Container Approval for the Disposal of Radioactive Waste with Negligible Heat Generation in the German Konrad Repository - 12148

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ABSTRACT

Since the license for the Konrad repository was finally confirmed by legal decision in 2007, the Federal Institute for Radiation Protection (BfS) has been performing further planning and preparation work to prepare the repository for operation. Waste conditioning and packaging has been continued by different waste producers as the nuclear industry and federal research institutes on the basis of the official disposal requirements. The necessary prerequisites for this are approved containers as well as certified waste conditioning and packaging procedures. The Federal Institute for Materials Research and Testing (BAM) is responsible for container design testing and evaluation of quality assurance measures on behalf of BfS under consideration of the Konrad disposal requirements. Besides assessing the container handling stability (stacking tests, handling loads), design testing procedures are performed that include fire tests (800°C, 1 hour) and drop tests from different heights and drop orientations.

This paper presents the current state of BAM design testing experiences about relevant container types (box shaped, cylindrical) made of steel sheets, ductile cast iron or concrete. It explains usual testing and evaluation methods which range from experimental testing to analytical and numerical calculations. Another focus has been laid on already existing containers and packages. The question arises as to how they can be evaluated properly especially with respect to lack of completeness of safety assessment and fabrication documentation.

INTRODUCTION

The Konrad repository for not heat generating radioactive wastes was licensed first in May 2002. With this decision the requirements on radioactive waste for disposal were fixed as of Dec. 1995. Additional obligations required a revision of these documents. Due to legal actions the license was confirmed finally not until 2007 and afterwards the revision of the waste acceptance requirements was finished not until October 2010 [1], [2]. Key points of the Konrad waste acceptance requirements are detailed regulations for waste conditioning and container approval procedures.

After the final court decision the Federal Office for Radiation Protection (BfS) began scheduling backfitting of the former iron ore mine into a repository. The licensed repository volume is 303,000 m^3 based on estimations of expected waste volumes to be disposed of although the mine itself would offer a much larger volume. Once the repository is ready for operation, waste packages can be disposed, but this is not expected before the end of this decade. Nevertheless, there is already today a great

interest in qualified and certified waste conditioning and packaging for disposal requiring containers, tested, evaluated and certified by BAM and BfS.

THE ROLE OF CONTAINER DESIGN TESTING

Based on the disposal requirements all applicants have to demonstrate compliance with the container specific needs to get a certificate of conformity by BfS for each container design which shall be used to dispose of radioactive waste into the Konrad repository. As the repository is not yet ready for operation, all manufactured and loaded containers have first to be put into interim storage and will be shipped to the repository later. For that reason packages have to fulfil requirements of licensed interim storage facilities and regulations for the transport of dangerous goods as well. Respective instructions for interim storage of low and intermediate level radioactive wastes and waste control are included in the recommendations and guidelines from the German Reactor Safety Commission (RSK) [3] and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) [4].

Since the Konrad repository is designed only for not heat generating radioactive wastes of low and intermediate level, the containers usually just have to satisfy the transport regulations for industrial packages (IP) or Type A packages. Only in a few cases they are classified as Type B packages and thus have to be approved by a competent authority. IP and Type A packages have to be certified by the manufacturer itself on the basis of a quality management system certified by BAM.

BfS, who is responsible for the confirmation and certification of containers and waste conditioning campaigns for disposal, has assigned BAM with the container design testing and the evaluation of all quality assurance measures as described in chapter 7 of [2] based on an administrative agreement. Safety assessments by the applicant may involve documents and proofs from interim storage or transport licensing procedures if they are suitable.

REQUIREMENTS FOR KONRAD DISPOSAL CONTAINERS

The Konrad requirements allow for different types of containers. They include cubic or cylindrical shaped containers made of steel, cast iron or concrete, whose outer dimensions are fixed and whose gross mass must not exceed 20,000 kg. Furthermore, the Konrad requirements define two different waste container classes, called ABK I and ABK II, for lower and higher activity levels which are limited in terms of nuclides and waste products [1], [2].

