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Technical regulations for predisposal management of high level radioactive waste

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Technical regulations for predisposal management of high level radioactive waste

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Contents

Foreword

This standard was proposed by China National Nuclear Corporation.

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Technical regulations for predisposal management of high level radioactive waste

1 Scope

This standard specifies the basic requirements and technical conditions for the predisposal management of high level radioactive waste (HLW).

This standard is applicable to high level radioactive liquid waste (hereinafter referred to as "liquid HLW"), waste form obtained by solidification of liquid HLW (also known as "HLW solidified form"), high level radioactive solid waste, spent fuel identified as waste and other wastes with comparable radioactivity.

This standard is also applicable to the design, operation and decommissioning of equipment or facilities for the predisposal management of HLW.

2 Normative references

The following normative documents contain provisions which through reference in this text, constitute provisions of this standard. For dated references, subsequent amendments (excluding corrections), or revisions, of any of these publications do not apply to this standard. However parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

GB 9133 Classification of radioactive waste

GB 11806 Regulations for the safe transport of radioactive material

GB 11929 Regulations for designing storage building of high level radioactive liquid waste

GB 14500 Regulations for radioactive waste management

GB 18871 Basic standards for protection against ionizing radiation and for the safety of radiation sources

EJ 1186 Characterization of radioactive waste forms and packages

HAD 301/02 Design of spent fuel storage facilities

HAD 301/03 Operation of spent fuel storage facilities

HAD 301/04 Safety Assessment of spent fuel storage facilities

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

high level radioactive waste（HLW）

Such level of Waste that has high activity concentrations and heat release rates require shielding and cooling during normal handling and transportation. Generally it refers to: liquid HLW containing a large amount of fission products and a small amount of lanthanides produced by a spent fuel reprocessing co-decontamination separation cycle and its solidified form, spent fuel identified as waste or other waste with similar radiological characteristics. For specific description, see GB 9133.

3.2

HLW predisposal

All management activities carried out prior to the disposal of HLW, including treatment, conditioning, transportation, storage, etc.

3.3

waste conditioning

An operation performed to form a waste package suitable for handling（(loading）, transportation, storage, and/or disposal. Conditioning can include converting the waste into a solid form, encapsulating it in a container, and including adding an overpack as necessary.

3.4

waste minimization

From the design of the facility to the decommissioning stage, the amount and activity of radioactive waste can be reduced to as low as reasonably achievable (ALARA) by reducing waste generation, recycling and reuse, and proper treatment of primary and secondary waste.

3.5

Containment

A method or physical structure that prevents the accidental release of radioactive material.

3.6

defense in depth

Applying multiple safeguards for a given safety goal allows the safety goal to be achieved even if one or more of the protective measures fail.

3.7

characterization

Activities by investigation, calculation, analysis, and/or measurement to determine the performance of physical, chemical, and radioactive of waste forms and waste packages

3.8

waste form

Solid waste with certain physical properties and chemical forms formed by treatment and/or conditioning. The waste form is an integral part of the waste package.

3.9

waste package

A product formed after conditioning in accordance with handling, transportation, storage, and/or disposal, including waste forms, containers, and fillings in containers. Also referred to as waste packages in transportation.

3.10

radioactive waste container

Containers for handling (loading), transportation, storage and/or final disposal of radioactive waste, including containers for direct containment of waste, shielding containers, outer packaging and shipping containers, and additional shock absorbing devices.

4 General considerations

4.1 Objective

The predisposal management of HLW shall be in accordance with the provisions of GB 14500 and other relevant standards, to produce waste packages that can be safely handled（loaded）, transported, stored and disposed, through scientific, reasonable administrative and technical measures.

4.2 Protection of human health

The predisposal management of HLW should ensure that the impact on the health of workers and the public is at an acceptable level. The relevant provisions of GB 18871 should be met in determining the acceptable level of radiation protection, which require that the possibility of exposure, the individual dose and the number of exposed people be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account. It should comply with the corresponding national standards in determining the acceptable level of damage to other toxic substances.

4.3 Protection of environment

The predisposal management of HLW should ensure that the environmental impact is at an acceptable level. The determination of acceptable level should comply with the requirements of the corresponding national standards, and meet the limits and conditions set by the regulatory authority.

4.4 Waste minimization

The amount and activity concentration of radioactive waste should be reduced to the practicable minimum that can be reasonably achieved through management and technical methods such as optimizing management, reduction at source, recycling and reusing and volume reduction.

4.5 Interrelation

When selecting strategies and activities for predisposal management of HLW, the different steps of management should be planned so that the safety plan adopted throughout the management can take into account the requirements of each step, and avoid the conflict between safety requirements and operational requirements. Acceptance criteria are established as necessary, and validation tests or inspection records are used to confirm compliance with acceptance criteria.

5 Characterization

5.1 The various steps of management prior to disposal of HLW should be characterized upon requirements, the basic information of nature and characteristics is provided in Appendix A.

5.2 The solidified HLW should be characterized by non-destructive testing, some special tools can be used for sampling and analysis if necessary.

