Topical Aspects of Waste Container Approval for the Upcoming KONRAD Repository

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ABSTRACT

Low and intermediate level radioactive waste from German nuclear and other industries, research facilities and increasingly decommissioned nuclear installations is handled and prepared for interim storage and later disposal in the licensed Konrad repository.

This paper presents aspects, experiences and perspectives of container design testing and qualification procedures. Several new container designs, in particular different types of steel plate containers, have been tested and licensed; some are handled at present or just applied. Examples from typical qualification procedures including drop tests from 0.8 and 5 m height with prototype containers are explained.

On the other hand several thousand waste packages are currently stored in interim storage facilities, many of them for more than 10 or 15 years. Based on existing package documentations applications and safety assessments for Konrad are prepared and have to be evaluated. The paper discusses aspects, difficulties and strategies to demonstrate sufficient compliance to the current Konrad repository requirements for the large number of existent waste packages.

INTRODUCTION

In Germany, two types of radioactive waste are differentiated: Heat-generating waste and waste with negligible heat generation. In the Konrad repository, only radioactive waste with negligible heat generation will be stored. Waste with negligible heat generation originates, for example, from the operation and decommissioning of nuclear power plants, from research establishments and the medical sector, and includes contaminated tools and protective clothing, sludge or suspensions. In Germany, the volume of the collected waste was determined to be about 115.000 m^3 in December 2006 [1], in which 42 % originates from research establishments. This waste has to be conditioned, which means specially treated (cemented, shredded, etc.) and subsequently packaged (e. g into steel drums) before being prepared for the final disposal. These drums are supposed to be packed in containers controlled and certified according to the transport regulations and the Konrad disposal requirements.

Radioactive waste is currently stored above ground at nuclear power plants, research establishments, etc. the latter storage places serve as intermediate storage since it wasn't clear so far where to dispose off the low and medium-level radioactive waste finally. The research centers in Karlsruhe and Jülich have the largest interim storage facilities for non-heat generating radioactive waste in Germany. They comprise containers that have to be re-qualified and re-conditioned with respect to the Konrad acceptance criteria [2, 3]. The documentation of old containers is also a relevant feature that needs to be adjusted to the Konrad requirements as described later in this paper.

The Konrad repository (Fig. 1) is now en route to start operation in 2014. It represents a deep, geologically stable, repository as a solution for the safe, maintenance-free, and permanent storage of radioactive waste. Future generations should not be confronted with the responsibility for managing a legacy of deposited waste or bringing such waste back to the light of day for other means of disposal. Further details are described in a BfS brochure [4]. The licensed capacity of this repository is 303.000 m^3, old containers from earlier fabrication as well as new containers of specified shape and dimension can be stored there. New containers are fabricated from the beginning according to the Konrad requirements and consequently controlled before starting the batch production and loading with radioactive waste. Old containers were manufactured before or during the preliminary discussion of the Konrad acceptance criteria with more or less lacks in specification or documentation quality which has to be evaluated with respect to the up to date container safety level.