All container types have to meet general basic requirements concerning dimensions, gross mass, stacking ability up to 6 meters, leak tightness if necessary, corrosion protection measures, freedom from corrosion and mechanical damages, and ISO standardised handling corners. Additionally, ABK I containers must keep their integrity after a collision with a velocity of 4 m/s or a 0.8 m drop respectively, and a subsequent fire with an average temperature of 800 °C for one hour in a way that waste products with a melting point above 300°C do not burn but pyrolyse (which is a thermal degradation without open fire). In addition to these basic requirements, ABK II

containers have to demonstrate their capability to keep a standard helium leakage rate of ≤ 10^{-4} Pa·m^3/s after a 5 m drop onto a representative repository foundation and a subsequent one hour fire at 800°C. This feature allows for a limitation of gas and activity release in case of higher waste activity levels. As an alternative it can be demonstrated that the thermal conductivity of the container wall is below 0.1 m^2·K/W and thus limits waste product heating to 80°C.

Both container classes can be qualified in combination with a so called accident safe packaging of the waste products. In this case the waste products have to be fixed in an inherently stable manner, e. g. through pouring with concrete. Concerning ABK I containers this can be achieved by fixing the waste in the container or by using inner packages like drums filled with fixed waste. It has to be demonstrated that the inherently stable fixing or the integrity of the inner packages withstand a container drop from 5 m height. In case of ABK II containers, waste products have to be fixed in inner packages and these are fixed in the container as well. In a 5 m drop the integrity of the inner packages must be maintained or the standard helium leakage rate of the container must not exceed 10^{-4} Pa·m^3/s. Sufficient thermal container wall isolation must be provided for a subsequent one hour 800°C fire or it has to be verified that no significant radiological activity release can occur.

Container design testing experiences of BAM have shown so far that compliance of mechanical resistance and leak tightness for ABK II containers with loose waste products like evaporator resins produce the highest demands on the container design. For that reason steel sheet containers are mostly used as ABK I and II containers with accident safe packaging.

SCOPE OF DESIGN TESTING WITH KONRAD DISPOSAL CONTAINERS

As part of the licensing procedure for a container design to be approved for the Konrad repository, each applicant has to demonstrate compliance with all relevant disposal requirements [1], [2]. This involves dimensions and masses of the specific design, material qualifications, construction of handling corners in accordance with expected loads leak tightness requirements by using appropriate sealing systems if needed and corrosion protection measures. These safety demonstrations shall prevent impairment of all functional- or safety-relevant container properties until the container's final disposal.

The applicant's safety assessments are central to any design testing procedure considering operating and accidental mechanical loads as well as thermal accident scenarios as follows:

- Staple test,
- Lifting test,
- Drop test,
- Fire test,
- Leakage rate measurements to confirm leak tightness if required.

Safety assessments may be based on prototype design tests representing the later serial container quality or on former design test results and their transferability from similar test objects. Alternatively, numerical and/or analytical methods can be applied if they are adequately and sufficiently verified.

Finally, the applicant's quality management system and the quality management program for container batch production and operations have to be approved.

Containers being already loaded and in interim storage operation have to fulfil all requirements similarly. Hence, the applicant has to demonstrate that the respective container meet the repository requirements in a sufficient manner by referring to available documentation about container type design testing and manufacturing quality assurance.

CONTAINER DESIGN TESTING BY BAM

Currently BAM deals with about 30 applications for design testing of several different Konrad container types. Applicants are federal research institutes as well as the nuclear industry and container manufacturers. The container types investigated range from Konrad steel sheet containers of Type II, III, IV and V, concrete and heavy concrete Type IV containers to cylindrical concrete and cast iron containers. The design testing procedures performed by BAM include drop tests and fire tests on concrete containers of the Karlsruhe research center in October 2006, Figure 1.

Fig 1. Disposal fire test scenario (800°C, 1 hour) on a round Konrad concrete container containing a 200 liter drum.

BAM has performed drop tests in June 2007 on two Konrad Type V steel sheet containers from Gesellschaft für Nuklear-Service (GNS) and in March 2009 on a Konrad Type II steel sheet container from GNS and Eisenwerk Bassum (EWB), Figure 2.

