers all potentially occurring events. For all events listed in chapters 9.1 and 9.2, the impacts on systems, safety-relevant installations and measures, buildings, etc., are to be investigated, and the source term for radiologically relevant events is to be determined and the resulting radiological effects must be identified unless it can be demonstrated that the respective event type can be excluded. Furthermore, it is to be examined whether there are other potential events that are not covered by the events listed in chapters 9.1 and 9.2. If this is the case, such events identified must also be considered.

In the safety analyses, the specific technical conditions and processes of the facility are to be analysed systematically and account is to be taken of experience from comparable facilities and projects. When analysing potential causes of incidents and accidents, human error is to be taken into account.

As far as credit is taken from protective measures, i.e. the function of safety-relevant installations or administrative measures, it is to be ensured that the functions assumed will be available with the postulated effectiveness and reliability.

For the operational incidents assigned to specified normal operation, it is to be demonstrated within the scope of an event analysis that, taking into account discharges during specified normal operation, the limits of § 99 StrlSchV and, if applicable, facility-specific discharge authorisations are complied with.

If a particular event is to be classified as design basis accident, compliance with the planning values of § 104 StrlSchV [2] in conjunction with § 194 StrlSchV is to be demonstrated as part of an accident analysis.

A facility-specific safety analysis is to be carried out for mobile conditioning facilities regardless of the installation location. Before starting operation, the concrete boundary conditions at the respective installation location are to be assessed from a safety point of view.

9.1 Internal hazards

The following internal hazards are to be analysed with regard to their impacts, also considering the damage prevention measures provided by the design of the facility:

- Internal fire
  Possible fires in the facility (including filter fires) are to be analysed for their impacts on safety (e.g. potential activity releases). The maximum stationary and temporary fire loads in the facility are to be taken into account. The entirety of all fire protection measures must ensure that even in the event of a random failure of an individual fire protection measure or device, the safety-related functions are not inadmissibly impaired.

- Leakages
  Leakages from containers and pipes with activity-containing media are to be analysed with regard to their impacts on safety (e.g. potential activity releases).

- Flooding
  It is to be checked whether flooding can occur in the facility.

- Component failure (e.g. failure of containers with high energy content).

- Events during the handling of loads and during transport operations
  - dropping of containers with releasable radioactive inventory, taking into account the most unfavourable combination of drop height, impact position and ground properties,
  - collision of loads with containers or systems with releasable radioactive inventory, taking into account the most unfavourable combination of mass and impact characteristics of the loads.

- Internal explosions

- Failures and malfunctions of safety-relevant installations
  - failures and malfunctions of supply systems (e.g. the electrical energy supply),
  - failures and malfunctions of systems for instrumentation and control and for monitoring (e.g. radiation and activity monitoring),
  - failures and malfunctions of fire protection systems, and
  - failures and malfunctions of ventilation systems and installations for the retention of radioactive substances.

9.2 External hazards

The following external hazards are to be analysed with regard to their impacts, also considering the damage prevention measures provided by the design of the facility:

- For natural hazards, the load assumptions for the site-specific conditions are to be defined conservatively. It is to be analysed for the site which natural hazards may be relevant; at least, impacts due to earthquakes, flooding (high water), rain (also heavy rain events), hail, storm (including tornado), snowfall, snow loads, frost, lightning, exceptional heat waves, high or low humidity, biological hazards (e.g. microbiological corrosion) and forest fires are to be considered.

- For man-made hazards such as aircraft crash, external explosion, intrusion of hazardous substances and external fire, the load assumptions are to be based on the site-specific conditions.

- As far as these events are categorised as beyond design basis events, adequate mitigation can be assumed if the radiological consequences determined under realistic boundary conditions do not necessitate major disaster control measures.

- Influence due to accidents in neighbouring facilities
  - collapse of structural parts,
  - failure of containers and components with high energy content,
  - retroactive effects from temporarily existing installations (such as overturning of slewing and construction cranes).

