DEMONSTRATION OF THE SPENT FUEL DISPOSAL TECHNIQUES TEST PROGRAM IN THE FEDERAL REPUBLIC OF GERMANY

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ABSTRACT

One result of the German R&D-program "Alternative Spent Fuel Management and Disposal Techniques" was the fact that there is practically no difference concerning radiological safety regards between the both back ends of the nuclear fuel cycle of fuel reprocessing and disposal of spent fuel. In January 1985 the german government recommended the further development of the option for the direct disposal to prove its technical application.

This paper will outline the conceptual design for the disposal techniques of spent fuel and the test program which ist necessary to demonstrate the reliable and safe handling with these techniques and to create proven facts for a public licensing procedure. This program consists of inactive and active tests (using radioactive sources) in surface facilities and in the ASSE salt mine, the german R&D underground facility for the disposal of radioactive waste.

BACKGROUND

The projects conducted in conjunction with the German direct disposal R&D-program have been described in part in two papers, by Arntzen and Papp, respectively. (Results of the German Alternative Fuel Cycle Evaluation and further Efforts Geared Toward Demonstration of Direct Disposal at WM '86). The German Federal Government has stated its position concerning the results of this program in a resolution adopted in January 1985 [1]. It was thereby agreed that direct disposal is technically feasible, however, further research and development efforts will be necessary before a stage of sufficient maturity for practical application has been reached. The Federal Government regards continued development of methods for direct disposal of spent nuclear fuel elements as expedient, and as a supplement to waste disposal methods involving reprocessing.

In the present report, an up-to-date survey is provided on the status of efforts toward further development of methods of direct disposal. This work includes the programs for four demonstration tests on a scale of 1 : 1, by means of which all required proofs of design maturity for application and elegibility for approval are to be furnished. The demonstration tests are being conducted in part with active sources and in part with inactive test packages and container dummies. To the extent necessary, they have been adapted to satisfy the boundary conditions of the German experimental repository in the ASSE salt mine.

THERMAL SIMULATION OF DISPOSAL IN DRIFTS

The plans for the disposal of spent nuclear fuel elements are based on the disposal of containers in salt mine drifts [2]. The disposal containers have a diameter of about 1.6 m and a length of about 5.5 m, as well as a mass of about 65 Mg (Fig. 1). They are intended for emplacement in a horizontal position in a disposal drift. After the emplacement of a container, it is back-filled with crushed salt.

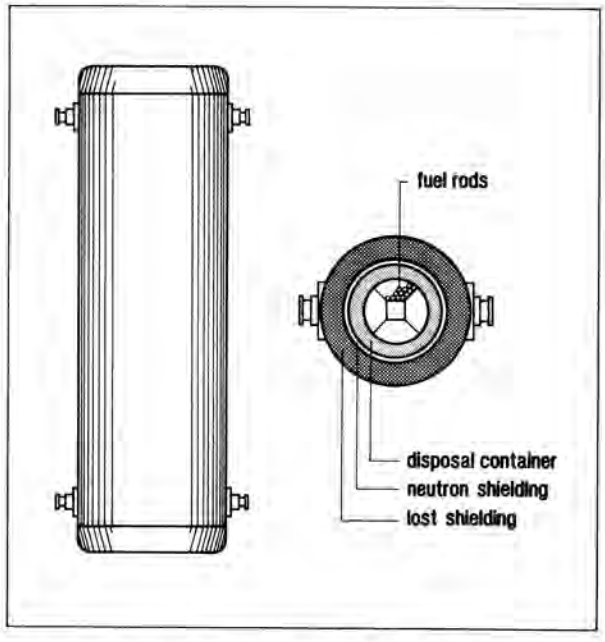

Fig. 1. Disposal Package for Spent Fuel.

The spent fuel elements contained therein exhibit a substantial residual decay heat . The heat which is thus generated must be conducted from the containers, through the surrounding crushed salt and container support on the floor of the drift, to the rock salt for dissipation. Thereby temperature increases and thermomechanical alterations result in the rock salt. The crushed salt employed for backfilling the space around the containers is likewise subject to heating, and therefore alters its degree of compaction, as a result of thermal and thermomechanical effects.

The quantification of these processes and effects, as well as the demonstration by means of in-situ tests, are essential results which are expected from this experiment. The boundary conditions for the

design of the mine openings, the configuration of the disposal drifts, and the occupation density of containers in the disposal drifts are to be derived from these results.

For this demonstration test, two parallel drifts are excavated each of which is to accomodate three container. The container dummies are equipped with electric heaters, by means of which the heat from the residual decay of spent fuel elements is simulated (Fig. 2). The simulated containers are surrounded with crushed salt. Preliminary tests are to be conducted on the back-filling method; thus, the test drifts themselves are to be back-filled by means of that method which proves to be best suited for the repository.

