Proceedings of the 18th International Symposium on the
Packaging and Transportation of Radioactive Materials
PATRAM 2016
September 18-23, 2016, Kobe, Japan

1024

SD-20K: A B(U)F transport system for final storage containers

Maik Hennebach
DAHER NUCLEAR TECHNOLOGIES GmbH

Franz Hilbert
DAHER NUCLEAR TECHNOLOGIES GmbH

Roland Baumann
SIEMENS AG

Abstract

For radioactive waste with negligible heat generation, final storage in the Konrad repository requires that the waste is conditioned and safely packed in containers with specified characteristics. While most of the Konrad containers (KC) with historical waste from the fuel fabrication sites in Hanau and Karlstein can be transported as industrial packages (IP), a minority requires transportation as type B(U)F packages. However, the KCs by themselves are not designed to meet all B(U)F requirements, especially with regard to the mechanical tests for accident conditions of transport (ACT).

The SD-20K transport system provides the necessary additional protection in the form of a protective packaging for the KCs. It consists of an outer steel frame with rigid foam plates to protect the contents from mechanical and thermal effects, and of an inner container with a double-sealed lid that serves as the containment system (in concert with the conditioning of the wastes and the KC itself). The outer dimensions correspond with those of a standard 20' container.

The SD-20K consisting of the SD-20K protective packaging and a single KC (maximum total mass of 20 Mg) fulfills the requirements towards a type B(U)F package. Size differences between different KC types are accommodated by spacers (rigid foam with a steel casing) within the inner SD-20K container. In addition to the protection of the contents, an important design goal for the SD-20K was to provide quasi-automatic unloading in the Konrad repository. Several innovative features of the transport system (e.g. completely automatic unbolting and opening of the inner SD-20K lid, a vehicle loading bed that can be telescoped) serve to restrict the dose exposure from manual handling to a single operation without any direct contact with the KC itself.

While our presentation will focus on the SD-20K design features and our safety assessment for KC inventories, we will also give a short outlook on future prospects of the design, which could easily be accommodated for the transport of other wastes destined for final storage.

Introduction

The Konrad repository in Lower Saxony, Germany, is intended for the final storage of radioactive waste with negligible heat generation. The waste has to be conditioned and packed in containers that have to fulfill very specific requirements regarding their radioactive inventory, their dimensions and construction, as well as safety requirements (surface dose rate, activity release rate, subcriticality etc.). While the majority of Konrad containers (KCs) will contain only relatively small amounts of radioactive inventory, allowing their transport as industrial packages (IP), the limits given by the Konrad requirements allow for considerably higher amounts of radioactive and fissile content.

Transporting KCs with inventories that exceed the IP limits will require additional safety measures: while the stringent Konrad requirements ensure that the KCs also comply with most of the B(U)F requirements, some safety aspects require additional measures during transport, especially regarding the mechanical tests for accident conditions of transport (ACT). The SD-20K provides the necessary additional protection in the form of a protective packaging for the KCs. This transport system, consisting of the SD-20K protective packaging and a single KC, fulfills the requirements towards a type B(U)F package. While the design was initiated to ensure safe transport of waste from the fuel fabrication sites in Hanau and Karlstein, it can be applied to all kinds of radioactive waste with negligible heat generation that exceeds the IP limits.

This paper mainly presents the design of the SD-20K, but will also give an overview of the safety assessment and a short outlook on future prospects of this transport system.

Design of the SD-20K

The main parts of the SD-20K design are an inner container that provides the confinement system, an outer container consisting of a steel frame with steel sheeting, and rigid foam shock absorbers inbetween the two containers that protect the inventory from mechanical impacts. These parts are shown in overview in Figure 1 and will be presented in more detail below. The outer dimensions are a length of 5.5 m, a width of 2.44 m and a height of 2.6 m. The mass of the SD-20K itself is 10 Mg, the payload is up to 20 Mg, which amounts to a maximum total mass of 30 Mg.