10 Emergency preparedness

For autonomous conditioning facilities, an on-site emergency plan is to be drawn up. The emergency plan includes provisions for both radiological and non-radiological events. The emergency plan must include at least the information listed in Annex 3 [20, 21]. The necessary internal organisational structures are to be established and continuously maintained. The internally responsible persons as well as the responsible persons for contact with the relevant external organisations for emergencies are to be defined. The persons responsible must be available for the entire duration of an emergency. Based on the on-site emergency plan it is to be ensured that for emergency response qualified and experienced staff and installations are appropriately prepared, reliably available and ready for operations in emergencies. The on-site emergency plan shall be communicated to the

competent regulatory authorities and relevant external organisations in case of emergencies. Emergency exercises are to be carried out at regular intervals. The competent regulatory authority is to be informed of the exercises in advance so that it may participate. Some of the emergency exercises are to be carried out as an integrated exercise together with the relevant external organisations. The emergency plan is to be reviewed regularly and the experience gained to be taken into account when revising it.

Depending on the conditioning facility, different measures of off-site emergency preparedness may be required additionally (§§ 54, 106, 107, 152 StrlSchV [2]). In the case of conditioning facilities that exceed the activity limitations specified in § 106 StrlSchV, an emergency plan is required based on the possibilities for release of radioactive substances, including the necessary off-site emergency preparedness measures. The information required for this purpose shall be made available to the competent authority as laid down in § 106 StrlSchV.

For mobile and stationary conditioning facilities in existing nuclear installations or facilities, the requirements may be covered by the emergency plan of the nuclear installation or facility. This is to be agreed upon with the competent authorities.

11 Documentation

Documentation requirements exist for all conditioning facilities, their operation and for the acceptance and delivery of waste or waste packages. For stationary conditioning facilities in existing nuclear installations or facilities, this documentation may be part of the documentation of the nuclear installation or facility. The documentation requirements within the framework of quality assurance are dealt with in Chapter 12.

11.1 Documentation of the conditioning facility

The documentation of a conditioning facility has to take place within a systematically structured documentation system. With regard to the structure, nuclear safety standard KTA 1404 [22] may be used as a reference.

The documentation includes at least the following documents:

- licences and modification licences,
- application documents as far as considered in the licensing procedure, individual proofs provided (e.g. on fire protection, internal and external hazards), safety reviews,
- documents on design, manufacture, construction, commissioning, operation and maintenance of safety-relevant components of the facility, e.g. plans, drawings, manufacturer and test certificates,
- documents on the performance characteristics of the facility (acceptance conditions, throughput capacity, discharges),
- modifications from supervisory procedures,

- operating manual, testing manual including test reports for safety-relevant components, radiation protection instruction,
- information on radiation protection, and
- operating reports (see also Chapter 11.2).

From the time of commissioning of the conditioning facility, the entire documentation is to be stored such that it is protected against fire, flood, adverse magnetic effects, the effects of temperature, light and humidity as well as against vermin and unauthorised access by third parties.

Parts of the documentation of an autonomous conditioning facility are part of the safety documentation. This includes all the information and proofs that are relevant for the safe operation of the facilities and the level of protection.

An illustrative list for the contents of the safety documentation is given in Annex 4.

The safety documentation may consist of many individual documents., which should be clearly presented in a list with the corresponding revision status of the documents.

The safety documentation serves as a basis for safe operation throughout the operating life of the conditioning facility from planning to construction, commissioning, operation and decommissioning of the conditioning facility. It also serves as a reference for the safety assessment of modifications in the conditioning facility and for modifications in operating practice. It contains a description of all safety aspects of the conditioning facility and of all safety-relevant aspects of the site, the construction of the conditioning facility, operation, the provisions for decommissioning and dismantling as well as of the management that contribute to the safe operation of the conditioning facility. It should comprise the conditioning facility itself as well as the waste and its safety-relevant characteristics.

The safety documentation must always be kept up to date so that

- modifications, new regulatory requirements and relevant standards,
- the results of the periodic safety review, and
- the results of the evaluation of events

will be included in the documentation as soon as possible and appropriately according to their safety significance.

11.2 Documentation of operation

Parts of the documentation of operation are part of the safety documentation (see Annex 4).

Furthermore, the documentation of operation includes all documents that are prepared during operation. This includes:

- records of operating parameters,
- protocols of measuring equipment,
- documentation of discharges,
- results of radiation protection monitoring, and
- results of recurrent tests and other checks.