Main topics of current BAM design testing procedures are:

- Assessment of the strength of lid systems of steel sheet containers with different design, sealant and attachment to the container body,
- Evaluation of the material suitability under consideration of the lowest operation temperature of -20°C in the disposal facility,
- Evaluation of corrosion protection measures concerning outer decontamination ability and mechanical stability against impacts from outside, e.g. during container loading and handling operations, as well as long term resistance with regard to longer interim storage periods,
- Evaluation of the manufacturer's quality management systems and of quality assurance programs for container batch production and operation,
- Evaluation of safety demonstrations for the required drop test scenarios, where in cases of similar container designs the transferability of former drop test is examined with the help of analytical and/or numerical calculations,
- Evaluation of the stability of waste fixing systems using concrete or different techniques,
- Evaluation of the impact of fire tests, where frequently former fire test results are transferred to the actual scenarios by analytical and/or numerical calculations.

Fig 2. 5 m drop test on a Konrad Type II steel sheet container (EWB/GNS) onto the unyielding IAEA foundation of the BAM drop test facility on its Test Site Technical Safety (TTS).

BAM has already performed several container design testing procedures on the basis of the so far preliminary Konrad disposal requirements. The results are reported in dedicated safety evaluation reports and form the basis of the final BfS approval certificates to confirm the container type disposal qualification.

Already in the mid 1990-s BAM has performed and concluded very comprehensive design tests on a GNS ductile cast iron container of Type VI-15 as ABK II disposal container with specified leak tightness and without accident safe waste packaging. These cubic containers are made of monolithic ductile cast iron with spherical graphite and have a wall thickness of 150 mm. The upper side is closed with a bolted lid-seal-system to prevent waste and activity release under operational and accident conditions.

Designated waste products are spherical resins and vaporiser resins from nuclear power plants. The main topics of the safety assessments were a 5 m container drop test onto a representative repository foundation and a fire test scenario. In both cases prototype tests were conducted at the BAM drop test facility and at the fire test facility, respectively. The most critical drop orientation turned out to be the exactly flat, horizontal impact onto the container bottom yielding the lowest penetration of the foundation and the highest decelerations. Thereby, wall bending vibrations with comparatively high maximum strains and stresses occurred in wall centres and wall connecting edges. These strains and stresses had to be evaluated with respect to strain controlled strength values and to potential brittle fracture failure. Hereby, the lowest container material temperature of –20°C in the container reception area of the disposal facility as well as material defects such as flaws with a size below the non-destructive testing sensitivity had to be taken into account. As for the covering fire test scenario (800°C over 1 hour) for the Konrad repository, the maximum inner pressure development in the leak tight container cavity depending on heat input and following heating of the waste products was the most important aspect. The pressure development primarily depends on chemical composition and moisture content of the resins. It should also be noted that the highest pressure levels were reached only after the end of the one hour burning fire.

Prototype tests only allow for the investigation of single configurations, which should cover the later batch production and be representative as far as possible. Consequently, transferability considerations are often necessary to generalise test results and their safety relevant evaluation. This means that the test configuration and safety evaluation can only represent the underlying covering properties of container design and materials linked to the waste product properties which have to be set for container batch production and operations. In case of future deviations from these defined properties, e.g. due to modifications of the casting process, additional safety assessments are necessary and have to be checked and confirmed by BAM and BfS. Thus, each change of relevant material properties or decrease in material homogeneity has to be evaluated using appropriate material tests like tension tests or ultrasonic testing. These investigations have likewise to account for the batch production stability. The properties of waste products are other examples where additional safety assessments may become mandatory if they change. Relevant variations concern the resin types showing significant different thermal behavior during fire tests due to their chemical composition and moisture content.

Another comprehensive project, which was finished successfully in 2003, dealt with the qualification of about 1,000 Konrad Type IV and VI steel sheet containers for the Siemens Hanau fuel fabrication plant decommissioning project. Containers of the manufacturer Eisenwerk Bassum mbH were applied for as ABK I containers with and without accident safe waste product packaging and as ABK II just with accident safe waste product packaging. Waste products were high pressure compacted or cemented MOX- and uranium wastes packed in 200 liter drums as well as debris and large metallic components. Container qualification, waste conditioning and container packaging were performed at the same time as the decommissioning process. Apart from the Konrad disposal requirements, transport regulations and requirements for medium term interim storage had to be considered. Between 2000 and 2003 BAM has had accomplished several container design tests and elaborated final safety evaluation reports on the

applied container types in close collaboration with all parties to support an effective course of this decommissioning project.

