THE KONRAD WASTE ACCEPTANCE REQUIREMENTS: GUIDANCE FOR RADIOACTIVE WASTE CONDITIONING

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ABSTRACT

In the Federal Republic of Germany the planned Konrad repository is proposed for the disposal of all types of radioactive waste with a negligible thermal influence upon the host rock. The Bundesamt für Strahlenschutz (BfS-Federal Office for Radiation Protection) has established Waste Acceptance Requirements for this facility which were developed on the basis of the results of site-specific safety assessments. They include general requirements on waste packages, specific requirements on waste forms and packagings and limitations for activities of individual radionuclides. In order to comply with the Waste Acceptance Requirements a suitable waste management concept was developed and introduced into radioactive waste conditioning. In this respect, the waste type catalog which is a part of the Guideline on the Control of Radioactive Waste is used as a tool to collect and segregate radioactive waste in a way appropriate to the techniques applied to condition it for disposal. This catalog is a basis for the description and the tracking of radioactive waste from the primary waste to the waste package suitable for disposal. It helps to guarantee the necessary transparency in waste management and gives additional guidance for radioactive waste conditioning. In accordance with the Guideline a control of the waste packages independent of the waste generator/conditioner is required to assure compliance with the Konrad Waste Acceptance Requirements. The necessary actions have been taken and installations provided. The waste generators and conditioners have started to select appropriate conditioning processes and/or to adjust existing methods to the Konrad Waste Acceptance Requirements and the Guideline on the Control of Radioactive Waste.

INTRODUCTION

From its very beginning, radioactive waste disposal policy in the Federal Republic of Germany has been based on the decision that all types of radioactive waste should be disposed of in deep geological formations. Shallow land burial is not practiced because of high population density, climatic conditions and existing appropriate deep geological formations. The Bundesamt für Strahlenschutz (BfS-Federal Office for Radiation Protection) is responsible for the construction and operation of federal facilities for radioactive waste disposal. It is the authorized applicant in the respective licensing procedure.

Site specific safety assessments have been made for the Konrad repository. The results of these investigations provided information on the acceptability of waste in this facility. They have particularly served to define the Waste Acceptance Requirements and thus became an essential part of these requirements.

In developing Waste Acceptance Requirements, the BfS fulfills one of its obligations and by this provides guidance on radioactive waste conditioning to the waste generators and conditioners.

THE KONRAD REPOSITORY

According to the German radioactive waste disposal plans, the Konrad repository is assigned to accept radioactive waste with negligible heat generation, i.e., waste packages which do not increase the host rock temperature by more than 3 K on an average (1). This repository will be operated with two shafts. The coral oolite at a depth of 800 m to 1300 m is the host rock for this repository. Waste packages will be disposed of in drifts with an excavated volume of about 1 100 000 m^3 allowing an emplacement of about 650 000 m^3 waste package volume. The repository is scheduled to operate for at least 40 years. A total activity in the order of 10^{18} Bq is anticipated in this facility. The licensing procedure is in an advanced stage. At present, objections raised against the repository are discussed in a public debate. Operation of the Konrad repository is expected to begin in the second half of the nineties.

THE KONRAD WASTE ACCEPTANCE REQUIREMENTS

Derivation of Requirements

In order to prove the safety of the Konrad repository, safety assessments were carried out covering the normal operation of this facility, assumed incidents in the operational phase, the thermal influence upon the host rock, the criticality safety and the radiological long-term effects in the post-closure phase. Based on these results Waste Acceptance Requirements were elaborated in such a way that a flexible system of requirements could be established, which is not only tailored to the radioactive waste presently generated but which also allows improvements and future developments in waste conditioning techniques. Such a flexible system includes several alternatives and different options for the waste package design which ensures the required level of safety for the repository. The waste generators thus have the possibility of applying and fulfilling those requirements which are specifically applicable to the radioactive waste packages produced and to be disposed of. Of course, such a flexible system of requirements may be considerably extended and more complicated but the advantages are immense if it is taken into account that a substantial modification of the Waste Acceptance Requirements requires a new licensing procedure.