5.3 Characterization information of spent fuel should be obtained from the operational record of the reactor and the radionuclide decay record after the spent fuel is discharged, and non-destructive testing techniques should be used to verify the key parameters. At the same time, the integrity of the spent fuel cladding should be considered.

6 Safety considerations

6.1 General considerations

The radionuclide concentration and radiation level of HLW are very high. During the predisposal management activities of HLW, special attention should be paid to preventing and detecting the occurrence of events and accidents, reducing the seriousness of the consequences.

6.2 Containing

Management activities prior to disposal of HLW should be carried out in a manner that prevents leakage of radionuclides or prevents loss of inclusive integrity. Depending on the type of waste concerned, protection may be provided solely by a container or by a container supplemented by the safety systems of the facility. For the HLW that has been conditioned, sufficient containment capacity should be provided by the waste package.

6.3 Heat removal

The temperature of the HLW should be within acceptable limits in all stages of predisposal management. Such temperature limits should be based on the properties of the waste, with account taken of the material properties of the container, the containment structures and the waste form.

6.4 Criticality safety

In order to ensure that HLW is always in subcriticality during predisposal management, appropriate neutron multiplication factors should be used as limiting factors, with using safe geometrical configurations, limitations on concentrations and inventories of fissile material or the use of neutron poisons. If the operational scheme for the processing of HLW is changed, critical calculations should be repeated for each link to confirm that the change does not cause criticality.

6.5 Radiation safety

The management of HLW before disposal shall meet the requirements of GB 18871 for radiation protection. The activities of HLW management should be carefully planned and implemented with caution, evaluated prior to work and trained on physical models to minimize the exposure during operation and maintenance activities. Radiation doses should be kept ALARA by remote handling techniques for operations and maintenance, and by establishing limits on the activities and dose rates for the items to be removed from highly contaminated or radioactive areas to less contaminated or radioactive areas. When manually operating, adequate protection is provided by decontamination of the equipment and by the use of temporary or permanent shielding. Radiation workplace zoning should be considered for the relevant areas managed before the disposal of HLW, and access control should be carried out.

6.6 Industrial safety

Predisposal management of HLW should consider industrial safety. According to the relevant standards related to health and safety and environmental protection, measures should be taken to prevent human health and environmental hazards caused by hydrogen explosion and other physical and chemical properties.

6.7 Emergency preparedness

Radiation hazard assessment should be carried out for all possible events and accidents, and emergency preparedness should be carried out based on the results of this evaluation, providing necessary equipment and personnel to ensure the capability of responding effectively to various incidents and accidents. The preparations develop emergency procedures for each situation based on some hypothetical events or accidents . Care should be taken to ensure that the necessary emergency response procedures are documented, that the documents are available to the personnel concerned and that the procedures and documents are kept up to date. Emergency training and exercises should be conducted on a regular basis. Inspections should be performed regularly to ascertain whether the equipment needed in the event of an emergency is available and in working order.

6.8 Facility safety

6.8.1 Designing

6.8.1.1 The predisposal management facilities for HLW should be designed according to the specified design life. The design should consider the possibility of remote operation, which is convenient for personnel to inspect, maintain, replace and facilitate decommissioning.

6.8.1.2 The building (construction) of the facility, the structural materials of the important systems and equipment for safety, the manufacturing and construction techniques, and the testing procedures shall be based on the design specifications and standards and the requirements of the regulatory authority.

6.8.1.3 When designing pre-disposal management facilities for HLW disposal, the following main factors that may have an impact on safety should also be considered:

a) The retrieval of stored HLW or secondary waste generated in management operations;
b) The characterization of HLW;
c) The inspection of stored HLW;
d) The management of HLW for non-radiological hazards and of any secondary waste generated;
e) The control of liquid and gaseous effluents;
f) Protection against fires;
g) Access control and the control of movement between radiation and/or contamination zones.

6.8.2 **Operation**

6.8.2.1 The operation of a facility for the predisposal management of HLW should follow pre-established rules and procedures.

6.8.2.2 After the permanent shutdown of facility, it shall be safely closure according to relevant regulations and standards. Only after approval by the regulatory authority can the decommissioning stage be entered.

6.8.3 **Decommissioning**

6.8.3.1 A plan of decommissioning should be considered during the design of a facility for the management of HLW.

6.8.3.2 The key elements that should be considered for the decommissioning of facilities for the predisposal management of HLW are following:

a) Determining criteria for final state of decommissioning, including partial or complete deregulation of the facility;
b) The decommissioning programme should be selected, taking into account the radioactive source term and chemical composition of HLW, the type of management facility for the HLW, technical factors, costs, schedules and institutional factors are taken into account;
c) The development of a decommissioning plan, including an initial plan and a final plan in which any major modifications to the facility and information derived from its operational history after the preparation of the initial decommissioning plan are taken into account;
d) Describe in detail the key tasks involved in the decommissioning of facilities, in particular the identification of source items,, decontamination, dismantling, disassembling, supervision and final investigation of state;
e) Decommissioned training, organization, radioactivity monitoring, planning and control of waste management, physical protection, nuclear safeguards, and quality assurance.