Written reports on the operation of the storage facility are to be issued at regular intervals, containing information on all major operational processes. These include, in particular,

- the acceptance in and delivery from the conditioning facility of radioactive waste,
- the conditioning processes carried out, including accounting of the radioactive substances and other process-relevant parameters,
- the radioactive substances currently available for treatment with their radionuclide inventory and their material characteristics as well as resulting protective measures,
- the results of the recurrent tests,
- other significant operational processes and occurrences,
- conclusions and measures from internal and external occurrences,
- the results of measurements of the personal dose of individuals who were active in the storage facility, and
- the results of dose rate measurements at the specified measuring points.

The general purpose of the reports is to indicate whether the requirements for specified normal operation are being met.

11.3 Documentation of the waste packages

The requirements for the documentation of waste packages are described in Chapter 3.4, addressing the requirements for the documentation of the storage and disposal packages as well as for the intermediate products.

12 Quality assurance

Quality assurance is required to ensure compliance with the requirements for the construction and operation of the conditioning facility, the waste containers and the waste forms and packages. The establishment of a quality management system forms part of quality assurance and is stipulated with the licence for construction or operation and in the licences or approvals for conditioning. Requirements for quality assurance are derived

from DIN EN ISO 9001 [23].

12.1 Construction and operation of the conditioning facility

For quality assurance regarding the construction and operation of conditioning facilities for radioactive waste, basically, the licensing conditions according to chapters 5 and 6 as well as the requirements set out in Chapter 7.2 are to be fulfilled demonstrably.

12.2 Waste containers

For storage and disposal as well as for handling during conditioning and transport, approved and type-tested containers are used. Within the framework of the respective type test for the Konrad repository and approval procedure for the respective storage facility, the quality assurance measures for the manufacture, handling and operation of the containers as well as the related scope of documentation are examined and specified. Further details and requirements are described in Chapter 3.3.

12.3 Waste forms and packages

For process qualification of conditioning methods, the measures of the waste producers, the conditioners and the operators of storage and disposal facilities are to be considered in accordance with the requirements laid down by the competent authorities, taking into account the assessments, accompanying controls and inspections by independent experts. Within the framework of the authorities' approvals of the qualified processes, the corresponding quality assurance measures are thus examined. Further details and requirements are described in chapters 3.1 and 3.2.

13 Periodic safety review

The operator of an autonomous conditioning facility must perform a safety review for the conditioning facility regularly every ten years. The introduction of a safety review is based both on § 9h of the Atomic Energy Act (Atomgesetz – AtG [24] and Article 7(2) of the EU Directive on spent fuel and radioactive waste management [25] as well as on the so-called WENRA safety reference levels [20], to whose implementation in the national regulations and in practice Germany has committed itself as a WENRA member state.

Prior to the first periodic safety review, methodology and scope of the review are to be defined specifically for each facility in agreement with the competent supervisory authority. In subsequent reviews, methodology and scope are to be adapted based on the evaluation of experience gained from previous reviews.

The review begins with an update of the safety documentation, which is to be used as a reference. This is followed by an integrated safety assessment of any changes made to the conditioning facility, process sequences and to the operational organisation in the meantime.

A systematic evaluation of operating experience in the own as well as in similar conditioning facilities and the

assessment of transferability to the own conditioning facility are to be included in this compilation.

A monitoring concept is to be presented for the management of long-term and ageing effects during the envisaged operational lifetime. With regard to ageing, the results of regular walkdowns, inspections and checks of buildings, technical installations and, if applicable, of the waste stored are to be evaluated comprehensively with regard to long-term developments.

The safety review must conclude with an assessment on

- the current safety status of the conditioning facility,
- the expected development of the safety of the conditioning facility,
- the identification of relevant deviations (e.g. regarding technical developments and regulatory requirements) and how these deviations are to be assessed from the safety point of view, and
- which measures are foreseen to prevent any identified developments adverse to safety and to improve safety and in what time frame these measures shall be implemented (action plan).

The results of the safety review are to be documented in a report, so that the results achieved and experience gained can be communicated (operators of similar facilities, supervisory authority, transfer of knowledge to the own employees) and considered for future safety reviews. The report is to be submitted to the competent regulatory authority. Any improvement measures to be taken are determined by the operator in consultation with this authority.

