DISPOSAL OF SPENT FUEL IN VERTICAL BOREHOLES IN SALT - AN INDUSTRIAL DEMONSTRATION PROGRAM -

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ABSTRACT

In order to synchronize and optimize the emplacement technologies used for both categories of waste (vitrified waste and spent fuel) the borehole emplacement technique for consolidated spent fuel was reconsidered in Germany. The appropriate design resulted in a fuel rod canister of the type "BSK 3". This BSK 3 steel canister is of the same diameter as the standard HLW-canister which allows the use of a common transfer and handling technique. The canister is tightly sealed by welding and designed to withstand petrostatic pressure. Thermal calculations showed that the emplacement of a BSK 3-canister into a vertical borehole in a salt repository is possible after only about 3 to 7 years after reactor unloading of the fuel assemblies. Thus, the emplacement of BSK 3-canisters allows a complete revision of the schedule of spent fuel disposal concepts and may lead to a considerable reduction of time and costs. Accordingly, a research program was launched in 2004 within the framework of the 6th European Research Program to develop the transport and emplacement components, the functionality and reliability of which are to be tested in a one-year demonstration phase which will commence at the beginning of 2008.

1. Introduction

In the context of the repository development program for the Gorleben site the vertical borehole emplacement concept was developed as one option for the disposal of heat generating waste in rock salt. In this disposal concept unshielded canisters containing vitrified HLW or spent fuel are to be emplaced in vertical boreholes with a depth of 300 m which are situated in disposal zones at a depth of 870 m. The disposal zones consist of several disposal fields, each comprising several disposal drifts connected by transport drifts. Each disposal drift consists of a certain number of equally spaced boreholes. In order to facilitate the fast encapsulation of the waste by rock salt, no lining of the boreholes is planned. Figure 1 shows the disposal concept for the emplacement of waste canisters into vertical boreholes in a repository in rock salt.

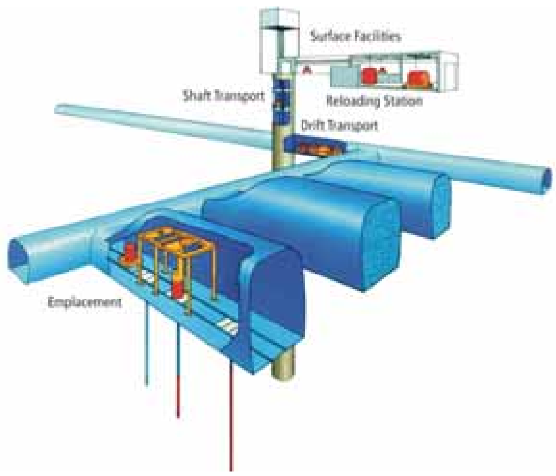

Fig. 1 Disposal concept for the emplacement of waste canisters into vertical boreholes in rock salt

To synchronize and optimize the emplacement technologies for both categories of waste (vitrified waste and spent fuel) the borehole emplacement technique for the direct disposal of spent fuel rods was reconsidered. The corresponding design resulted in a canister of the type “BSK 3”. This steel canister is of the same diameter as the standard HLW-canister which allows the use of a common transfer and handling technique. The canister is tightly sealed by welding and designed to withstand petrostatic pressure. The emplacement of BSK 3-canisters into vertical boreholes of a salt repository is possible after only about 3 to 7 years after reactor unloading of the fuel assemblies.

Accordingly, it was decided to set up an RTD-program to develop the necessary components for demonstrating and testing the functionality and reliability of a suitable emplacement technology. The research project is funded by the German Ministry of Economics and the German Nuclear Industry. In the context of an EC call for proposals for Integrated Projects in waste management in 2003, the BSK 3 emplacement concept was recommended to a consortium of mainly European Waste Management Organisations and accepted eventually as part of the five-year Integrated Project ESDRED. The technological project ESDRED: "Engineering Studies and Demonstration of repository Designs" is co-funded by the European Commission (EC) as part of the sixth Euratom research and training Framework Programme (FP6) on nuclear energy (2002-2006).