6.8.3.3 The decommissioning of facilities for the predisposal management of HLW may give rise to many serious contaminated components that are difficult to decontaminate. Designated storage, processing or disposal arrangements for such items should be provided. It should be ensured that the decontamination is carried out safely and that the requirements of clearance for materials are met.

7 **Predisposal management of liquid HLW**

7.1 **Storage of liquid HLW**

7.1.1 The liquid HLW storage facility shall have safe and reliable pipes and containers, equipment department coverings and liquid collection pits related to the waste liquid storage tanks.

7.1.2 The liquid HLW storage tank should be made of corrosion-resistant stainless steel or other corrosion-resistant alloy materials to meet the requirements of strength, rigidity and seismic resistance. The seismic characteristics should be calculated in combination with the site characteristics. The storage tank should undergo strict inspection.

7.1.3 Protective measures to prevent hazards associated with high-level effluent storage should be provided through the use of multiple active or passive safety systems. These special safety features include measures to maintain the suspension of solids, venting of gases that may be generated, and shielding and containment systems.

7.1.4 Monitoring equipment should be configured for liquid HLW storage facilities to ensure proper operation of safety-related systems such as ventilation, cooling and level detection systems.

7.1.5 Measures should be provided to monitor the key physical and chemical parameters of the waste (e.g. temperature and pressure, concentrations of key constituents, the degree of the radiolytic decomposition of aqueous solutions and levels of potentially flammable or explosive substances). Consideration should be given to providing redundant capabilities for the monitoring and indication of the measured values.

7.1.6 Means should also be provided for maintaining these parameters of 7.1.5 within acceptable operational limits, as well as for maintaining the discharge of airborne and liquid effluents within the regulatory limits.

7.1.7 Other regulations regarding the storage of liquid HLW shall be in accordance with GB 11929.

7.2 Conditioning of liquid HLW

7.2.1 Solidification

7.2.1.1 Basic requirements

The basic requirements for Liquid HLW solidification and its solidified form include:

a) The solidification process should be able to adapt to components and changes of composition of Liquid HLW;
b) The solidified form has good thermal conductivity, radiation stability and mechanical strength;
c) The solidified form has a low radionuclide leaching rate;
d) The solidified form is non-explosive, non-self-igniting and non-corrosive to the waste packaging container;
e) Has a obvious capacity reduction effect and a large waste package capacity;
f) Minimize the generation of secondary waste;
g) Simple process, safe and reliable remote operation and maintenance, low processing costs.

7.2.1.2 Solidification Processing

The solidification process of liquid HLW includes: glass solidification, ceramic solidification, glass ceramic solidification, artificial rock solidification, composite solidification, and so on. It should be selected according to the advantages and disadvantages of each process and the application conditions.

If a glass solidification process is used, the performance requirements of the solidified form should meet the requirements of EJ 1186. If other solidified processes are used, the properties of the solidified form should meet the relevant requirements.

7.2.2 HLW packaging

7.2.2.1 The HLW packages shall be designed to meet the safety requirements for handling, transport and storage.

7.2.2.2 When the HLW packages do not meet the specified technical requirements or require remedial action, the existing waste facilities shall have the ability to handle and store HLW packages.

7.2.2.3 Other requirements for HLW packages shall comply with the requirements of EJ 1186.

7.3 Storage of liquid HLW waste solidified form

7.3.1 During storage, the state of the waste package containing the prepared waste shall be maintained within the acceptance requirements and shall not be adversely affected by the loading and unloading operations including retrieval.

7.3.2 The integrity and temperature limits of the waste package need to be maintained. Means for monitoring the condition of the waste packages and the storage conditions should be provided or technical analyses should be performed to evaluate the condition of the packages from relevant parameters.

7.3.3 Storage facilities for conditioned waste from reprocessing should be so designed and operated as to avoid unnecessary handling, in order to prevent the undue exposure of workers and to maintain the integrity of the waste packages

7.3.4 Storage facilities of liquid HLW waste solidified form should have means to deal with damaged waste packages.

8 Predisposal management of solid HLW

8.1 Source

Solid HLW mainly comes from the following facilities:

a) spent fuel reprocessing facilities, including:
   1) Waste structural materials, spent cladding and other wastes generated during maintenance of spent fuel shearing, dissolution section operation and maintenance;
   2) 1AF material liquid filter generated by the co-decontamination section, waste valve core generated during maintenance, waste pump head, contaminated tools, gloves, overalls, etc.;
   3) Highly polluting parts, cutting and dismantling waste equipment and other wastes from the shearing, dissolving and co-decontamination sections during decommissioning.
b) Nuclear reactor facilities, mainly including:
   1) Waste resin produced by primary circuit water treatment;
   2) HLW generated during reactor overhaul and/or accident handling;
   3) Waste components in reactor during decommissioning.