14 Termination of operation

The conditioning facility is to be designed and constructed such that it can be dismantled and removed or put to further use in compliance with the radiation protection requirements. Prior to any further use or dismantling of the conditioning facility, it is to be demonstrated by measurement that it is not contaminated or sufficiently decontaminated and free from any inadmissible activation. The requirements of conventional building and waste legislation are to be observed.

15 Provisions, guidelines and standards

[1] Gesetz zum Schutz vor der schädlichen Wirkung ionisierender Strahlung (Strahlenschutzgesetz – StrlSchG) vom 27. Juni 2017 (BGBl. I S. 1966), zuletzt geändert durch Artikel 5 Absatz 1 des Gesetzes vom 23. Oktober 2020 (BGBl. I S. 2232)

[2] Verordnung zum Schutz vor der schädlichen Wirkung ionisierender Strahlung (Strahlenschutzverordnung – StrlSchV) vom 29. November 2018 (BGBl. I S. 2034, 2036), zuletzt geändert durch Art. 1 der Verordnung vom 20. November 2020 (BGBl. I S. 2502)

[3] BMU-Richtlinie zur Kontrolle radioaktiver Reststoffe und radioaktiver Abfälle vom 19. November 2008, BAnz. 2008, Nr. 197, S. 4777

[4] Verordnung über Anforderungen und Verfahren zur Entsorgung radioaktiver Abfälle (Atomrechtliche Entsorgungsverordnung - AtEV) vom 29. November 2018 (BGBl. I S. 2034, 2172)

[5] Entsorgungskommission
Leitlinien zur Stilllegung kerntechnischer Anlagen
Empfehlung vom 05.11.2020

[6] Bundesamt für Strahlenschutz
Anforderungen an endzulagernde radioaktive Abfälle (Endlagerungsbedingungen, Stand: Dezember 2014) - Endlager Konrad -, SE-IB-29/08-REV-2

[7] Bundesamt für Strahlenschutz
Produktkontrolle radioaktiver Abfälle, radiologische Aspekte - Endlager Konrad - Stand: Oktober 2010, SE-IB-30/08-REV-1

[8] Bundesamt für Strahlenschutz
Produktkontrolle radioaktiver Abfälle, stoffliche Aspekte - Endlager Konrad - Stand: Oktober 2010, SE-IB-31/08-REV-1

[9] Entsorgungskommission
Leitlinien für die Zwischenlagerung von radioaktiven Abfällen mit vernachlässigbarer Wärmeentwicklung,
Empfehlung vom 10. Juni 2013, Bundesanzeiger AT 22.01.2014 B3, S. 2-47
(revidierte Fassung). Aktualisierte Fassung ist in Vorbereitung.

[10] GGVSEB
Verordnung über die innerstaatliche und grenzüberschreitende Beförderung gefährlicher Güter auf der Straße, mit Eisenbahnen und auf Binnengewässern (Gefahrgutverordnung Straße, Eisenbahn und Binnenschifffahrt - GGVSEB)
vom 17. Juni 2009 in der Fassung der Bekanntmachung vom 11. März 2019 (BGBl. I S. 258), zuletzt geändert durch Artikel 14 des Gesetzes vom 12. Dezember 2019 (BGBl. I S. 2510)

[11] GGVSEB-Durchführungsrichtlinien – RSEB
Richtlinien zur Durchführung der Gefahrgutverordnung Straße, Eisenbahn und Binnenschifffahrt (GGVSEB) und weiterer gefahrgutrechtlicher Verordnungen (Durchführungsrichtlinien-Gefahrgut) - RSEB
vom 03. Mai 2019 (VkBl. 2017, Nr. 8, S. 306)

[12] ADR
Anlagen A und B des Europäischen Übereinkommens vom 30. September 1957 über die internationale Beförderung gefährlicher Güter auf der Straße (ADR)
in der seit dem 01. Januar 2019 geltenden Fassung (BGBl. 2018 II S. 443 mit Anlagenband)

[13] RID
Ordnung für die internationale Eisenbahnbeförderung gefährlicher Güter - RID (BGBl.II 1999, Nr. 33, S. 2256), Neufassung vom 16. Mai 2008 (BGBl.II 2008, Nr. 12, S. 475 mit Anlagenband), zuletzt geändert durch 21. RID-Änderungsverordnung vom 05. November 2018 (BGBl. 2018 II 2010, Nr. 21, S. 494)