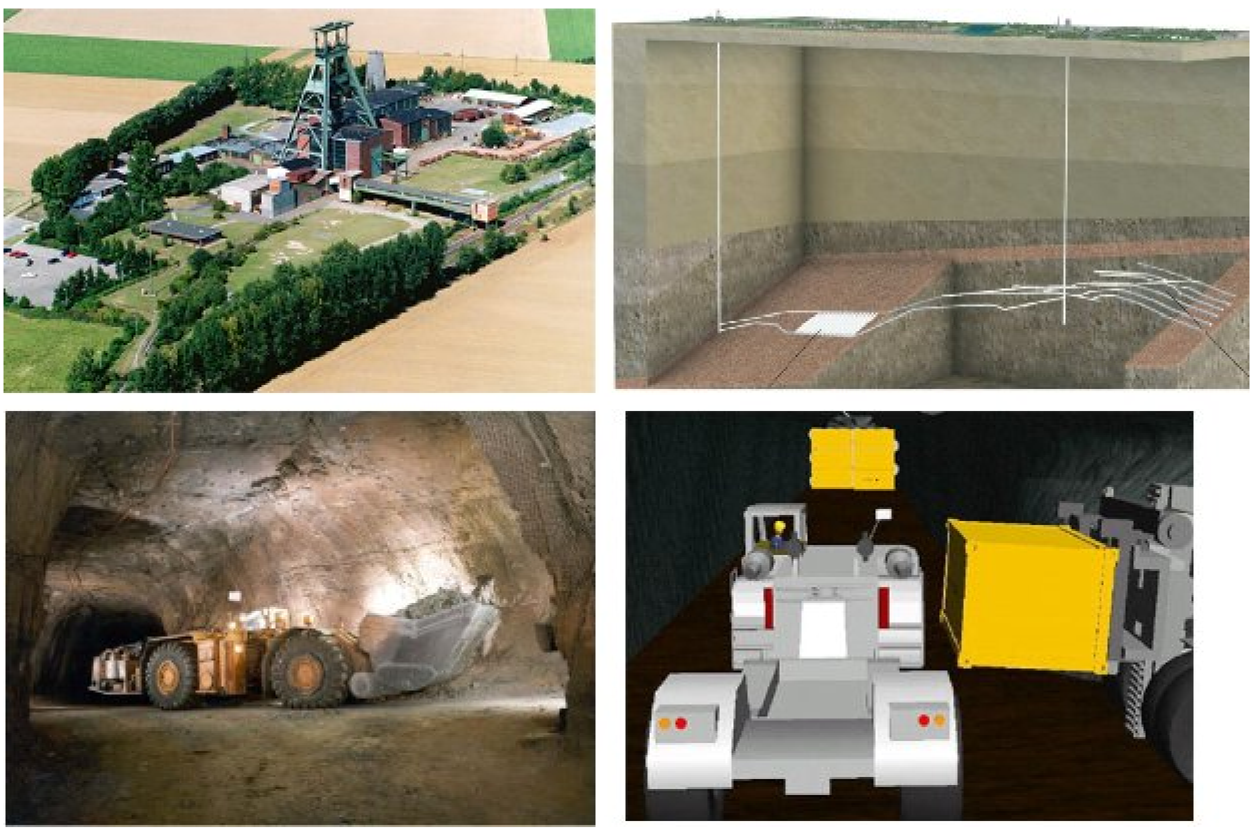

Fig. 1. The Konrad repository (top left: aerial view, top right: geological situation, bottom left: under ground, bottom right: container handling animation).

This paper reports about the relevant issues of the container qualification and licensing procedures, tells about the Konrad acceptance criteria giving the container classes and their respective specifications and the testing strategies followed by BAM. Proceeding of old containers licensing is also described and discussed where certification procedures of still existing containers is presented.

KONRAD REPOSITORY: GENERAL CONSPECTUS AND REQUIREMENTS FOR CONTAINERS

In general, stringent official regulations govern the handling and final storage of radioactive waste in order to maintain radiation and contamination levels below official threshold values. Qualification procedures, technical and safety requirements for containers, fixed by the Federal Office for Radiation Protection (BfS) for the waste conditioning and packaging, include:

- German Atomic Act,
- German Radiation Protection Ordinance
- National Transport Regulations for Dangerous Goods based on the international IAEA Regulations,
- German guideline on radioactive waste monitoring ("Abfallkontrollrichtlinie"),
- Recommendations by the German Reactor Safety Commission (RSK) for long term interim storage ,
- Interim storage licenses with their specific waste and package acceptance criteria,
- Konrad acceptance criteria [2, 3].

Since low and intermediate waste activity level packages with negligible heat generation are considered within this paper, most containers have to fulfil Industrial Package (IP) or Type A transport requirements and in limited cases Type B requirements for public transport to and from the nuclear facilities. The certification of the waste containers for interim storage at the respective storage facility is mostly realized based on the transport qualification with respect to additional requirements caused by the site specific safety analyses. Konrad acceptance criteria [2, 3] contain waste type, waste form, container type, activity limitation and waste package.