8.2 Processing and Conditioning

The purpose of solid HLW processing and conditioning is to reduce volume and stabilize. The main measures include:

a) sorting out solid HLW;
b) reduce the volume by compaction;
c) Pack solid HLW in HLW containers. If necessary, it can be fixed in a container with a suitable, radiation-resistant fixing medium;
d) The HLW package formed after conditioning shall meet the requirements for subsequent storage, retrieval, transportation and disposal;
e) In special cases, solid HLW can be decontaminated to reduce its pollution level.

8.3 Storage and retrieval

The purpose of solid HLW storage is to ensure the safety and retrievability of solid HLW packages before they are disposed of. The main measures include the following devices or systems:

a) adequate and effective cooling and monitoring systems to prevent the temperature of the waste package from exceeding the limits specified in the design;
b) devices capable of properly monitoring the damage of the waste package;
c) Safe and reliable means for remote operation and retrieval of waste packages.

9 Predisposal management of spent fuel

9.1 Intermediate storage

9.1.1 There are two types of intermediate storage methods for spent fuel: wet storage and dry storage. The facilities for them should have anti-seismic and anti-critical measures.

9.1.2 The wet storage tank shall be of concrete construction with stainless steel lining and shall have measures for detecting leakage. The pool water should be kept at a low temperature and excellent water quality. It should be treated by ion exchange and filtration continuously or periodically, and appropriate measures should be taken to avoid sludge at the bottom of the pool.

9.1.3 For dry storage, spent fuel should be stored in special containers and structures made of steel or concrete.

9.1.4 The design of spent fuel storage facilities should meet the requirements of HAD 301/02.

9.1.5 The operation of spent fuel storage facilities shall be in accordance with HAD 301/03.

9.1.6 The safety assessment of spent fuel storage facilities shall be carried out in accordance with HAD 301/04.

9.2 Processing and storage

9.2.1 Processing and storage should be based on the type of spent fuel and its subsequent management requirements. Most light water reactor spent fuel should be reprocessed to extract nuclear material from it. Other reactor-type spent fuel may be sent to intermediate storage or directly to a deep geological repository for disposal.

9.2.2 The management of spent fuel reprocessing shall be carried out in accordance with the relevant national regulations and standards. The once-through conditioning of spent fuel shall be managed in accordance with the requirements of 9.3.

9.2.3 The spent fuel assembly should be placed directly into the spent fuel intermediate storage container or storage container based on the characteristics of the spent fuel (see Table A.1). The former usually uses stainless steel containers, welded and sealed, and then placed in a spent fuel cooling pool or dry storage for cooling storage. The latter usually uses spent fuel storage or transport containers, sealed and placed in a rudder storage or open storage yard for dry cooling storage.

9.3 Conditioning

9.3.1 Suitable containers should be selected according to the characteristics of the spent fuel. Then loading, fixing, sealing and inspecting to form a waste package which meets the requirements for storage, transportation and disposal. In principle, spent fuel should be loaded into the container in the form of fuel assemblies.

9.3.2 The design of the container shall meet the following basic requirements:

a) Appropriate measures should be taken to prevent nuclear critical reactions, such as setting up shelves or baskets that maintain a fixed distance between components, and adding materials containing neutron absorbing materials;
b) shall have sufficient mechanical strength to ensure the integrity and dimensional stability of the container and its interior during handling, transportation, storage and design basis accidents;
c) should have good heat dissipation and thermal conductivity, such as setting the surface heat sink and internal thermal pad;
d) should have good airtight performance to ensure long-term containment of the container;
e) that there should be sufficient shielding thickness against neutrons and gamma radiation to protect the personal safety of workers and the public;
f) For containers made of non-corrosive materials, a certified coating or coating of approved anti-corrosion coatings shall be used.

9.3.3 When the designed container cannot withstand the mechanical load expected in the disposal facility alone, the internal space of the container may be filled with a pressure-resistant material that provides better thermal conductivity and provides internal support.

9.3.4 The secondary waste generated during the conditioning process shall be classified and partially solid waste generated by disassembling the fuel element may be conditioned together with the spent fuel.

9.3.5 The choice of packaging container materials and disposal plan should consider the geological structure of the repository, geochemistry, and the effects of temperature and pressure, and should be tested for a long time.

9.3.6 Damaged spent fuel assembly should be handled, conditioned and stored separately to avoid contaminating storage pool, storage repository or containers.

9.4 Storage of conditioned spent fuel

The storage of conditioned spent fuel is similar to the storage of conditioned liquid HLW from reprocessing, see 7.3. But it should pay more attention to the critical safety.

10 Transportation of HLW

10.1 The operating organization should establish requirements and authorizations for ensuring the safety of on-site transport.

10.2 The operating organization shall formulate an emergency response plan for various scenarios of possible accidents.

10.3 Off-site transportation of solid HLW (including spent fuel) shall comply with relevant national regulations and meet the requirements of GB 11806.

11 Record keeping and reporting

11.1 Record keeping

11.1.1 The operating organization of a facility should establish a procedure for maintaining adequate documentation and records in accordance with the quality assurance programme.