[14] BLG
Technische Annahmebedingungen (TA) für das Abfalllager Gorleben
Rev. 2.0, Stand 12/95

[15] DIN 4102, Teile 1 bis 4
Brandverhalten von Baustoffen und Bauteilen
(Teil 1: Fassung 05/1998; Teil 2: Fassung 09/1977; Teil 3 Fassung 09/1977;
Teil 4: Fassung 05/2016)

[16] KTA 2201, Teil 1
Auslegung von Kernkraftwerken gegen seismische Einwirkungen
Teil 1: Grundsätze, Fassung 11/2011

[17] Verordnung über den kerntechnischen Sicherheitsbeauftragten und über die Meldung von Störfällen und sonstigen Ereignissen (Atomrechtliche Sicherheitsbeauftragten- und Meldeverordnung – AtSMV) vom 14. Oktober 1992 (BGBl. I S. 1766), zuletzt geändert durch Artikel 18 der Verordnung vom 29. November 2018 (BGBl. I. S. 2034)

[18] KTA 1201
Anforderungen an das Betriebshandbuch; Fassung 11/2015

[19] Richtlinie zur Emissions- und Immissionsüberwachung kerntechnischer Anlagen (REI) vom 7. Dezember 2005 (GMBl. 2006, Nr. 14-17, S. 254)

[20] Western European Nuclear Regulator's Agency (WENRA)
Radioactive Waste Treatment and Conditioning Safety Reference Levels v. 1.1
Report of the Working Group on Waste and Decommissioning (WGWD), April 2018

[21] IAEA Safety Standards
Preparedness and Response for a Nuclear or Radiological Emergency
General Safety Requirements No. GSR Part 7, November 2015

[22] KTA 1404
Dokumentation beim Bau und Betrieb von Kernkraftwerken; Fassung 11/13

[23] DIN EN ISO 9001
Qualitätsmanagementsysteme – Anforderungen (ISO 9001:2015); letzte Ausgabe 11/2015

[24] Gesetz über die friedliche Verwendung der Kernenergie und den Schutz gegen ihre Gefahren (Atomgesetz - AtG) vom 23. Dezember 1959,
Neufassung vom 15. Juli 1985 (BGBl. I. S.1565), zuletzt geändert durch Artikel 239 der Verordnung vom 19. Juni 2020 (BGBl. I S. 1328)