2. Types of waste canisters

The high level waste to be taken into account in the repository layout in Germany consists of three different types (see figure 2): Heat generating vitrified HLW which is stored in standard Cogema canisters, low heat-producing highly-active technical waste, i.e. mainly hulls and claddings, which is stored in CSD-C canisters, and spent nuclear fuel rods which will be packed in BSK 3-canisters. BSK 3-canisters are designed to hold the fuel rods of three PWR or 9 BWR fuel assemblies. The BSK 3 consists of a cylindrical steel canister with a height of 4.99 m and a diameter of 0.43 m. The wall thickness is 50 mm and the total mass is 5,200 kg. The quantities of waste canisters considered for repository design amount to:

HLW-canisters:	4,778
CSD-C-canisters:	8,764
BSK 3-canisters:	5,525

3. Emplacement system

The emplacement system developed for the handling and disposal of BSK 3-canisters comprises a transfer cask which provides appropriate shielding during the transport and emplacement process, a transport unit consisting of a mining locomotive and a transport cart, and an emplacement device. During the conceptual phase, different options were taken into consideration in order to find a technically feasible and safe emplacement system. Figure 2 shows the components of the system selected for the transport and emplacement of BSK 3-canisters in an underground emplacement drift. The emplacement device swivels the transfer cask from the transport cart, tilts the cask into an upright position and lowers it down onto the top of the borehole lock.

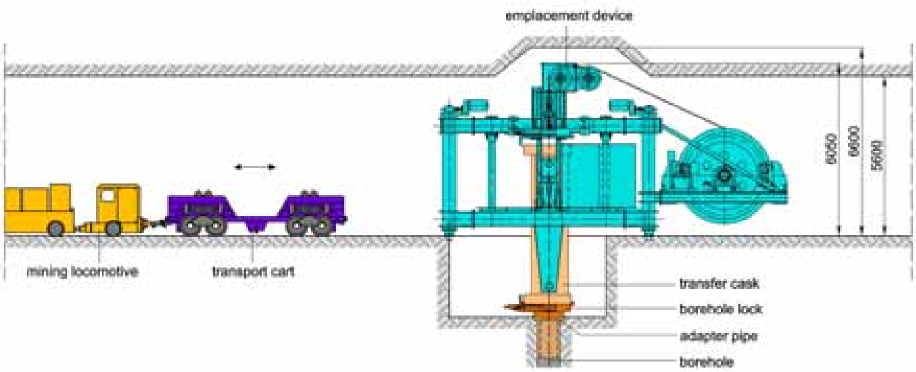

Fig. 2 Transport and emplacement system for BSK 3 canister disposal

3.1 Transfer cask

Aboveground, the BSK 3-canister is inserted into the transfer cask (Figure 3) which is transported by the transport cart through the shaft to the emplacement drift underground. The mining locomotive drives the transport cart with the transfer cask to the emplacement device. The body of the transport cask consists of a thick-walled hollow cylinder made of cast iron with nodular graphite (GJS) or cast steel. The wall thickness and wall structure of the cask body are designed in accordance with the requirements concerning mechanical strength and gamma and neutron shielding.

There are two drill hole lines in the cask wall on separate circles which are filled with polyethylene rods which serve as neutron moderators. The neutron shielding at the base and lid is effected by flattened disc-like neutron moderators. Direct radiation transitions are avoided by means of constructional measures. The locks are made of stainless steel and are screwed to the cask body. The flat slide latches integrated into the locks work like drawers and run in slide bars. When in locked position the flat slide latch is kept in place by two locking bolts set into the side walls.