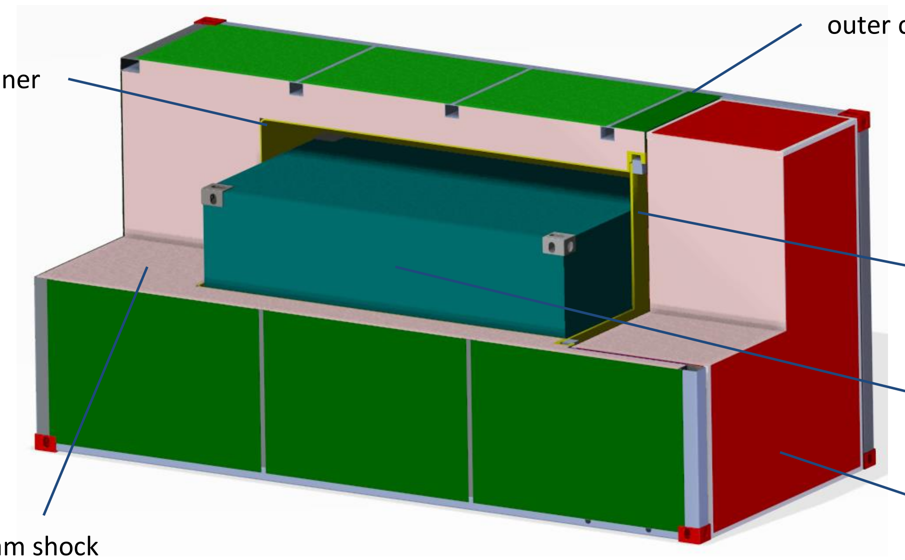

Figure 1 Main design parts of the SD-20K

Outer container

The steel frame of the outer container provides structural stability and protection of the other components. All eight corners of the frame are equipped with ISO corner fixtures. The lower four corners are used to safely fix the SD-20K on the transport vehicle. The connection is designed to fail under accident conditions without damaging the SD-20K itself. The upper four corners are used for handling of the protective packaging during inspections or repairs; the loading and unloading are performed without disconnecting the protective packaging from the vehicle.

Apart from the area around the front shock absorber, the steel frame is sheeted with steel plates for protection against rain and similar external influences. The steel plates are welded to the frame and serve as an easily decontaminated outer surface of the protective packaging.

Shock absorber

To absorb the mechanical impact from the drop tests that have to be taken into account under ACT, shock absorbers made of Polyisocyanurat foam are used in the space between the inner and the outer container. This material is a rigid foam with low density and excellent behavior under stress. It also provides thermal insulation of the inner container in case of a fire or other external thermal loads (the heat generated by the inventory is expected to be negligible).

The thickness of the foam layer varies from ca. 110 cm at the front and back to approx. 30 cm at the top, bottom and sides. There is no fixed connection between the foam and the steel of the outer or inner container; the small gaps due to manufacturing tolerances are taken into account in the SD-20K design.

Inner container

The inner container with its double sealed lid constitutes the containment system of the SD-20K. It is made of high tensile steel with a wall thickness of 12 mm. The dimensions of the cavity are 309 cm length, 175 cm width and 193 cm height. For inventories smaller than the cavity, foam spacers encased in steel are affixed to the back wall and ceiling of the cavity, so that they can stay in place during loading and unloading. The inventory is moved into and out of the inner container by placing it on an automatic traversing unit.

The inside of the inner container is painted with a layer of paint that is easily decontaminated. Furthermore, a passive hydrogen recombinater is provided to prevent the buildup of an explosive mixture of hydrogen and air in case the waste is producing hydrogen (the KCs are not leaktight).

The lid is equipped with a double O-ring seal and closed with four motor-driven wedges that connect with the flange frame of the lid (see Figure 2). The sealing system is designed for a standard air leakage rate of 10^{-4} Pa·m³/s. Most of its design features are necessary for the quasi-automatic unloading in the Konrad storage facility, as described below.