11.1.2 Records have different validity periods. The requirements are for the records that relate to the waste management facility, the waste itself and compliance with the acceptance criteria for waste disposal, the documents must be retained for a period as required by the regulatory authority. These records should include:

a) The data needed for a national inventory of waste;
b) The data needed for waste characterization;
c) The records from the control processes for treatment, packaging and conditioning;
d) The documents on the procurement of containers required to provide confinement for a certain period (e.g. in a repository);
e) The specifications for waste packages and audit records for individual containers and packages;
f) Trends in operating performance;
g) Non-compliances with the specifications for waste packages and the actions taken to rectify them;
h) The monitoring records;
i) The results of safety assessments;
j) The written operating procedures;
k) Any additional data as required by the regulatory authority.

11.1.3 A waste characterization record should contain the following information pertaining to the waste:

a) The source or origin;
b) The physical and chemical form;
c) The amount (volume and/or mass);

d) The radiological characteristics (the activity concentration, the total activity, the radionuclides present and their relative proportions);
e) The classification in accordance with the national waste classification system;
f) Any chemical, pathogenic or other hazards associated with the waste and the concentrations of hazardous material;
g) Any special handling necessary owing to criticality concerns, the need for the removal of decay heat or significantly elevated radiation fields.

11.2 Reporting

11.2.1 The operating organization of the facility should periodically submit reports depending on the conditions of authorization to the regulatory authority, in accordance with the required schedule. Routine reports should provide information on the waste management operations conducted during the reporting period and the situation at the time of reporting. In general, the report should include a summary description of:

a) The liquid HLW or spent fuel received, either of external origin or generated within the facility itself, including secondary waste from the processing of primary waste and waste from the maintenance or decommissioning of any structures, systems or components at the facility;
b) The processing of the waste, as well as details of the processes used;
c) Any waste released by transfer;
d) Effluent discharges;
e) Material from which regulatory control is removed;
f) An inventory and the net changes over several years in the inventory of the liquid HLW and spent fuel received, processed, stored and transferred at the facility, as well as trends in safety performance;
g) Estimates of the impacts of the facility in terms of the radiation exposure of workers and the public;
h) Non-compliances with the waste acceptance criteria or other requirements.

11.2.2 The operating organization of a facility should report promptly to the regulatory authority any incident or accident or the discovery of any information that calls into question any aspect of the safety of the facility or the basis for its authorization. Non-compliances with the acceptance criteria for waste and the actions taken or proposed to rectify the situation should also be reported to the regulatory authority.

12 Environmental impact assessment and safety assessment

12.1 The operating organization that manages facilities or activities prior to the disposal of HLW shall conduct environmental impact assessment and safety assessment in accordance with the provisions of the regulations and the requirements of the regulatory authorities.

12.2 Impacts on public and environmental and safety of facilities and activities should be assessed under normal operations and hypothetical accidents.

12.3 The assessment shall be carried out before the construction and operation of the predisposal management facility of HLW. Operating organization shall prepare the facility decommissioning plan and estimate the environmental impact of the decommissioning after a certain period of operation and experience accumulated.

12.4 The operating organization shall improve the safety of the facility and the reliability of the operation according to the important pathways, operations and equipment indicated in the environmental impact and safety analysis report to reduce the possibility or mitigate the consequences of the event or accident.

12.5 The scope and level of detail of environmental impact assessment and safety assessment should be compatible with the characteristics of HLW and the type of facility.

12.6 A safety assessment for a facility for the predisposal management of HLW should, as a minimum, address the following topics:

a) The specification of relevant safety criteria;

b) Methods for the identification, collection and evaluation of data and information;
c) The specification of normal and abnormal operating conditions;
d) The determination of potential consequences of normal operations and abnormal events;
e) An assessment of the potential consequences of normal operations and abnormal events on the basis of safety criteria.

12.7 The following data and information as a minimum should be obtained and analysed in order to conduct a safety assessment for a facility for the predisposal management of HLW:

a) Detailed data about the design of the facility
b) Data on the physical and chemical properties of the HLW in processing;
c) Possible variations in the composition of the HLW;
d) Data related to the selected site;
e) Data on the operating ranges or limits necessary to establish safety limits and operating conditions.

12.8 Safety-related information on the following pre-disposal management facilities for HLW should be obtained:

a) the exposure dose of the staff member and the nature and intensity of the radiation consequences to the environment;
b) organizational safety and protective measures;
c) The quality assurance plan of the operating organization.

12.9 Consideration should be given to the conditions, processes and events affecting the safety and integrity of the facility, see Appendix B, C, D.

12.10 The safety assessment of abnormal operating conditions should cover expected operational events as well as accident conditions.

13 Quality assurance

13.1 The operating organization of facilities and activities shall formulate and implement a quality assurance program for predisposal management of HLW in accordance with relevant regulatory standards and as required by the regulatory authority. This quality assurance program should ensure that:

a) Facilities and equipment for the predisposal management of HLW are designed, constructed, commissioned, operated and decommissioned in accordance with the appropriate specifications and requirements for safe operation;
b) Steps in the predisposal management of HLW are such as to facilitate compliance with known or anticipated acceptance requirements for the storage and disposal of the waste;
c) The regulations and conditions of authorization are complied with.