The transfer cask does not have any inherent mechanism to open and operate the flat slide latches. Cask opening and closing is effected at the base by means of the borehole lock mechanism and at the lid by means of the emplacement device (shielding cover). During the lowering processes opening bolts in the borehole lock and shielding cover mechanism slide into recesses in the latches and open them. At the cask base the opening bolts of the borehole lock are part of the borehole latch. The opening of the borehole causes the simultaneous opening of the transfer cask.

There are two diametrically positioned trunnions at the ends of the cask body to facilitate the handling of the transfer cask. The trunnions have an additional offset collar next to the collar which during transport serves to fasten a lifting sling when in the surface transfer area and to allow it to be picked up by the emplacement facility.

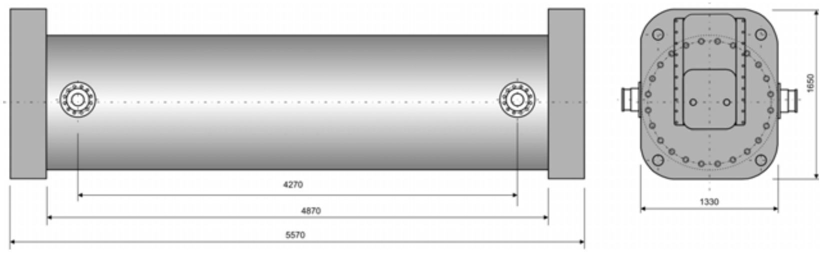

Fig 3 Transfer cask

3.2 Transport cart and mining locomotive

The transport cart (Figure 4) is used for on-site transportation of the transfer cask from the surface to the emplacement location. It has four axles and a pick up attachment under the middle of the chassis for transportation by stationary lifting gear and a coupling at each end for traction units.

The inner collar of the transfer cask trunnions serves as a bearing when the transfer cask is transported by the transport cart. The design of the frame parts of these bearings takes the required operating space for the loading (swivel girder) of the emplacement facility into consideration. To lift the transfer cask free from the transport cart half-covers, a lifting distance of 200 mm is necessary. This distance makes allowance for a 30 mm protrusion of the half cover hinges above the middle of the carrying-pegs and a max. spring relaxation of the transport cart of 20 mm.

For the experiments the existing battery-powered locomotive will be used. In the final repository the locomotive gage will have to be widened

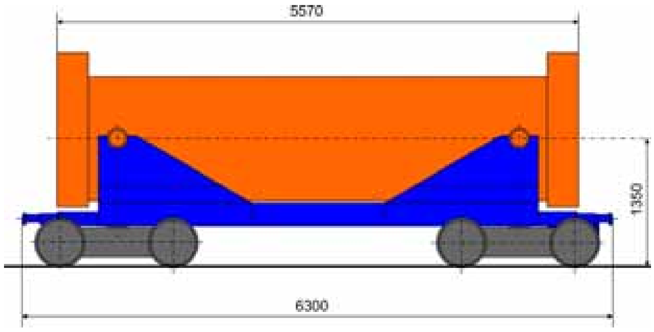

Fig. 4 Transport cart

3.3 Emplacement device

The emplacement device, Figure 5, is the central device of the entire emplacement process. Accordingly, it is equipped with all means for the safe handling of the transfer cask and BSK 3-canister. In a final repository an emplacement cycle usually includes the following procedures: The BSK 3-canister is delivered in the transfer cask on the transport cart. In the emplacement drift the transfer cask is lifted off the transport cart by the emplacement device and swivelled into an upright position after the transport cart has been removed. After lowering the transfer cask onto the borehole lock and opening the transfer cask and borehole lock, the BSK 3-canister is lowered to the planned position in the borehole with the canister grapple. The canister grapple is removed and the transfer cask and the borehole lock are closed. After swivelling the transfer cask into a horizontal position, the transport cart is again driven under the emplacement device and the transfer cask is placed on the wagon. Finally, the transport cart and transfer cask are driven out of the emplacement drift for reloading. Accordingly, the emplacement device basically consists of the following assembly units:

- Lifting gantry
- Flap-frame with controls
- Swivel gear
- Canister lifting gear including hoist cable and lifting tackle
- Shielding cover

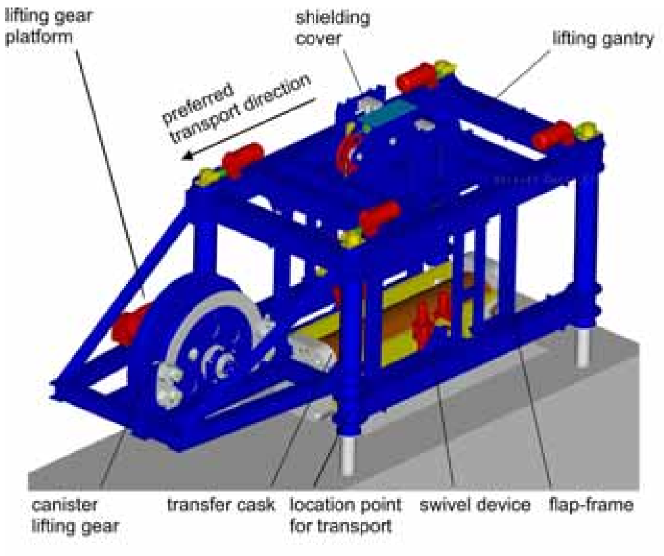

Fig. 5 Emplacement device

3.4 Borehole lock

The borehole lock (Figure 6) provides the sealing of the borehole and consists of a body and a flat slide latch as well as the equipment for the slide latch guidance and the slide motor. The upper part of the body is collar-shaped to take the transfer cask. Four guide pins at the base of the collar help line up the transfer cask. The flat slide latch is a massive block-shaped steel body which is moved by a spindle and a geared engine unit. The flat slide latch has two opening bolts to unlock the borehole lock and to mechanically connect it to the transfer cask's locking latch.

The lower part of the body is flange-shaped to allow its connection to the borehole support pipe. In the upper, inner part of this offset flange ducts arranged in segments carry used air from the borehole via a ring channel to the connection with the ventilation plant.

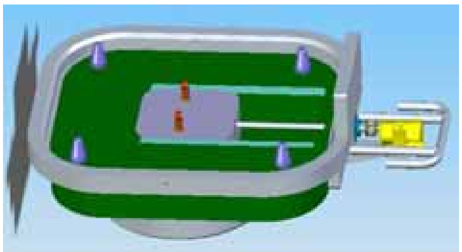

Fig. 6 Borehole lock

4. Demonstration tests

The demonstration tests will be performed in the former turbine hall of a power station in the village of Landesbergen in the vicinity of Hanover, Lower-Saxony. The testing procedure is to simulate the feasibility of emplacing BSK 3-canisters in boreholes of up to 300 m depth in salt rock.

In the demonstration test facility, emplacement will be simulated for two depths. The borehole will be simulated by a sheet steel metal casing. Only one BSK 3-canister will be used for the tests. In the first test, the BSK 3-canister is lowered down to the lower position in the borehole. The canister grapple of the emplacement device is released and removed. Subsequently, the BSK 3-canister is removed from the borehole and placed into the transfer cask on the transport cart.

In the second test, the BSK 3-canister is lowered down to the upper emplacement position in the bore-hole which is simulated by installing a seal into the sheet steel metal casing. As in the first test, the BSK 3-canister is lowered into the borehole and then removed again.

5. Outlook

The components for the demonstration test will be manufactured in 2007 and will be available for test purposes at the beginning of 2008. Thus, the test series will start with the site acceptance test followed by functionality and demonstration tests. During the test series which will last for 10 - 12 months, the functionality and reliability of the components as well as of the entire system will be tested. Eventu-ally, a qualified emplacement system should be available for industrial application.