Konrad Container Requirements

Based on the Konrad requirements, various designs are defined for the low and intermediate waste containers. Box-shaped and cylindrical containers are available with different weight, size, wall thickness and construction. Basic materials are steel, cast iron or concrete. The designations and respective details of the containers certified to be stored in the Konrad repository are classified in Table 1.

Cylindrical concrete containers may be made of standard concrete or heavy concrete and are supposed to fulfil special requirements concerning the properties of the chosen concrete and the construction details (e.g. container lid assembling).

Cylindrical or box-shaped cast iron containers have to be thick-walled and their specifications can be fixed based on ISO 1083 "Spheroidal graphite cast irons – Classification" (former DIN EN 1563 following DIN 1693). They are fabricated with respect to the Konrad requirements [2] which deal, among others, with the construction of the lifting corners and lid sealing.

Table 1: Basic Konrad container type classification

	Overall dimensions			
	Length / Diameter [mm]	Width [mm]	Height [mm]	Gross volume [m^3]
Cylindrical concrete container Type I	Φ 1060	--	1370[1)]	1.2
Cylindrical concrete container Type II	Φ 1060	--	1510[2)]	1.3
Cylindrical cast iron container Type I	Φ 900	--	1150	0.7
Cylindrical cast iron container Type II	Φ 1060	--	1500	1.3
Cylindrical cast iron container Type III	Φ 1000	--	1240	1.0
Box-shaped container Type I	1600	1700	1450	3.9
Box-shaped container Type II	1600	1700	1700	4.6
Box-shaped container Type III	3000	1700	1700	8.7
Box-shaped container Type IV	3000	1700	1450	7.4
Box-shaped container Type V	3200	2000	1700	10.9
Box-shaped container Type VI	1600	2000	1700	5.4

[1)] Height 1370 mm + ear 90 mm = 1460 mm
[2)] Height 1370 mm + ear 90 mm = 1460 mm

Box-shaped containers can be made of steel, cast iron or concrete. The basic structure of the steel containers is a frame construction fulfilling basic requirements given in [2]. The specifications of the cast iron and concrete containers are similar to those presented for the cylindrical ones. Also in this case lifting corners represent a relevant component enabling the safe handling and transport of the containers, and they are conceived and described in detail in [2]

If necessary, additional internal lining of the containers may be added for shielding purposes. Such lining, that should be declared, can be made of plumb or a different materiel such as depleted uranium.

The Konrad acceptance criteria [2, 3] define two package categories, called Waste Container Class I (ABK I) for lower activity levels and Waste Container, Class II (ABK II) for higher activity levels. The corresponding activity limits are nuclide and waste product specific following from the safety analyses of the repository.
All container types have to fulfil basic requirements like shape, volume, gross mass, 6 m stacking height, if necessary a specified leakage rate, corrosion protection, exclusion of mechanical and corrosion damages, consideration of ISO standards for container lifting corners.
Additionally, ABK I containers have to demonstrate integrity after a collision with a velocity of 4 m/s, respectively a 0.8 m drop, so that in a following accident fire (1h, 800°C) waste products with a melting point >300°C do not burn in an open fire.

In addition to the basic requirements, ABK II containers have to demonstrate a standard leakage rate ≤ 10^{-4} Pa·m³/s after a 5 m drop onto the ground of the repository and a following accident fire (1h, 800°C). This guarantees a defined limitation of gas and activity release. Alternatively, demonstration of sufficient thermal insulation by the container walls due to a heat conduction resistance of <0.1 m^2K/W with a limitation of waste product temperatures to < 80°C is appropriate.

Both container classes can be used in combination with an accident safe packaging of the waste products. This makes container class requirements change in some aspects. In case of ABK I containers the waste must be fixed in stable form or must be packed in inner packages like drums which are themselves fixed in stable form. The fixing has to demonstrate its stability in case of a 5 m drop or the inner packages must stay integer. In case of ABK II containers the waste must be fixed in stable form and must be packed in inner packages which are themselves fixed in stable form. After a 5 m drop, the integrity of the inner packages has to be demonstrated or the leakage rate of the container has to be ≤ 10^{-4} Pa·m³/s. With respect to a following accident fire (1h, 800°C) demonstration of a stable thermal insulation of the container walls is sufficient or it has to be proven that no radiological relevant activity release occurs.