Waste Acceptance Requirements

The site-specific safety assessments have demonstrated the safety of the Konrad repository and the results were transferred into Waste Acceptance Requirements (2). These requirements had a last amendment in July 1991. They provide general requirements and also specific requirements on waste forms, packagings, activity limitations for individual radionuclides, documentation and delivery of waste packages to the Konrad repository:

- The general requirements on waste packages reflect various boundary conditions for the planning of the Konrad repository, e.g., the local dose rate and the non-adherent surface contamination of a waste package, the maximum mass and the mass distribution of a shipping unit and the provision for the identification of waste packages and the respective waste data sheets.
- Specific requirements on waste forms resulted, e.g., from the safety assessment of postulated incidents. Waste forms with similar properties, i.e., with a similar radionuclide release behavior in the case of mechanical and/or thermal impacts can be allocated to one of the six defined waste form groups which differ in quality requirements.
- Specific requirements on waste packagings result from the assessment of postulated incidents. A distinction is made between containers without increased barrier properties (waste container class I) and containers with increased barrier properties (waste container class II). Both classes differ in requirements on the quality of the packaging, e.g., mechanical stability, thermal resistance and leak tightness.
- Practical considerations call for a standardization of waste packages. Two cylindrical concrete containers, three cylindrical cast iron containers and six rectangular boxes made of sheet steel, reinforced concrete or cast iron were standardized.
- The permissible activities of radionuclides and radionuclide groups (non-specified alpha and beta/gamma emitters) per waste package have been limited. They result from each of the individual safety assessments for normal operation of the repository, postulated incidents, thermal influence upon the host rock, criticality safety and radiological long-term effects in the post-closure phase of the repository. The activity values for individual radionuclides depend on the respective waste form, the waste container class or the size of the packaging. The requirements must be fulfilled individually and independently of one another. Thus, compliance with the most restrictive requirement is demanded.

As the licensing procedure for the Konrad repository is still pending, the Konrad Waste Acceptance Requirements are still in a preliminary form. They can only be finalized after a positive licensing decision has been obtained. However, those requirements are of utmost importance to provide guidance in waste management decisions even when they are in their preliminary form.

Waste Form Groups and Waste Container Classes

The results of the Konrad incident analysis are of particular importance to waste conditioning. Attention shall be focussed on the six waste form groups and the two waste container classes derived from this analysis. The different waste forms must be assigned to one of the following groups (2):

a. Group 1 - Bitumen and plastic products
b. Group 2 - Solid matter
c. Group 3 - Metallic solid matter
d. Group 4 - Compacted waste
e. Group 5 - Cemented/concreted waste
f. Group 6 - Concentrates

Specific requirements characterize each waste form group (Table I). They must be fulfilled by each waste form assigned to a group. If a waste form is, for example, assigned to group 1, it must be guaranteed that the basic requirements are met. Therefore, each waste form can be assigned to group 1. If an assignment to other groups is made, specific requirements must be fulfilled in addition to the basic requirements. For example,

a. compacted waste must be compacted with a pressure of at least 30 MPa into a stable form,
b. concentrates, which result from drying of liquid waste and are made up of the solid residue, must consist of a non- combustible solid with a compressive strength of at least 10 N/mm^2.

In general, the requirements rise from waste form group 1 to 6.

With the specific requirements superior waste forms are resulting, thus limiting the release of radioactive substances in the case of an incident. As the activity concentration in a waste package and the increased quality of the waste form or the waste container are connected, the permissible activity in a waste package can be increased from waste form group 1 to waste form group 6. This demonstrates the very close connection between waste form, packaging and radionuclide inventory and their interdependence and interaction with respect to the requirements to be met. The waste forms can be assigned to that group for which the specific requirements are fulfilled. No generally valid rule can be defined for a distinctive assignment of a waste form to a waste form group. Careful consideration must be given by the waste generator or conditioner to the identification of the waste form and packaging properties and the determination of the radionuclide inventory of each waste package.