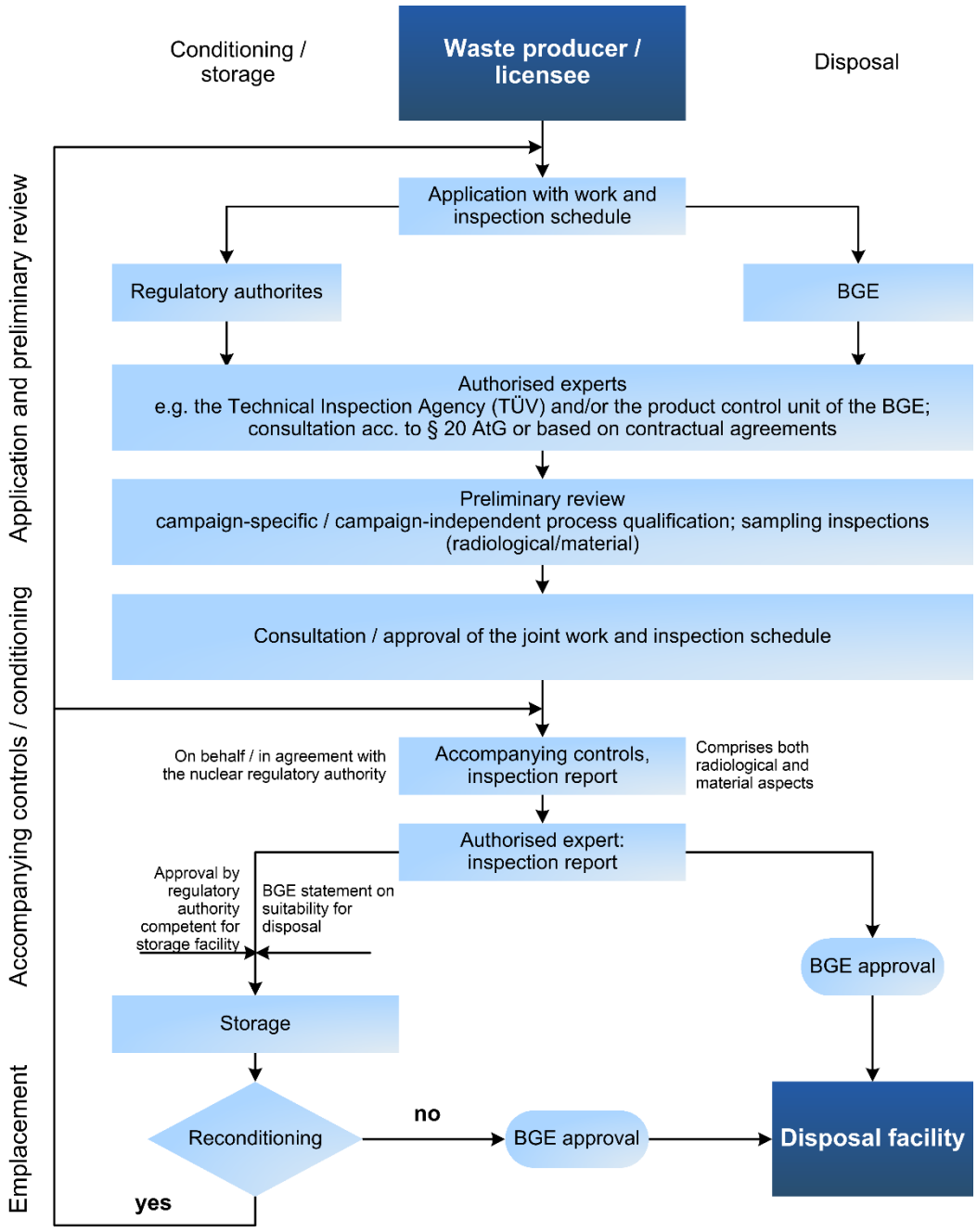
[25] Richtlinie 2011/70/EURATOM des Rates vom 19. Juli 2011 über einen Gemeinschaftsrahmen für die verantwortungsvolle und sichere Entsorgung abgebrannter Brennelemente und radioaktiver Abfälle. – EU-Abl. L199/48 v. 2.8.2011

[26] Gutachtergemeinschaft RADWASTE
TÜV NORD EnSys Hannover GmbH & Co. KG, Produktkontrollstelle des BfS in der Forschungszentrum Jülich GmbH, WEITERE STANDORTE,
Langzeitverhalten von vernachlässigbar Wärme entwickelnden, radioaktiven Abfallprodukten / -gebinden, August / September 2009

[27] Stefan Steyer (Bundesamt für Strahlenschutz), Birgit Peschel (TÜV NORD EnSys Hannover GmbH & Co. KG) et. al.
Gasbildungsraten als Indiz für die Langzeitstabilität radioaktiver Abfallprodukte
KONTEC 2007

Annexes

Annex 1 to Chapter 3.1: Product control flow chart for radioactive waste [3, 8]



Flow chart legend [3]

Waste producer / licensee
Submits an application to the federal company for radioactive waste disposal (Bundesgesellschaft für Endlagerung – BGE) and the regulatory authority on conditioning and inspection plans together with a work and inspection schedule. The institutional waste collecting facilities of the *Länder* in general assume the tasks of the waste producers within the frame of product control.

Application with work and inspection schedule
A submitted application may address process qualification, a specific conditioning campaign (including sampling inspection) or a sampling inspection. The respective schedule comprises all relevant work and inspection steps of the project with regard to the waste packages. The application with the part relevant for the verification that the waste acceptance criteria for disposal have been meet and the parts of the schedule that are facility-specific and/or relevant for storage is submitted to the BGE and the competent supervisory authorities by the waste producer / licensee.

Regulatory authority
Competent for facilities and measures of the waste producer / licensee and for a potential storage facility. In accordance with § 20 AtG, it commissions, where required, experts to review the documents submitted regarding compliance with the requirements of a specific nuclear installation or storage facility, respectively, in agreement with the experts consulted by the BGE. It approves the planned conditioning or storage and informs the BGE of its decision.