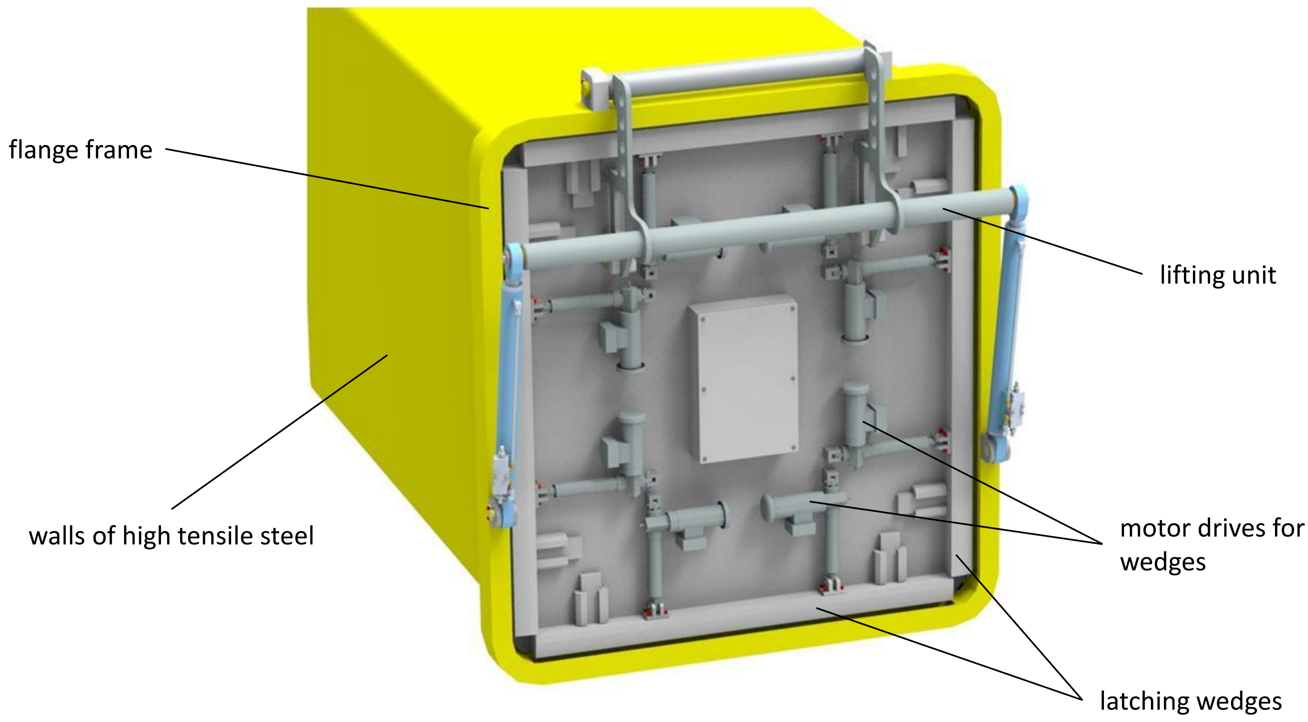

Figure 2 Lid of the inner container

Automatic unloading

A crucial requirement for acceptance of a transport at the final storage repository is unloading without any direct manual contact with the KC itself. DAHER NT designed a quasi-automatic unloading procedure to fulfill this requirement.

After arrival at the repository and connection to an external electricity source, the front shock absorber is released and removed to a distance of ca. 3 m via the telescopable loading rack of the transport vehicle. In the next step, the wedges of the inner container lid are unlatched and the lid is automatically opened upwards by the lifting unit. Once the lid is open, the traversing unit will move the KC into position for the repository crane (see Figure 3).

The whole unloading procedure is performed in less than 30 minutes. It requires only very few manual handling actions (mainly connection of power sources) and there is absolutely no manual contact of the workers with the inventory itself.