13.2 The quality assurance programme should address the managerial elements, including planning and scheduling activities and the use of resources. These elements should be documented in the quality assurance programme plan. The responsibilities and authorities of the personnel and organizations involved should be clearly specified in the plan. This plan should be submitted for approval by the regulatory authority.

13.3 Safety related systems and components should be managed in accordance with their importance for the safe operation of facilities for the predisposal management of HLW. The extent of quality assurance applied to the design, fabrication, construction and operation of such components and systems should be related to their importance to safety.

13.4 It should be ensured that waste packages are prepared in compliance with the requirements for the acceptance of the waste at a storage facility or for disposal. Non-conformances in waste packages should be prevented, particularly for those activities that could lead to an irreversible non-conformance if not properly performed. This may be achieved by means of a quality assurance programme, including implementing procedures, for the following activities:

a) The characterization of the HLW;

b) The development of the technical specifications for packages for HLW;
c) The approval of the conditioning process for the HLW;
d) The confirmation of the characteristics for HLW packages;
e) The review of quality control records.

13.5 For HLW from the reprocessing of spent fuel a characterization programme should be followed to assess the suitability of the pretreated and/or treated HLW for the conditioning process chosen as well as to optimize the composition of the solidified waste.

13.6 The specifications for an HLW package should specify the waste acceptance requirements for handling, transport, storage and, as far as possible, disposal. The operating organization should develop a conditioning process that results in the production of waste packages within the specifications. Part of this process should be to identify those parameters that should be controlled.

13.7 The technical specifications for HLW should refer to the characteristics, properties and limiting values of the parameters for HLW, the HLW include liquid HLW before conditioning, conditioned HLW and spent fuel.

13.8 Quality records should be established and maintained for each conditioned package of HLW. These records should be reviewed against the specifications to determine the acceptability of the waste package. A record of the results of the review should be made and retained for a specified period of time as approved by the regulatory authority. Should a waste package not meet the specifications or the waste acceptance requirements, the nature of the non-conformance should be recorded as well as any decision taken to carry out appropriate corrective actions. The operating organization should develop a plan for resolving non-conformances prior to the start of conditioning operations for HLW.

13.9 Records of the various steps of management prior to disposal should be maintained to ensure that the HLW characteristics of each step are traceable and a document management system is in place.

13.10 The quality assurance program should be designed during long-term storage to ensure that the quality and integrity of the product are maintained and that the quality of the markings and labels and records on the waste package is sufficient to identify, maintain and preservation such information.

13.11 An audit outline should be developed and a process audit conducted to verify that the waste management process is carried out within the specified parameters and in accordance with the safe operating procedures and the requirements specified by the regulatory authority in a permit or other type of approval.

13.12 Process audits should focus on:

a) Ensuring that important process variables have not changed unfavorably from those values established at the time that the original safety assessment was carried out;
b) Ensuring that required inspections and measurements are performed and that records are retained;
c) Verifying that traceability is maintained during the transfer and storage of waste;
d) Ensuring that the instrumentation used to monitor or control waste processing has not degraded in service or has not been modified without approval, and that a recalibration of instruments is carried out at appropriate intervals in accordance with the applicable specifications or other requirements;
e) Ensuring that the values of all important parameters of the waste packages are kept within established limits;
f) Ensuring that the facility is being operated within the assumptions of the safety assessment;
g) Ensuring that only suitable containers that have been tested as fit for the purpose are used, and within the original specifications for test parameters;
h) Ensuring that there is a satisfactory training programme for staff

13.13 When the auditing organization considers it necessary, it shall conduct product audits. Product audits include the examination of the waste form, the waste container or the waste package, usually by non-destructive methods. Additional audits may be performed by the operator of the disposal facility to assess compliance with the disposal requirements.

The qualifications of operators who perform management tasks prior to the disposal of HLW should be reviewed in accordance with the requirements of the regulatory authority. All staff involved in predisposal management activities of HLW should be trained to ensure that all staff, including operators, maintenance personnel and technicians, discern the nature of the waste and its associated hazards, relevant operational procedures and related safety procedures and procedures to be followed in the event of an event or accident.

Annex A
(informative)
Key properties and characteristics of HLW

Key properties and characteristics of HLW (liquid HLW, solid HLW, HLW solidified form, spent fuel, HLW container and HLW package) are given in Table A.1.