Responsibilities during the Qualification Process

Transport regulations require approvals by the competent authority BfS only in case of Type B packages. Type A and IP-2, IP-3 packages demonstrate their qualification by the manufacturer itself and only the quality assurance system has to be evaluated by BAM.

Interim storage qualification is evaluated by the German state authorities who are supported by technical supervision organisations (TÜV's). The approval is given by the responsible state authority. Usually, container transport qualification is a basis also for interim storage qualification because all packages have to be shipped at least to the central repository in the future. For that same reason, also disposal requirements are commonly considered if possible.

BfS is the competent authority for the Konrad container and packaging qualification processes. Container design testing and safety evaluation including quality assurance system and measures are performed by BAM as regulated by a co-operation contract with BfS. Application and safety assessments must be arranged as defined by the Konrad acceptance criteria. Safety assessments from transport and interim storage qualification can be applied and are accepted if appropriate.

TESTING OF NEW CONTAINER DESIGNS

Container design testing is based upon complete application documents do demonstrate compliance with the Konrad requirements. In terms of container design essential items are:

- Material qualification,
- Dimensions and masses,
- Container handling corners,
- Leakage rate requirements,
- Corrosion protection,
- Mechanical design considering normal operation and accident loads,

- Thermal design considering Konrad test scenario.

In case of a new container designs without transferable safety assessments and prototype tests of similar designs a prototype test program is required considering the following test conditions:
- Selection of a representative test container,
- Stacking test,
- Lifting test,
- Drop test(s),
- Thermal test,
- Leak-tightness.

Test results have to be recorded and evaluated in a comprehensive test report.

In order to check the compliance of the container type with the Konrad requirements, four principal ways can be taken into account:

- Experimental testing of a representative container prototype with respect to the Konrad requirements (e.g. drop test, fire test, handling test). A representative, respectively conservative simulation of the container's contents has to be considered as well (especially under mechanical or thermal aspects) to cover the later operation conditions.
- Calculation or justified conclusions by analogies whose calculation strategies and parameters are shown to be reliable and conservative by agreement of the concerned authorities.
- Reference to previous satisfying comparable testing and certification.
- Tests realized on models according to an appropriate scale where the characteristics of the real containers are considered (models laws).

In the last decade, various containers with different designs were tested and certified based on the principles mentioned above. Based on available certifications for different types of box-shaped steel containers (Konrad type III, IV, V, VI) some applicants applied for container design variations as well as different manufacturers developed and fabricated containers of the same Konrad type. Among others, seven different box-shaped steel containers of Konrad Type IV were evaluated, including five containers applied by Eisenwerk Bassum GmbH (EWB) between 2001 and 2007 and two containers manufactured by the Karlsruhe Research Center (FZK) in 2007 and 2008. They have been already certified as ABK I and ABK I+II (with and without accident safe packaging of the waste products). Several containers made by EWB were certified with the help of analogy studies based on previous comparable testing results since, e.g. some of them differ only by lid design. Furthermore, two box-shaped steel containers of Konrad Type III, produced by EWB, have also been certified in 2006 as ABK I and ABK I+II (with and without an accident safe packaging of the waste products). These container types were certified based on comparisons with tests carried out for steel containers of Type IV showing comparable dimensions and construction details to those of the Type III. Two other box-shaped steel containers, Type V and VI fabricated by EWB, have been certified in 2003 and 2005 as ABK I+II (with and without accident safe packaging of the waste products) and ABK II with accident safe packaging of the waste products, respectively.