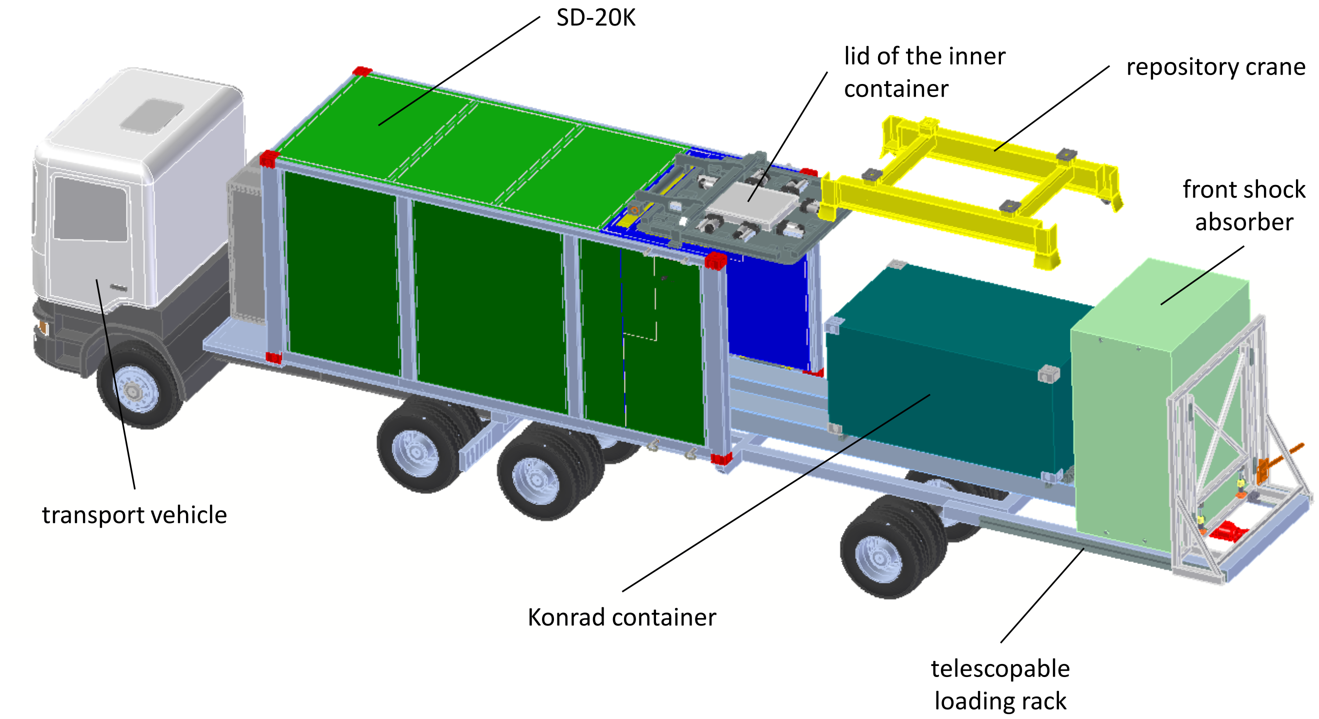

Figure 3 Final step of the unloading process with the KC in position for the crane

Concept of the safety assessment

Characteristics of the inventory

Our package design safety report is based on a general specification of the content. While the properties of the KCs support the proof of safe transport, taking into account the requirements of NCT and ACT, the transport safety assessment can not be based on acceptance of the inventory in another context (i.e. the Konrad requirements). Accordingly, the specification of the inventory for the safety report is self-contained but incorporates the positive KC properties.

As an example, we do not rely on the official confirmation of safe subcriticality of the KCs under storage conditions for our criticality safety assessment during transport, but we do make use of the inventory qualities that derive from the Konrad requirements. In this example, the limited density of fissile material that is already verified for all KCs allows for a short and clear demonstration of safe subcriticality under all conditions of transport.

A similar approach is taken for the safety aspects of radioactivity release, external dose rate and behaviour under thermal loads. Apart from the inventory description, one of the most important parts of the safety assessment is the mechanical analysis, especially regarding the impact of accident conditions of transport.

Mechanical analysis

To determine the most unfavorable drop orientation for the actual drop tests that will be part of the safety assessment, simulation calculations are performed for all scenarios where a significant impact on the safety relevant parts of the SD-20K is expected.

These calculations use the finite element method with a very detailed calculation model. In the analyses, special attention is given to crucial components of the protective packaging, like the sealing of the inner container lid and the shock absorber behavior.

The drop orientations that will be investigated through simulation of a complete accident sequence (30 cm drop followed by a 9 m drop and a 1 m drop onto a rigid bar) include flat drops on the front, back and sides, as well as edge drops on the front and back side and a slap down on the side. An example of the outer deformations resulting from a simulation of a 9 m drop test is given in Figure 4.

Figure 4 Deformations of the calculation model after the 9 m drop on the front edge

Deformations of the inner components caused by the 9 m flat drop on the bottom side are shown as cross sections of the calculation model in Figure 5. As can be seen from these plots, the impact results in severe deformations of the floor of the inner container and the shock absorber beneath it. The design of the connection between the flange frame of the inner container lid and the floor ensures that the effect of these deformations on the leak tightness of the lid is limited.