BGE
Commissions, if required, experts to review the documents submitted on the requirements for disposal in agreement with the experts consulted by the supervisory authorities. The BGE informs the competent regulatory authorities of the result of its review.

Preliminary review
The preliminary review is the review of the work and inspection schedule submitted and, where required, further documents. It takes place campaign-dependently or campaign-independently of a conditioning process or a sampling inspection procedure. On the basis of the preliminary review, the experts involved specify in the schedule which inspections are regarded as necessary. Experts are commissioned in specific cases, as defined in the BGE schedule, in consultation with the BGE. The review results of the experts shall in each case be outlined in one statement under consideration of the results of the consultation of the other experts involved, which forms the basis for the corresponding authority's decision on the project applied for.

Approval of the joint work and inspection schedule
The BGE approval regards the compliance with the waste acceptance criteria for disposal fulfilled. The approval of implementation of the schedule is granted by the competent regulatory authority.

Accompanying controls
The inspections performed by the experts specified in the work and inspection schedule are performed and documented on behalf of the supervisory authority of the waste producer (see also preliminary review). In case of external conditioning, the accompanying control is also performed on behalf of this authority with the possibility of consulting local experts.

Authorised experts
The expert for accompanying controls summarises the results of the accompanying controls regarding the requirements of the storage facility and the disposal facility in an inspection protocol for the supervisory authorities and the BGE. On the basis of this inspection protocol and review of the documentation, the BGE expert prepares an inspection report for the BGE.

Storage
Depending on the requirements for the storage facility (storage in terms of § 7 AtEV [4] or § 6(1) AtG /24/ or as part of a practice subject to licensing pursuant to § 7 or § 9 AtG /24/ or other type of storage), the competent supervisory authority gives its approval to the emplacement. The BGE issues a statement on the compliance with waste acceptance criteria for disposal as far as at this time the results of the examinations required from the point of view of disposal are available to it.

Post-conditioning
In the case of work and inspection plans already subjected to preliminary reviews that consider post-conditioning measures that might be required, still necessary post-conditioning of waste packages requires accompanying controls. For waste packages to be subjected to post-conditioning without approved work and inspection schedule, the entire product control process has to be carried out.

Disposal facility
The transport of the waste packages to the disposal facility is subject to the approval by the BGE.

Annex 2 to Chapter 3.2 (from [26, 27]):

Assessment of gas formation rates of conditioned waste regarding maintenance of waste form characteristics during storage that are relevant for disposal

Changes of waste form characteristics are indicated by changes in the gas compositions of the atmosphere inside the waste packages. Gases such as hydrogen, methane, carbon dioxide or carbon monoxide are formed by digestion, fermentation or corrosion processes. Here, the extent of the changes of waste form characteristics corresponds to the amount of gas developed. The assessment of the analysis results of the gas samples has so far been based on a gas formation rate of 2 ml/(m^3 h), which after application of the present state of the conditioning technique is generally reached for compacted mixed waste.

The evaluation of the gas analysis results showed that compliance with this recommendation in principle presents no major problems. Exemplary considerations show that in some cases even larger gas formation rates can be tolerated regarding compliance with the waste acceptance criteria for disposal. Even with conservative approaches regarding the effect of the chemical reactions that lead to gas formation and regarding the assumed kinetics of these reactions, studies showed that with gas formation rates below 10 ml/(m^3 h), except for waste forms of the waste form group APG03, adverse effects regarding the suitability of the products for disposal are not to be suspected also for a storage period of 20 years.

Since the estimated maximum permissible gas formation rates relate to the classification of the waste forms according to waste form groups to determine the cumulative values for accidents, these are to be adhered to with high reliability for each waste package of a test batch. To limit the efforts and occupational radiation exposure, usually, only a limited number of gas samples are taken. For assessing the suitability of the units of this test batch for disposal, a mean value of the gas formation rates determined can then be referred to. To cover the possible distributions of gas formation rates within this test batch, the permissible mean value of a sample is lower than the maximum permissible gas formation rate for a single waste package.