In addition to the steel containers, a box-shaped ductile cast iron container of Konrad Type VI with specified leak-tightness manufactured by GNS was comprehensively tested, evaluated and finally certified in 1999. Up to now, BAM is involved in quality assurance procedures, especially with respect to the material quality and ultrasonic inspection. Another example is a cylindrical concrete container of the Konrad Type II with an outer steel liner, fabricated by GNS, too, which has been certified in 2007.

Fig. 2. 5 m drop test of a steel container Konrad Type II (ABK I with accident safe packaging) manufactured by Eisenwerk Bassum GmbH at the BAM drop test facility. Left bottom picture shows minor plastic deformation without loss of integrity after the test. Right bottom picture shows investigation of 200 liter drum condition.

Subsequently, two examples of container design testing from the overview given above are explained more detailed. At first, a box-shaped steel container of Konrad Type II manufactured by EWB was dropped from 5 m height onto the BAM test foundation to demonstrate safety in case of ABK I and II considering accident safe packaging of the waste products as well as non accident safe packaging, see Fig. 2. For this purpose, a container prototype was first charged with 200 liter steel drums. Each drum was filled with gravel and steel crap and finally closed with a sealed standard lid. The drums were fixed by means of cast concrete with respect to the Konrad requirements. Two drop orientations were followed in this test: a flat 5 m drop onto the container bottom and a 5 m drop onto the front wall. Inspection of the test container after the drop tests confirmed the container integrity without discharge of any component despite a few minor damages like local plastic deformations in the impact area.