Currently, the main focus is on the large number of already manufactured and loaded waste packages which are designated for later transportation to the Konrad repository but have been in interim storage so far. The final disposal requirements define specific assessment conditions for so-called “old” containers. They essentially correspond to those for “new” containers which are manufactured on the basis of an existing Konrad container design approval and according to the defined quality assurance measures. In addition to container design testing, the evaluation of the quality management system of the manufacturer and the container fabrication documentation sheets are of vital importance. In practise there are big differences in the documentation quality and therefore specific strategies have to be developed to close existing gaps in that field.

First experiences in design testing of still existing “old” containers have led to the conclusion that it makes sense to classify them with respect to specific fabrication periods or the status of the applied quality management system. Assuming that later fabrication periods usually result in better documentation qualities and are easier verifiable than old ones, the evaluation procedure should start with the younger container groups and proceed to the older ones step by step. Depending on the documentation quality in terms of availability and completeness of container fabrication documentation including material test reports, extensive investigations by the applicant and discussions on how to close gaps in the documentation status may be necessary. Thus, a recent survey performed by WAK Karlsruhe (Wiederaufarbeitungsanlage Karlsruhe Rückbau- und Entsorgungs-GmbH) identified 10 different container types in 58 different configurations. Among others, there are about 10,000 Konrad Type IV concrete containers.

Eventually, safety requirements can only be assessed on the basis of sufficient documentation and proofs about container properties and quality. Depending on the results of these efforts, the container approval procedure can be finished without additional measures or further investigations with selected and representative containers have to be performed to close existing gaps. Dependent on complexity and feasibility, waste reloading into already approved containers like Konrad Type V steel sheet containers may be indispensable in the worst case.

Since no precise definition of so-called “old” containers is given in the Konrad disposal requirements, applicants tend to load containers without a valid Konrad approval and declare them as “old” containers later on. BAM and BfS are discussing a clarification of that topic where BAM argues that after the final confirmation of the Konrad license and requirements on June 26, 2007, only approved containers should be used for further loading with radioactive wastes in preparation for later disposal into the Konrad repository. However, BAM will decisively treat any applications for “old“ containers in compliance with the requirements and safety assessments as specified for “new” containers.

BAM has initiated an experience exchange forum, so-called “ERFA QM Konrad-Containers”, aiming to encourage discussions on the interpretation of container specific

disposal requirements, on numerous questions related to the fabrication of waste packages, on procedures in case of “old” containers, on questions about interfaces in-between transport, interim storage and disposal, about container handling and delivery, and on many other issues. It takes place twice a year bringing together private and public waste producers, container manufacturers, state and federal authorities and technical expert organisations. Besides discussions of specific questions, mutual information about important issues, interests and needs constitute an essential part of these meetings attended so far by about 40 experts in a very constructive manner. BAM is convinced that this forum provide valuable support for all involved parties with respect to current and future container design testing procedures for the Konrad repository.

SUMMARY

At present BAM works on numerous applications for container design testing for the Konrad repository. Some licensing procedures were successfully finished in the past and BfS certified several container types like steel sheet, concrete until cast iron containers which are now available for waste packaging for final disposal. However, large quantities of radioactive wastes had been placed into interim storage using containers which are not already licensed for the Konrad repository. Safety assessment of these so-called “old” containers is a big challenge for all parties because documentation sheets about container design testing and fabrication often contain gaps or have not yet been completed. Appropriate solution strategies are currently under development and discussion. Furthermore, BAM has successfully initiated and established an information forum, called „ERFA QM Konrad Containers“, which facilitates discussions on various issues of common interest with respect to Konrad container licensing procedures as well as the interpretation of disposal requirements under consideration of operational needs. Thus, it provides additional, valuable supports for container licensing procedures.

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