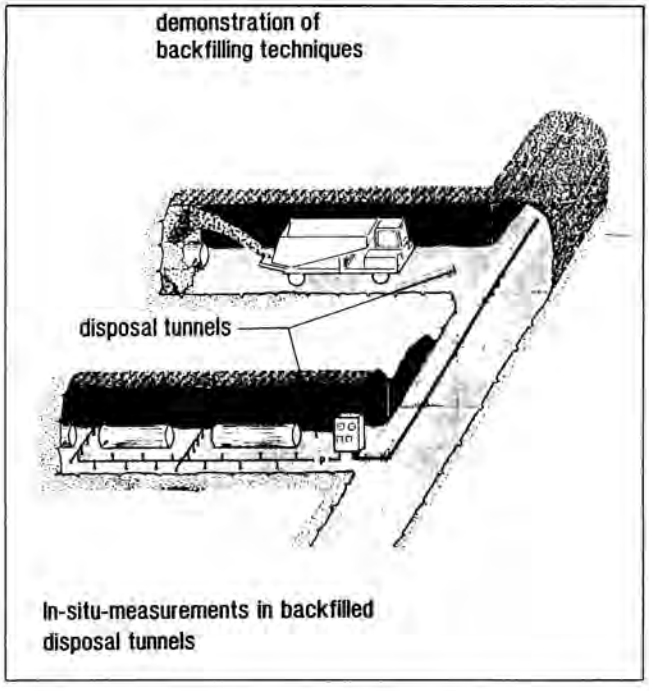

Fig. 2: Inacitve Thermal Simulation of the Emplacement in Disposal Drifts

Different types of measuring instruments are installed in the crushed salt and surrounding formation, in order to record and evaluate all relevant parameters (temperature, pressure, room-closure rate, heat transmission, compaction behavior) throughout the duration of the test.

A test duration of three years has first been planned. In addition to the thermal simulation, the technique of back-filling large packages with crushed salt is to be demonstrated and optimized. Conclusions concerning exposure of the operating personnel to radiation are to be reached in conjunction with the radiation fields determined in active tests. For this purpose, the time residence and distance between the personnel and the package are to be recorded.

In the course of this test, the following vital objectives are to be emphasized:

- Measurement of the surface temperature of the containers as a function of time, with and without back-filling; checking of the thermal calculations in the near range.
- Demonstration of the back-filling technique during emplacement in drifts, optimizing of the processes for transporting the back-filling material, and demonstration of the attainable back-filling density.
- In situ determination of the compacting capability, porosity, and permeability of the back-filling material in thermally stressed disposal drifts.
- In situ measurements of the room-closure rate, with and without back-filling, in thermally stressed disposal drifts.
- In situ corrosion investigations.
- Brine migration in moistened crushed salt in the disposal drifts.

MANIPULATION TESTS FOR DISPOSAL IN DRIFTS

Licensing of disposal of spent fuel elements in large containers depends essentially on the demonstration of safe handling of the packages both above and below ground. In the course of this demonstration test, the machine technology required for underground transport and the disposal process is to be developed, constructed on a 1 : 1 scale, and tested in situ. The objective is to obtain general approval for the components under the provisions of mining law.