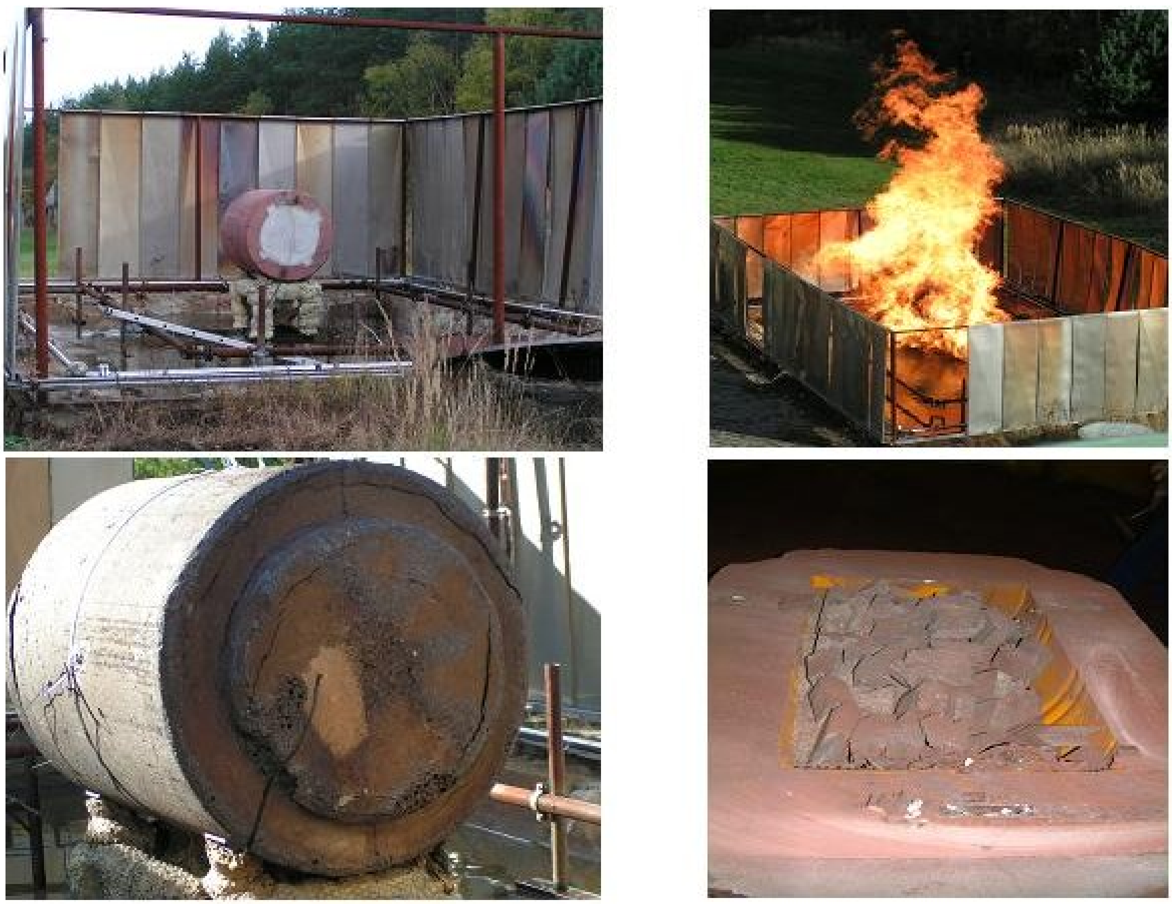

Fig. 3. Concrete container Konrad Type I fire test; ABK I+II with accident safe waste packaging. The figures above show the experimental set-up before and during the fire test. The figures below illustrate the container after the test (general and cross-section view).

The second example is a fire test at 800°C fire temperature over one hour with a cylindrical concrete container of Konrad Type I containing one 200 liter steel drum at the BAM gas fire test facility. The goal of this experiment was to demonstrate the integrity of the container to protect waste products with melting points higher than 300°C from burning in the open fire. The container prototype to be tested was equipped by some thermocouples placed at the wall of the steel drum and at the inner and outer wall of the concrete container. In order to simulate the real case of using flammable components, the drum was charged with a mixture of plumb parts and Styrofoam parts. The experiment set up is presented in Fig. 3. The temperature values measured at the different positions remained lower than the temperature of the flammable components when burning. Observing the section of the container after the test (Fig. 3, right bottom) confirmed also the absence of any burning of the waste products.

QUALITY ASSURANCE MEASURES FOR PACKAGE FABRICATION AND OPERATION

Quality assurance measures for package fabrication and operation are obligatory for transport, interim storage and disposal. The basic guideline, primarily issued for transport packages but also applied in the field of storage, is given by the German technical rule TRV 006 [5]. The container manufacturer has to demonstrate a certified quality management system and a container fabrication according to an appropriate quality assurance program. Each container type should be fabricated based on certified "Inspection and Test Plans". Once the container fabrication is certified, the manufacturer's quality management system can be audited officially by authorities like BAM or TÜV at regular intervals as fixed in the certification. In the case the licensee charges an external manufacturer with container fabrication, that subcontractor has to fulfil quality assurance measures on the same level and shall be evaluated regularly by the licensee.

According to the German Radiation Protection Ordinance all waste treatment and conditioning processes must be approved, with respect to disposal, by BfS since 2002. Treatment and conditioning processes for interim storage approved by BfS with respect to disposal are required in most cases since 1996.

Due to the fact that the Konrad container approval is carried out independently from any waste conditioning procedure and considers specific mechanical and/or thermal waste properties with potential relevance to the former container design testing, interactions between container and waste products have to be checked within the waste specific treatment and conditioning campaign evaluation. Typical issues are mechanical and thermal waste product properties with relevance to the design testing conditions. If there are limitations in the test certificate and approval additional safety assessments would be necessary. Another aspect is corrosion protection especially at the inner container surfaces. It has to be assured, if necessary by additional handling requirements, that waste products do not damage corrosion protection coating during the loading procedure. Because different parties are involved in container design testing (BAM), design approval (BfS), waste specific treatment and conditioning campaign evaluation (TÜV) it was obvious that a co-operation is useful especially in difficult cases, primarily with regard to waste product conditions and properties. In order to facilitate that task, BfS, BAM and TÜV are planning a data based package documentation including waste data and waste conditioning campaigns in relation with container approval and fabrication documentation. Benefits are expected for today's daily work when containers are loaded and prepared for disposal as well as questions for package properties may come up some years later when delivery campaigns to Konrad are planned.