According to the barrier quality of the packaging, a basic distinction is made between two waste container classes. A packaging may be assigned to waste container class I if its design is such that its integrity is preserved after a mechanical

TABLE I

Specific Requirements on the Waste Form Groups Derived from the Safety Assessment of Postulated Incident

Waste form group	Quality characteristics
01	- Basic requirements
02	- Basic requirements - In the waste form, limitation of the activity portion of combustible waste material with a melting point <300°C to ≤1% - Imobilization of the above-mentioned combustible waste material so that it cannot emerge from the waste form when becoming fluid under thermal load
03	- Basic requirements Waste consists only of metallic parts or materials of core components of a reactor, with an exception of graphite
04	- Basic requirements - Compacting of the waste into an inherently stable form with a pressure ≥30 MPa
05	- Basic requirements - Imobilization of the waste in cement or concrete - In the case of embedded or solidified waste (e.g., ashes, powders or aqueous concentrates), uniform and complete distribution of the activity in cement or concrete - In the case of grouted waste (e.g., scrap), distribution of the activity as uniformly as possible - Compressive strength of the waste form is ≥10 N/mm^2
06	- Basic requirements - The waste itself consists of a solid - Compressive strength of the waste form is ≥10 N/mm^2 - The waste is not combustible

impact with up to 4 m/s to such an extent that in the case of a subsequent fire flammable waste forms with a melting point above 300°C do not burn but pyrolyze. A packaging assigned to waste container class II must particularly withstand a 5 m drop onto an unyielding target in such a way that the total leak rate after the drop does not exceed 10^{-4} Pa m^3/s and must have either a thermal conductivity resistance of at least 0.1 m^2 K/W or a total leak rate of 10^{-5} Pa m^3/s or less (standard conditions); it must also be ensured that the amount of substance released in the case of a fire (800 °C, 1 hour) does not exceed 1 mole of gas within 24 hours.

The packaging can be assigned to one of the two waste container classes if the specific requirements are fulfilled. The respective activity limiting values for waste packages with class I containers are dependent on the waste form. This is not the case for waste class II containers which are of such a quality that the barrier function of the waste form does not contribute significantly to the total quality of a waste package.

WASTE TYPE CATALOG

Regarding the envisaged disposal of radioactive waste in the Konrad repository, the waste generators and conditioners are obliged to undertake organizational and technical measures to demonstrate the adequate quality of their waste packages. In order to meet the Waste Acceptance Requirements it was reasonable to develop a suitable waste management concept and to introduce it into radioactive waste conditioning. The objective of such a system is to provide thorough orientation to all the waste management steps.

Thus, the definition of the six waste form groups and the two waste container classes was the starting point for the development of a waste type catalog because radioactive wastes must be sufficiently collected and segregated to allow their appropriate pretreatment and conditioning for interim storage and disposal. This waste type catalog surveys the radioactive wastes from their arising in a nuclear facility to their disposal in a repository. It specifies the primary wastes, the pretreatment methods, the resulting intermediate products, the conditioning methods and the resulting waste packages. It thus describes the "flow" of radioactive waste "from the cradle to its grave".

The subdivision of primary wastes is hierarchically organized into waste groups, waste subgroups and waste types. The assignment of the primary waste to a waste group, waste subgroup or waste type must be done in accordance with the requirements of the waste pretreatment and the conditioning process. If necessary, primary wastes must be sorted. They must be specified in more detail, for example, if they are categorized as chemicals, filters or metals. They can be pretreated to form an intermediate product and must be conditioned (treatment and packing) to a waste package (waste form and packaging).