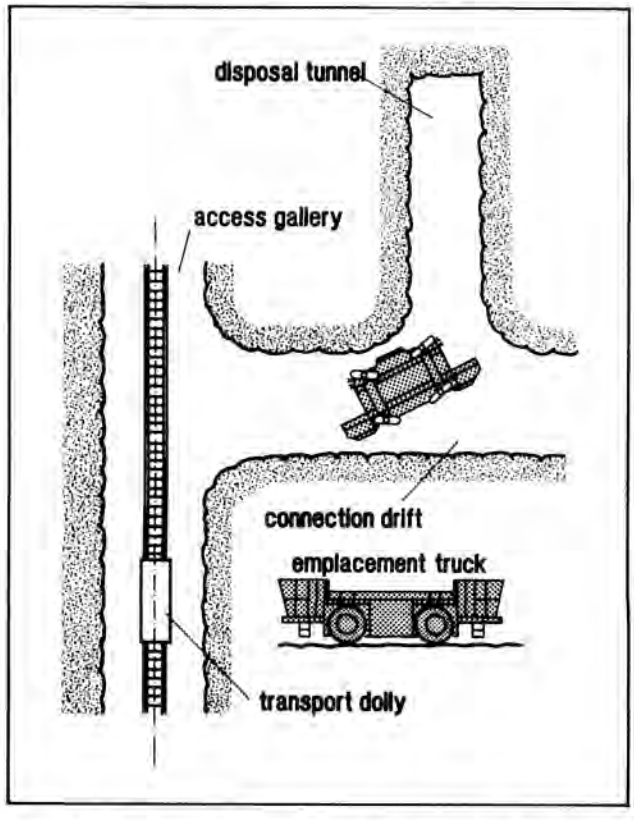

Fig. 3: Inactive Manipulation Tests with Self-Shielded Packages

The boundary conditions for the disposal system under development result from the properties of the packages destinded for final disposal (size, weight), the technical safety requirements and specifications, as well as the dimensions of the underground cavities. Particular importance is thereby placed on keeping the drifts for disposal as small as possible, in order to promote the conduction of the heat generated by the residual radioactivity of the spent fuel elements into the surrounding formation. In Fig. 3, a Diesel-driven vehicle which transports the container to the disposal site and deposits it in place is shown as an example for a possible disposal system of this kind. The test is to be conducted with the use of inactive, simulated containers, since a mine in which an original, active container can be conveyed underground is currently not available. During the testing of the disposal system on site, malfunctions are to be artificially induced, and mishaps simulated, in order to plan and test measures for avoiding or correcting such situations. Moreover, the manipulation sequence is to be optimized, the residence time and distance from the container are to be recorded, in order to obtain results on logistical sequences and exposure of personnel to radiation for the purpose of subsequent planning. In particular, results for further work are expected to accrue from the following vital aspects of the test:

- Inactive demonstration of safe transport, handling, and deposition processes involving heavy containers under conditions relevant to disposal in a salt mine.

- Optimization of handling time, distance of the operation personnel, and transport routes as referred to the facility, for the purpose of minimizing the exposure of the operating personnel to radiation during later operation.

- Acquisition of data for designing the geometry of the drifts, that is, optimizing of the space and area requirements, and thus minimizing of the operating costs for the repository.

- Conclusions on the function, handling, wear, and availability of individual components and equipment, as well as necessity for redundant designs.

- Demonstration of the ability to cope with malfunctions and relevant failures involving heavy containers.

- Obtaining of operating licenses by mining authorities for the components for transport, manipulation, and deposition of heavy containers.

SIMULATION OF SHAFT TRANSPORT

At present, no suitable shaft hoisting equipment is available anywhere in the world for lowering the packages with the given geometrical dimensions and mass of 65 Mg, *together with* the transport vehicle, from the surface to an underground level. This transport process involves several features which do not represent current state-of-the art; examples include:

- pushing of a load onto a locked hoisting cage,

- loading of the hoisting cables and hoisting machinery upon release of the loaded hoisting cage,

- locking of the loaded hoisting cage,

as well as other partial processes.

Within the scope of this investigation, a test stand comprising several levels is to be constructed in a large shop building at the surface. This facility has to include all decisive components, together with their essential functions. The entire loading and unloading process, both above and below ground, is to be simulated here. For this purpose, the transport vehicle, simulated package, hoisting cage frame, locking device, and the systems for pushing on and off are to be constructed on a 1 : 1 scale and then thoroughly tested for proper functioning. The following aspects are to be emphasized in the test:

- demonstration of technical feasibility,

- demonstration of correct functioning of the constituent systems,

- inactive demonstration of the manipulation and hoisting processes,

- optimization of handling time and distance of the operating personnel, for later minimizing of exposure of the operating personnel to radiation,

- conclusions on the function, handling, wear, and availability of individual components and equipment, as well as determination of necessary redundant designs, and

- demonstration of the ability to cope with malfunctions.

ACTIVE DISPOSAL OF SPENT FUEL CANISTERS IN BOREHOLES

One version of direct disposal involves the deposition of spent fuel rods cut into pieces in a canister with the same external dimensions as a canister filled with vitrified, highly-radioactive waste material from the reprocessing plant. The transport and disposal of canisters of this package is to proceed with the same components as does the handling of waste from the reprocessing plant.

In this in-situ test, up to five canisters are to be filled with spent fuel elements and placed in a borehole at the experimental repository ASSE for a period of three years. Prior to the actual emplacement, comprehensive handling tests are to be performed with the packages, both above- and below-ground, in order to demonstrate that these spent fuel canisters can be safely transported, handled, and deposited with the same technical components as vitrified, highly radioactive waste from the reprocessing plant.

The spent fuel elements canisters are to be delivered to the experimental repository and conveyed to a transfer container specifically designed for this type of disposal. The radiation field surrounding this transfer container is to be measured at various locations above and below ground, in order to ascertain the effects on buildings, shops, small underground cavities, and surrounding materials. The existing theoretical calculations will then be compared with these data. Subsequently, conclusions will be reached in advance on radiation fields prevailing in the vicinity of real containers in various cavities at various locations, both above and below ground. Thus, a reliable basis can be created for ascertaining the radiation dose incurred by plant personnel during the intended operation.