With the purpose to realise a networking between all the parties involved in the container specific quality and safety evaluation as well as package preparation, BAM initiated, for the first time held in Berlin in September 2009, an information exchange forum where authorities, waste producers and owners, container manufacturers and technical experts participated. The discussed topics dealt with the interpretation of the Konrad acceptance criteria, container design testing and certification procedures, interfaces between transport, interim storage and disposal regulations, quality assurance requirements for container fabrication and operation, qualification of existing containers for disposal up to an optimised design of application procedures. This first meeting was very successful and it was agreed to hold it twice a year in the future.

CERTIFICATION OF EXISTING CONTAINERS

Due to the continuous need of conditioning radioactive waste also in the past some thousand waste packages do exist in German interim storage facilities. Analyses performed show that in many cases Packages contain waste products, which are conditioned based on an approved treatment and conditioning process. But containers are only qualified and approved for interim storage by the respective authority. On the other hand a large number of legacy packages (most of them conditioned before 1988) exist, where neither a full description of the conditioning process nor a detailed documentation of the containers are available.

For such predictable situations the Konrad acceptance criteria contain special paragraphs defining test requirements for existing containers. Documentation, design testing and quality assurance measures are also for such containers the main assessment goals. Generally, the equivalence of container safety assessments and the manufacturing documentations in comparison to a new container design testing procedure has to be evaluated. Possible strategies include reference to comparable objects/containers and additional investigations with representative reference containers to demonstrate necessary compliance with the Konrad requirements. In addition to containers, waste products have to be evaluated as well. If documentations are not sufficient additional investigations might be necessary to determine required physical, chemical and nuclear waste properties. Currently, first applications were made and evaluation procedures for containers of a wide range of fabrication time and documentation quality have started. The strategy agreed between BAM, BfS and the applicants is to start with the latest containers showing least differences in documentation and to move step by step to the older containers with poorer documentation status.

In the last years, e.g. two old container types, a box-shaped steel container Type V and a cylindrical concrete container Type II, both of GNS, were tested, evaluated and certified by BAM, according to the Konrad requirements, both as ABK I without specific leak-tightness (the steel container with accident safe packaging of the waste products, the concrete container with and without accident safe packaging of the waste products). In a first step, the quality assurance measures and their documentation for container fabrication were evaluated, where each batch production container has to demonstrate compliance with the Konrad requirements. Such evaluation was based on representative manufacturing documents on basis of a comprehensible qualified quality management system. On a next step, safety demonstrations were evaluated for the specific container type under consideration of the properties of the existing containers. Design tests (e. g.

drop test and fire test) were examined with representative containers from the batch production, with a simulated charge or existing results from comparable design test were considered. Fig. 4 illustrates the drop test setup. As a result, the compliance with the Konrad requirements could be demonstrated sufficiently and the containers could consequently be certified.

Fig. 4. Steel container Konrad Type V (old) including 26 charged 200 liter drums fixed with concrete; ABK I; drop test: 80 cm height.

CONCLUSIONS

In the German Konrad repository, radioactive waste with negligible heat generation is expected to be disposed off starting 2014. Technical requirements for containers and waste products are now widely mandatory and container design qualification as well as waste conditioning and treatment campaigns are increasing tasks. BAM has performed container design evaluations for different container types, including drop and fire tests, and given subsequent certifications according to the Konrad acceptance criteria.

Furthermore, the numerous existing waste containers and packages have to be evaluated as well and approved if possible. Good chances are expected for evaluation and certification, with respect to the Konrad acceptance criteria, of packages conditioned based on design and waste conditioning and treatment campaign approvals for interim storage with a good documentation basis. Higher effort is expected for legacy packages with poorer documentation status. In cases of major lacks in container fabrication and waste product documentation, it might be an option to perform additional investigations to determine the missing container and, if necessary, waste properties. The appropriate procedure depends significantly on the individual situation and is difficult to estimate in advance. With that, prospects to get the Konrad license should be discussed in cooperation with authorities and applicants continuously during the licensing procedure considering economic and radiological efforts. First licensing procedures in this field are currently under way.

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