The waste type catalog, therefore, forms the basis for the description and tracking of radioactive waste from the primary waste to a waste package suitable for disposal. It helps to provide the necessary transparency in waste management and, in particular, gives guidance to the waste conditioners.

GUIDANCE FOR WASTE CONDITIONING

Guideline for the Control of Radioactive Waste

In 1989, a new guideline for the control of radioactive wastes with negligible heat generation has been published. Its purpose is to guarantee more clarity in waste management and to ensure better supervision of the various waste management steps by the responsible authorities. The guideline gives guidance to the control of waste and facilitates supervision. The main points are as follows:

- A conditioning concept for radioactive waste must be presented by the waste producer to the authorities.
- Radioactive waste must be collected, pre-treated, and conditioned according to the principles given in the waste-type catalog and the preliminary Konrad Waste Acceptance Requirements. Organic materials should be incinerated. Conditioning processes qualified by the BfS should preferably be applied.

- Pretreatment and conditioning of radioactive waste should be carried out on-site with stationary or mobile equipment.
- *Central* facilities may be used if they have any advantage over on-site facilities, for example, in the product quality or the safety of the plant.
- The various steps in the pretreatment and conditioning of radioactive waste must be recorded in the documentation system.

Conditioning Techniques

Conditioning of radioactive waste includes processing and/or packing of the waste, eventually after a pretreatment or a sorting. Various strategies and techniques are applied. The selection of a conditioning process is dependent upon factors such as the requirements for interim storage and disposal, acceptance of the process, and volume of the resulting waste packages. Therefore, it is not surprising that different conditioning techniques for the same type of waste may be applied. Furthermore, the necessity of repositories necessitates the minimization of the conditioned waste volume and stimulates the development of new and advanced conditioning techniques.

According to the Konrad Waste Acceptance Requirements and the waste type catalog, the waste generators and conditioners have started to select appropriate conditioning techniques and/or to adjust existing methods to these requirements. The relationship between waste form groups and waste container classes of the Konrad Waste Acceptance Requirements and the respective waste conditioning techniques will be explained.

Primary waste must be collected and pre-treated in such a way that it is suitable for the selected conditioning process. Principal pretreatment methods are decontamination, crushing, compression, evaporation/distillation/rectification, decantation/dewatering/ filtration and incineration/pyrolysis.

Especially the incineration is attractive for all types of combustible waste. Solid or liquid waste and also alpha-bearing waste may be incinerated. The large volume reduction and, in particular, the inorganic and inert character of the intermediate product (e.g., ashes or slags) are reasons to recommend the incineration process from a repository-related point of view. Nevertheless, the off-gas treatment and the secondary waste must be taken into account.

The cementation of radioactive waste is the most well-known immobilization process being widely applied. It is used for the solidification of liquids, the embedding of solids (e.g., ashes, powders and granules) as well as the grouting of voids in scrap, rubble or filters. Various cementation techniques are used and the equipment might be mobile or stationary. Liquid radioactive waste will react with the cement and is bound in the product. In accordance with the basic requirements on waste products (2), it is of utmost importance to check the compatibility of the cement and the liquid radioactive waste to guarantee the setting of the product or the required compressive strength. If necessary, special cement formulas and/or suitable additives are to be used. Solid radioactive waste, e.g., drying residues of liquids, ashes from incineration of combustible radioactive waste or granulated materials, e.g., silicagel or resins, are often embedded in cement by mixing techniques. Reactions with the cement, e.g., gas generation by amphoteric metals in the ashes must be taken into account. Possible chemical reactions between the radioactive waste, the immobilization material and the packaging must be limited to permissible levels (2).

The bituminization is a classic process for the solidification of liquid radioactive waste. The liquid and the bitumen are mixed at elevated temperatures of $\geq 120°C$ in an extruder, film or mixer evaporator. The remaining solids are incorporated into the bitumen which cools down after it is poured into a packaging. However, the tendency of swelling due to radiolytic gas generation has to be taken into consideration and may limit the application of bituminization.