Table A.1 Key properties and characteristics of HLW

Properties and characteristics	Unconditioned spent fuel	Conditioned spent fuel	Liquid HLW from reprocessing	Conditioned HLW	Solid HLW
Spent fuel data: fuel and component types, initial fissile content, burnup and cooling time, heat release rate, cladding breakage rate, and radioactive release source	√	-	To interpolate from sampled data	To inter-polate from sampled data	-
Activity: β–γ and α activity by radionuclide for the major contributors to activity	√	√	√	√	√
Criticality safety: Geometrical configuration, concentration and inventory of fissile material (e.g. ^{233}U, ^{235}U, ^{239}Pu, ^{241}Pu), presence of neutron poisons and demonstration of non-criticality	√	-	√	-	-
Dose rate: Neutron and γ dose rate at the surface and at a distance of 1 m	√	√	√	√	√
Surface contamination: Levels of β–γ and a contamination	-	√	√	√	√
Thermal properties: Thermal power, thermal conductivity and predicted maximum temperatures of the HLW (with and without cooling by engineered systems)	√	√	√	√	√
Chemical properties: pH, main chemical species and compounds, toxic substances and corrosive compounds	√	-	√	-	√
Physical properties: Viscosity and density	Density	-	√	Viscosity during the pouring of glass	√
Mass of waste and/or waste package: Total mass (mass of waste form and canister, if applicable)	√	√	√	√	√
Quality of canister/container: Material specification, tare weight, dimensions, corrosion resistance, quality of seal weld, material certifications from manufacture; quality assurance records from conditioning process; compatibility with the wasteform.	-	√	-	√	-
Stackability and handling: Number of packages stackable without deformation, results of package drop tests and requirements for lifting packages (e.g. lifting features)	-	√	-	√	-
Package labelling: Unique permanent identification	-	√	-	√	-
Quality of matrix material: Certification and quality assurance records for matrix material	-	√	Possible for intermediate waste forms (e.g. calcine)	-	√

Table A.1 (Cont.)

Properties and characteristics	Unconditioned spent fuel	Conditioned spent fuel	Liquid HLW from reprocessing	Conditioned HLW	Solid HLW
Mass fractions of waste form: Fractions of waste, fixation materials and additives (to be within specified limits)	–	√	–	√	–
Stability of the HLW package: Corrosion and/or leaching behaviour in relevant atmospheres or aqueous solutions, data on long term corrosion and data extrapolation, influence of surface area and solubility of radionuclides in relevant aqueous solutions	√	√	–	√	–
Homogeneity of the waste form: Reasonably achievable homogeneity and distribution of radionuclides	–	–	–	√	–

Annex B
(informative)
Site conditions, processes and events for consideration in a safety assessment (external natural phenomena)

B.1 Meteorology and climatology on the site and in region

The meteorology and climatology of the site and region for consideration in a safety assessment including:

a) Precipitation (averages and extremes, including frequency, duration and intensity)
   1) rain, hail, snow and ice;
   2) snow cover and ice cover (including potential for blocking inlets or outlets);
   3) drought.
b) Wind (averages and extremes, including frequency, duration and intensity)
   1) tornadoes;
   2) hurricanes
   3) cyclones.
c) Rate and duration of the input direct solar radiation (insolation, averages and extremes);
d) Temperature (averages and extremes, including frequency and duration): permafrost and the cyclic freezing and thawing of soil;
e) Barometric pressure (averages and extremes, including frequency and duration);
f) Humidity (averages and extremes, including frequency and duration): fog and frost;
g) Lightning (frequency and intensity).

B.2 Hydrology and hydrogeology on the site and/or in region

The hydrology and hydrogeology of the site and region for consideration in a safety assessment including:

a) Surface runoff (averages and extremes, including frequency, duration and intensity)
   1) flooding (frequency, duration and intensity);
   2) erosion (rate).
b) Groundwater conditions (averages and extremes, including frequency and duration).
c) Wave action (averages and extremes, including frequency, duration and intensity)
   1) high tides, storm surges and tsunami;
   2) flooding (frequency, duration and intensity);
   3) shore erosion (rate).

B.3 Geology of the site and region

The geology of the site and region for consideration in a safety assessment including:

a) Lithology and stratigraphy: the geotechnical characteristics of site materials.
b) Seismicity
   1) faults and zones of weakness;
   2) earthquakes (frequency and intensity).
c) Volcanology: volcanic debris and ash.
d) Historical mining and quarrying: ground subsidence.

B.4 Geomorphology and topography of the site

The geomorphology and topography of the site for consideration in a safety assessment including:

a) Stability of natural material
   1) slope failures, landslides and subsidence;

2) avalanches.

b) Surface erosion.

c) The effects of the terrain (topography) on weather conditions or on the consequences of extreme weather.

B.5 Terrestrial and aquatic flora and fauna of the site (in terms of their effects on the facility)

The terrestrial and aquatic flora and fauna of the site (in terms of their effects on the facility) for consideration in a safety assessment including:

a) Vegetation (terrestrial and aquatic)

1) The blocking of inlets and outlets;

2) damage to structures.

b) Rodents, birds and other wildlife

1) direct damage due to burrowing, chewing, etc；

2) accumulation of nesting debris, guano, etc.

B.6 The potential for:

a) Naturally occurring fires and explosions at the site.

b) Methane gas or natural toxic gas (from marshland or landfill sites).

c) Dust storms or sand storms (including the possible blocking of inlets and outlets).