Supplementary residence time and distance studies are to be conducted during the other tests, too; thus, all aspects of the exposure of the operating personnel to radiation are to be determined in the course of the tests as a whole.

The process of disposal has been planned in such a way that the spent fuel canisters are to be delivered in a multiple transport container and conveyed to a transfer container by means of a transfer station. The transfer containers are to be placed on the hoisting cage at ASSE with the use of a fork lift, and then lowered into the mine. After arrival underground, it is loaded onto a Diesel-driven vehicle and transported to the disposal site, where it is set down on an interlock system situated over the borehole. The mobile disposal machine, which lowers the spent fuel canister situated in the transfer container through the interlock system into the borehole, is shown in Fig. 4.

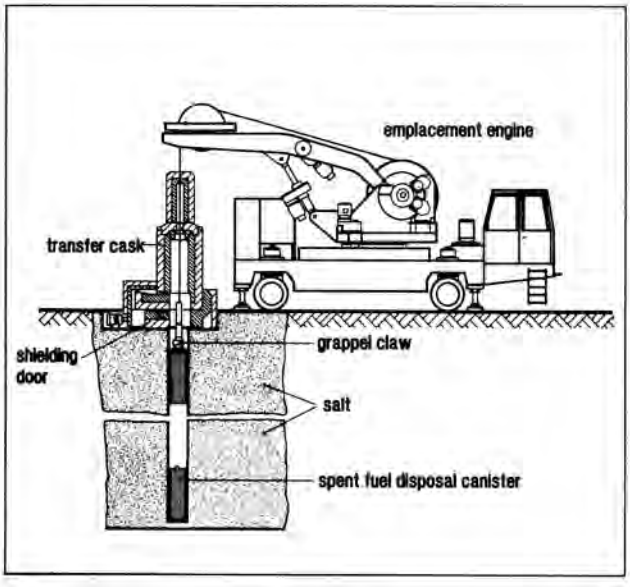

Fig. 4: Borehole Emplacement

During the disposal test, the borehole and the atmosphere within the borehole are monitored, in order to allow conclusions concerning the long-term behavior of the spent fuel packages, and to quantitatively investigate the mutual interaction between radiation, especially that of neutrons, and the atmosphere within the borehole, as well as the surrounding salt.

In this test, the emphasis has been placed on the following aspects:

- inactive testing of the components and handling technology at the surface,
- inactive simulation of malfunctions at the surface,
- inactive simulation of malfunctions underground,
- test program for ascertaining the probability of failure, wear, maintenance, and repair underground,
- measurement of radiation fields at the surface,
- measurement of radiation fields at the surface,
- active manipulation at the surface,
- active manipulation underground,
- experimental disposal (scientific test program involving the deposited fuel element canisters, and
- retrieval (active).

SCHEDULE

The tests just described are to be executed in three phases. The objective is to make all of the test results available in due time for the planning and for the zoning case for the German federal repository at Gorleben in 1993. The schedule, with its three phases for the individual tests, is illustrated in Fig. 5.

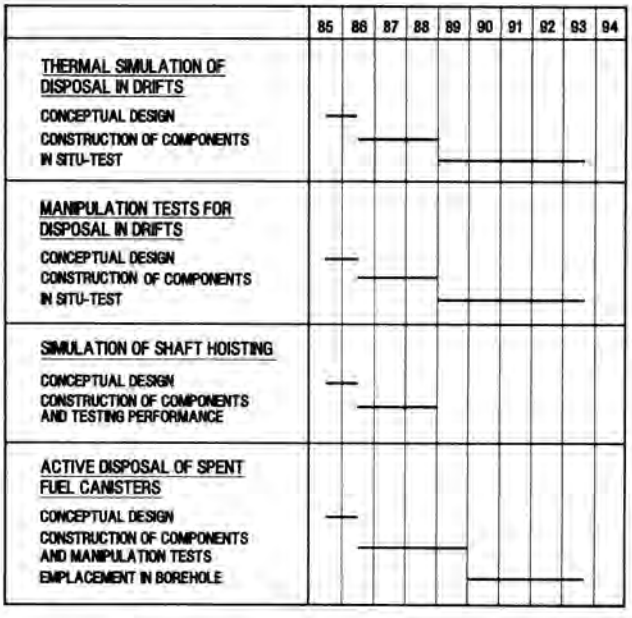

Fig. 5: Schedule for the Demonstration of Spent Fuel Disposal Techniques

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