The cementation of radioactive waste must be carried out in such a way that the specific requirements of waste form group 5 are fulfilled in order to assign cemented waste to this group. Bituminized waste may be assigned to waste form group 1.

The high-pressure compaction with 1500 Mg to 2000 Mg compactors is a new development to minimize waste amounts. Solid materials are compacted to a stable pellet. This technique is applied to, e.g., metallic materials, paper, plastic, rubble and even ashes from the incineration of organic radioactive waste. Due to possible gas generation occurring in compacted waste, a segregation before compaction is reasonable, i.e., to separate metallic and wet organic materials. Alternatively, the compacted pellets may be dried. This waste product may be assigned to waste form group 4.

The drying of liquid radioactive waste is another new development for waste minimization. The liquids are fed into a packaging which is heated. The evaporation is supported by application of a slight vacuum. The resulting dry residue consists of the constituents dissolved or dispersed in the liquid. The resulting product contains a higher activity concentration than, e.g., the cemented waste form and needs therefore a superior shielding which is often made of cast iron, i.e., a waste container class II packaging. The drying process must be designed in such a way that the specific requirements of waste form group 6 are fulfilled.

The melting of activated and/or contaminated metallic materials is of special interest for the decommissioning and dismantling as well as the repair and maintenance of nuclear facilities. Depending on the radioactivity level in the melt it is of special interest to re-use the metals by casting packagings for radioactive waste disposal. If the radionuclide content is too high the melt might be poured into a packaging as radioactive waste. The resulting slag has also to be conditioned and disposed of. The respective waste product (melt) may be assigned to waste form group 3.

Radioactive waste has to be packed for handling, transportation and storage. Packagings for disposal might have been designed according to the requirements given in the definition of both waste container classes. The necessary quality of a packaging is dependent on the type of waste and its radionuclide inventory. Sheet steel, reinforced concrete and cast iron are common as packaging materials. Cylindrical and rectangular packagings of different sizes and weights are being used. A standardization of the packagings has successfully been realized in order to harmonize the equipment as well as the handling and emplacement techniques for the Konrad repository.

Containers should preferably be used to package radioactive waste in immobilized or non-immobilized form. Especially the larger containers or boxes are very appropriate for bulky components or bigger segments, thus avoiding further crushing or cutting and advantageously reducing radiation exposures. In addition, 200 litre and 400 litre drums will not be accepted as single waste packages in the Konrad repository and must be packed into standardized containers.

The conditioning of radioactive wastes by packing only is also applied. Superior packagings, e.g., made of cast iron are primarily applied. These packagings have to fulfill the requirements as imposed for waste container class II, if activated metallic core components, scrap or ion exchange resins with higher radionuclide inventories are packed into these containers.

Such techniques lead to waste packages complying with the Konrad Waste Acceptance Requirements. They contribute to the avoidance or reduction of wastes and have already been successfully applied. These efforts result in continuously declining specific amounts of conditioned radioactive waste to be disposed of.

CONCLUSIONS

The Waste Acceptance Requirements, the waste type catalog and the guideline for the control of radioactive waste provide an excellent basis for an appropriate selection of pretreatment and conditioning techniques. Thus, the waste generators and conditioners have already started to adopt and to convert this guidance within their waste management system. According to a successful continuation and final realization of these efforts, the license for the Konrad repository is an important factor for a proper management of radioactive waste which is therefore a highly political and not a technical subject.

REFERENCES

1. H.P. BERG, and P.BRENNECKE, "The Konrad Mine - The Planned German Repository for Radioactive Waste with Negligible Heat Generation", ET- 6/90, Bundesamt für Strahlenschutz (July 1990).
2. P.W. BRENNECKE, and E.H. WARNECKE, "Preliminary Waste Acceptance Requirements - Konrad Repository Project," Nuclear Energy, 30, No. 3, pp. 173-181 (1991).