Annex C
(informative)
Site conditions, processes and events for consideration in a safety assessment (external human induced phenomena)

Site conditions, processes and events for consideration in a safety assessment (external human induced phenomena) mainly include:

a) Explosion
   1) Solid substance;
   2) Gas, dust or aerosol cloud.
b) Fire
   1) Solid substance;
   2) Liquid substance;
   3) Gas, dust or aerosol cloud.
c) Aircraft crash.
d) Missiles due to structural or mechanical failure in nearby installations.
e) Flooding
   1) The structural failure of a dam;
   2) The blockage of a river.
f) Ground subsidence or collapse due to tunneling or mining.
g) Ground vibration.
h) The release of any corrosive, toxic and/or radioactive substance
   1) Liquid;
   2) Gas, dust or aerosol cloud.
i) Geographic and demographic data
   1) Population density and expected changes over the lifetime of the facility;
   2) Industrial and military installations and related activities and the effects on the facility of accidents at such installations;
   3) Pedestrians and vehicles;
   4) Transport infrastructure (highways, airports and/or flight paths, railway lines, rivers and canals, pipelines and the potential for impacts or accidents involving hazardous material).
j) Power supply and the potential loss of power.
k) Civil strife
   1) Terrorism, sabotage and perimeter incursions;
   2) The failure of infrastructure;
   3) Civil disorder;
   4) Strikes and blockades;
   5) Health issues (e.g. endemic diseases or epidemics).

Annex D
(informative)
Postulated initiating events for consideration in a safety assessment
(internal phenomena)

Postulated initiating events for consideration in a safety assessment (internal phenomena) mainly include:

a) The acceptance (inadvertent or otherwise) of incoming waste, waste containers, process chemicals, conditioning agents, etc., that do not meet the specifications (acceptance criteria) included in the design basis.
b) The processing of waste that meets acceptance criteria but that is subsequently processed in an inappropriate way for the particular type of waste (either inadvertently or otherwise).
c) A criticality event due to the inappropriate accumulation of fissile material, change of geometrical configuration, introduction of moderating material, removal of neutron absorbing material or various combinations of these.
d) Explosion due to the evolution of explosive gas mixtures as a result of
    1) Radiolysis.
    2) Off-gassing or volatilization.
    3) Chemical reactions from inappropriate mixing or contact with
        ——different waste streams;
        ——waste and conditioning agents;
        ——waste container material and conditioning agents;
        ——process chemicals;
        ——waste, waste containers, conditioning agents, process chemicals and the prevailing conditions of the work environment or storage environment.
    4) The inclusion of items such as bottles of compressed gas in the input to incinerators or compactors.
e) Fire due to
    1) Spontaneous combustion;
    2) Local hot spots generated by malfunctions of structures, systems or components.
    3) Sparks from machinery, equipment or electrical circuits.
    4) Sparks from human activities such as welding or smoking.
    5) Explosions.
f) Gross incompatibilities between the components of a process system and the materials introduced into the system.
g) The degradation of process materials (chemicals, additives or binders) due to improper handling or storage.
h) The failure to take account of the non-radiological hazards presented by the waste (physical, chemical or pathogenic).
i) The generation of a toxic atmosphere by chemical reactions due to the inappropriate mixing or contact of various reagents and materials.
j) Dropping waste packages or other loads due to mishandling or equipment failure, with consequences to the dropped waste package and possibly to other waste packages or to the structures, systems and components of the facility.
k) Collisions of vehicles or suspended loads with structures, systems and components of the facility or with waste packages, waste containment vessels and pipes.
l) Failures of structures, systems and components due to

1) The loss of structural competence or mechanical integrity.
2) Vibrations originating within the facility.
3) Pressure imbalances (pressure surges or pressure collapses).
4) Internal corrosion or erosion or the chemical effects of the work or storage environment.

m) The generation of missiles and flying debris due to the explosion of pressurized components or the gross failure of rotating equipment.
n) The malfunctioning of heating or cooling equipment, leading to unintended temperature excursions in process systems or storage systems.
o) The malfunctioning of process control equipment.
p) The malfunctioning of equipment that maintains the ambient conditions in the facility, such as the ventilation system or dewatering system.
q) The malfunctioning of monitoring or alarm systems so that an adverse condition goes unnoticed.
r) Incorrect settings (errors or unauthorized changes) on monitors, alarms or control equipment.
s) The failure to function when called upon of emergency equipment such as the fire suppression system, pressure relief valves and ducts.
t) The failure of the power supply, either the main system or various subsystems.
u) The malfunctioning of key equipment for handling waste, such as transfer cranes or conveyors.
v) The malfunctioning of structures, systems and components that control releases to the environment, such as filters or valves.
w) The failure properly to inspect, test and maintain structures, systems and components.
x) Incorrect operator action due to inaccurate or incomplete information.
y) Incorrect operator action in spite of having accurate and complete information.
z) Sabotage by employees.
aa) The failure of systems and components such as incinerator linings, compactor hydraulics or cutting machinery that poses the risk of significant additional radiation exposure of personnel called on to assist in effecting repairs or replacements.
bb) Encountering an unanticipated radiation source in decommissioning (e.g. different in nature or amount) and not recognizing immediately the changed circumstances.
cc) Removing or weakening a structure or component in decommissioning without realizing the possible effects on the structural competence of other structures and components.