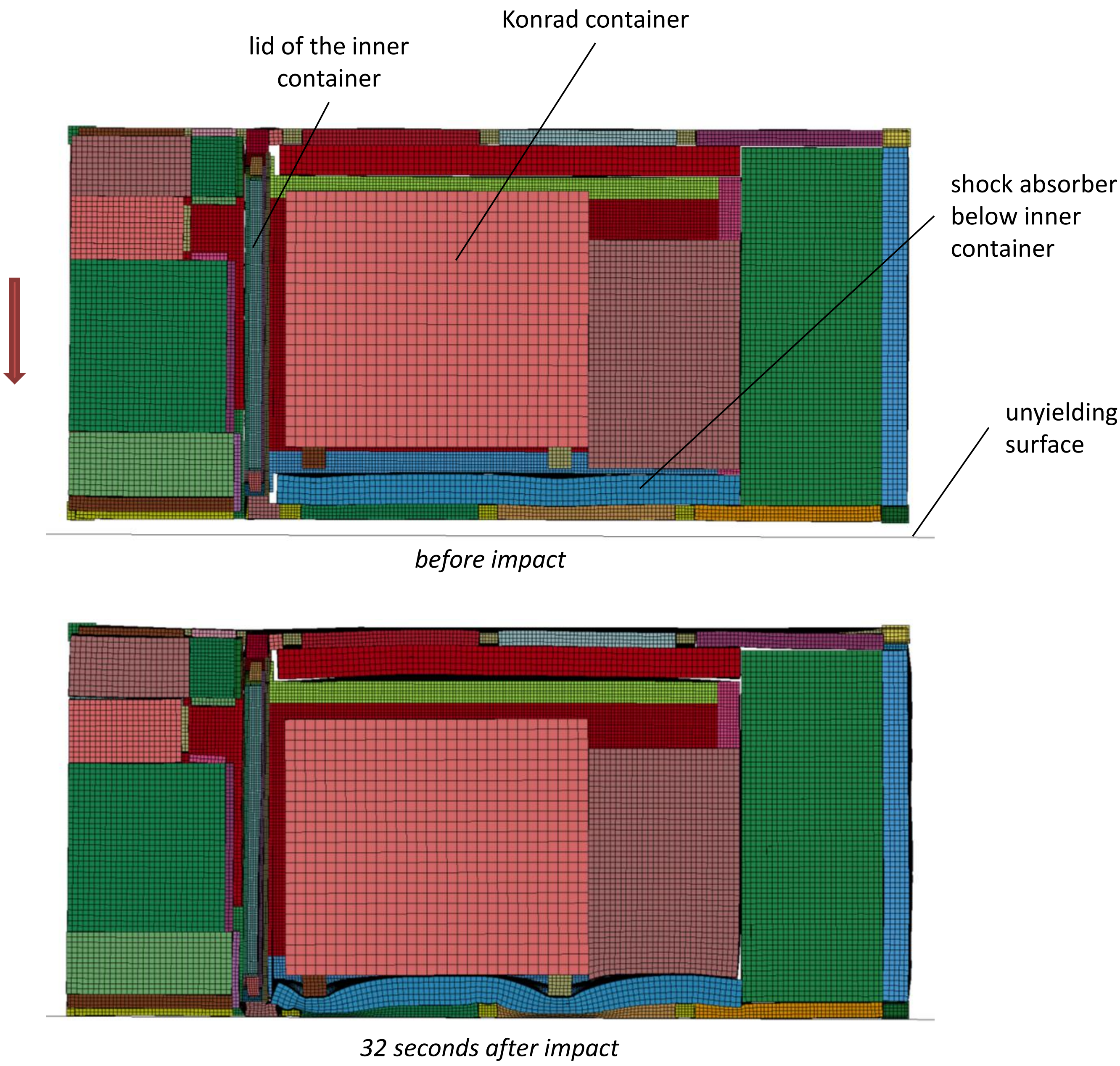

Figure 5 Deformations of the calculation model after the 9 m drop on the front edge

Outlook on future prospects of the SD-20K

While the initial license application will be restricted to steel KCs with inventories from the fuel fabrication sites in Hanau and Karlstein, Germany, the design margins we estimate would allow the transport of a large range of other inventories destined for final storage. Especially for historic wastes where the Konrad requirements are challenging due to insufficient documentation or for waste containers that do not comply with the Konrad requirements for other technical reasons, repackaging and conditioning in a KC and subsequent transport in the SD-20K protective packaging is a viable way to bring these wastes into the final storage repository.

Conclusions

With the SD-20K protective packaging design, DAHER NT and SIEMENS provide a practical solution for the transfer of problematic wastes into final storage. The initial license application is orientated towards inventories from fuel fabrication sites, but the design can easily accommodate other radioactive waste with low heat generation.