Table 1 summarises for the various requirements for waste form groups, the maximum permissible gas formation rates for each package of a test batch, and the permissible mean values for a sample. If each waste package of a test or conditioning batch is tested individually, the maximum gas formation rate can of course be used to assess the suitability for disposal.

Regarding compliance with the basic requirement “free liquid”, maximum permissible gas formation rates of 10 and 20 ml/(m^3·h) were determined for a single package with waste of waste form groups APG01 and APG02, and APG04 and APG05, respectively. The gas samples of a sampling must show a mean value of the gas formation rate of less than 5 or 10 ml/(m^3 h), respectively.

For waste forms of APG06, the table does not include information on permissible gas formation rates. For such waste forms, no mechanisms for the formation of gases due to relocation of the waste after a cooling phase were found.

Table 1: Maximum permissible gas formation rates and maximum permissible mean values of analyses of a sampling

Waste form-group	Requirements	Maximum gas formation rate [ml/(m³ h)]	Permissible mean value for a conditioning batch [ml/(m³ h)]
APG01	Free liquid	10	5
APG02	Flammable, meltable substances	10	5
APG03	Non-metallic components	3	2
APG04	Strength of the compacts	20	10
APG05	Compressive strength	20	10

By increasing the extent of sampling, the waste deliverer may demonstrate that the requirements are met. If this should not be feasible or successful, post-conditioning measures are to be carried out for the test batch. Packages with waste forms of waste form group APG01, 02, 04 or 05, with gas formation rate above 10 and 20 ml/(m³ • h), respectively, have to be post-conditioned e.g. by drying. If due to knowledge of the waste composition it can be excluded that liquids or flammable substances with a melting point below 300°C can be formed by decomposition of organic material, the maximum permissible gas formation rate of 20 ml/(m³ h) may be referred to for assessments of waste forms of the waste form groups APG01, 02, 04 and 05.

Annex 3 to Chapter 10: Contents of the on-site emergency plan

Emergency preparedness

- List of conceivable events, including combinations of nuclear and non-nuclear hazard situations, which may collectively lead to an emergency; where relevant: description of such possible events and their consequences,
- conditions and criteria for declaration of an emergency and description of appropriate means of alerting the responsible personnel and the authorities,
- an inventory list of emergency aids provided and their locations, and
- requirements for training of the personnel.

Personnel, organisational responsibilities and provisions

- Names of the persons in charge of internal activities and being responsible for contacts with external organisations,
- a list of authorised persons entitled to declare an emergency, including their occupational title and description of functions,
- command and communication structure, including a description of related facilities and processes; means for instructing all persons who are to be informed on the on-site emergency measures should be provided,
- the measures to be performed by persons and organisations for execution of the emergency plan, and,
- the provisions for termination of the emergency.

Assessment of the impacts of the event

- Provisions for monitoring the radiological conditions on-site and off-site (water, vegetation, soil, air),
- assessment of the condition of the facility,
- provisions for minimisation of doses to individuals and medical care for injured people, and
- on-site measures to limit releases and prevent dispersion of radioactive substances.

Annex 4 to Chapter 11.1 and 11.2: Contents of the safety documentation

The safety documentation of the conditioning facility should include the following:

- a description of the site characteristics, the conditioning facility(ies) and ancillary installations/infrastructure, design features and safety functions, as well as a list of safety-relevant structures, systems and components,
- a description of the handling procedures and other operational processes,
- a description of the performance characteristics (acceptance criteria, processing capacity, discharges) and the expected throughput,
- information on the expected operating time,
- the safety assessment for normal operation and for possible accidents during postulated initiating events, as well as proof of compliance with the safety criteria and radiological limits,
- a description of the management system,
- a description of the provisions to minimise operational waste,
- a description of commissioning, assessment of the deviations identified during commissioning including the reasons for deviations,
- definition of an adequate programme for the continuous proof that the conditioning facility produces waste forms of required and consistent quality,
- the operating documentation on
  - operational limits and the conditions for the safe operation of the conditioning facility and its technical basis,
  - process descriptions and operating procedures for safety-relevant operations,
  - provisions for operational inspections, maintenance and testing,
  - programme for the evaluation of operating experience,
  - ageing management programme, and
  - training programme for employees,
- a preliminary description of the decommissioning concept for the conditioning facility.