REPOSITORY DESIGN FOR THE SYSTEMS ANALYSIS DUAL- PURPOSE REPOSITORY

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ABSTRACT

The exploration of the Gorleben saltdome for its suitability as a repository for all kind of radioactive waste restarted in January 1989. Since 1986 engineering studies have been carried out to find a best disposal concept for the heat generating waste produced in the FRG. Within these studies different concepts of waste treatment and encapsulation procedures as well as repository concepts were examined. This report summarizes the work for the surface facilities of a repository.

INTRODUCTION

In the systems study of alternative disposal techniques (1) direct disposal of spent LWR fuel was compared with the traditional fuel cycle based on reprocessing and thermal recycling. The results of the study did not exhibit decisive advantages of direct disposal over fuel reprocessing. The German Federal Government concluded it would continue to adhere to fuel reprocessing as the reference back-end of the fuel cycle (2). Under existing German atomic law, direct disposal is only permissible for fuel for which reprocessing is neither technically feasible nor economically justified. Accordingly direct disposal was selected as the reference technology for spherical fuel elements of the high temperature reactors (HTR). In the case of LWR fuel direct disposal serves as a supplementary option. A program has been launched by BMFT (the German equivalent of the USDOE) to further develop direct disposal to technical maturity. Against this background various disposal systems are to be investigated within the scope of a systems analysis dual purpose repository.

The starting point of this engineering study was the back end of the fuel cycle of 700 tons of heavy metal from light water reactors and also one million spherical fuel elements from high temperature reactors (HTR). This starting point was chosen under the aspect of a simple boundary condition of the planning procedure and in the long-term not fixed amount of the spent fuel element from the german reactors. The principal parameters were the ratio of the both waste management systems, intermediate storage times, conditioning processes and concepts in the mining. The objects of the investigations were all appreciably heat generating wastes of the fuel cycle, hence fuel elements for disposal (LWR, HTR) and also vitrified highly radioactive waste and intermediate level radioactive waste from reprocessing. By reason of their decay heat and high concentration of radiun nuclides, these wastes are of vital importance for the design of an underground repository.

Various companies and institutions have cooperated in the systems analysis of the dual-purpose repository. The DBE was responsible for all activities concerning the planning and design of the underground repository. Twenty-two concepts were planned for the underground workings based on the thermal near field design calculations. Internal shunting and transport systems and the necessary facilities and equipment were designed for the planned repository container concepts (canisters, drums, containers with lost shielding). Radiation protection planning and handling studies were worked out and also possible accidents identified in order to estimate the radiological consequences of the various repository concepts. Cost estimations were completed for the planned facility and equipment planning and used as a basis for the economic evaluations of the investigated disposal systems.

Within the scope of the general analysis which is to be under-

taken by the KfK, DWK and DBE, the technical planning forms the basis for the evaluation of all the investigated waste management systems.

The following criteria will be used for the evaluation:

- technical feasibility
- radiation protection during the operational phase
- long-term safety
- safeguards aspects
- costs

The preliminary results of this systems analysis dual-purpose repository are given in (3).

The technical possibilities together with the respective advan-tages and disadvantages of the investigated parameters are identified by this procedure, i.e. the implementation of planning and subsequent evaluation of the waste management systems. The results obtained are therefore suitable for use by the planning institutions being responsible for the disposal facilities as decision-making guidelines.

This report only includes details of the works for the surface facilities of the repository and covers the aspects of the technical realization (state-of-the-art technology, likelihood of approval) and radiation protection during the operational phase.

REPOSITORY CONTAINERS

Disposal systems which are based on two different types of repository container were investigated in the systems analysis (see Table I). Type 1 are containers with lost shielding and are characterized by the fact that they can be handled throughout the repository without any additional shielding measures.

On account of their size and weight, they can only be emplaced in drifts. A container was designed for every type

TABLE I

Repository Containers for the Systems Analysis Dual-Purpose Repository

	type 1 with lost shielding	type 2 canisters	drums
Weight, max	65 t	1.2 t	2.0 t
Diameter, max	1.65 m	0.43 m	0.775 m
Length, max	5.9 m	1.34 m	1.14 m
Examples for loading	LWR - fuel elements HAW - canisters; HTR - fuel elements ILW(Q) - drums1)	vitrified HAW, cut fuel rods, ILW(Q)1),, HTR fuel elements	

1) ILW (Q) intermediate level waste with a considerable heat development

of waste, its special features are, however, only of minor importance for the operation of the repository.

Type 2 are containers (canisters and drums) which can only be specially handled in the repository, i.e. in reusable shielding. These containers will be delivered in shipping casks each containing 9 drums or 21 canisters, remote control reloaded into shaft transportable transfer casks and emplaced underground in approximately 300 m deep boreholes. In this case also, there are different containers for every special type of waste and which, however, for handling and emplacement operations can only be classified in terms of containers with lost shielding, canisters and drums.

TECHNICAL EMPLACEMENT CONCEPTS

Drift Emplacement

Drift emplacement is performed for all type 1 containers. These containers are designed as transport and repository containers and satisfy the requirements of the IAEO (Type B (U)).

These containers are delivered to the repository surface facilities. Following passage through the entrance control and into the transfer hall, they are placed on a transport vehicle. This transport vehicle is moved to the shaft and into the waiting winding cage. The cage is then lowered to the emplacement level.

The loaded transport vehicle is hauled by a mine locomotive along the access drift in the underground to the emplacement area. The locomotive is then coupled to the transport vehicle on a shunting track so that it can be shunted along the cross-drift into the emplacement drift up to the prepared emplacement position.

At this point, the container is lifted from the transport vehicle by the emplacement device, the transport vehicle pulled clear of the container by the locomotive and the container placed on the drift floor by the emplacement device. The emplacement device is then connected to the transport vehicle and withdrawn from the emplacement position. The transport vehicle is then returned to the surface for reloading. The cavities around the emplaced container are backfilled with crushed salt /4/. The emplacement procedure is shown in Fig. 1.

BOREHOLE EMPLACEMENT

All drums and canisters are emplaced in deep boreholes. These containers are delivered to the repository in shipping cask. The planning basis for the systems analysis dual-purpose repository was a shipping cask capacity of 21 canisters or 9 drums. The entrance control on the shipping cask are undertaken in the transfer hall, the containers are then lifted from the delivery vehicle and transported to a reloading station. There the repository containers are then removed and placed in internal facility transfer casks which stand on a transport vehicle. This forms the respository transport unit.

The transport unit is moved from the transfer hall to the shaft and pushed into the winding cage. It is then lowered to the emplacement level, pulled from the winding cage and coupled to a mine locomotive which hauls it along a drift to the emplacement area. The transport vehicle is recoupled so that it can be shunted along the cross-drift into the emplacement drift up to the emplacing machine. The transfer cask is lifted from the transport vehicle at this point by a crane which is integral in the emplacing machine and placed on the borehole slide hatch which seals the emplacement borehole from the drift. Emplacement in the approx. 300 m deep borehole then takes place by gripping and lowering equipment and also additional shielding on the emplacing machine and thruster systems in the transfer casks. The canisters are stacked on top of each other at this point up to approximately 10 m below the drift level. After successful emplacement, the transfer casks are returned to the surface for reloading. The emplacement procedure is shown in Fig. 2.

FACILITY PLANNING

Fig. 3 shows a panoramic view of all the important surface facilities of the repository. The facilities only vary in a very limited area in the transfer facility from those of a

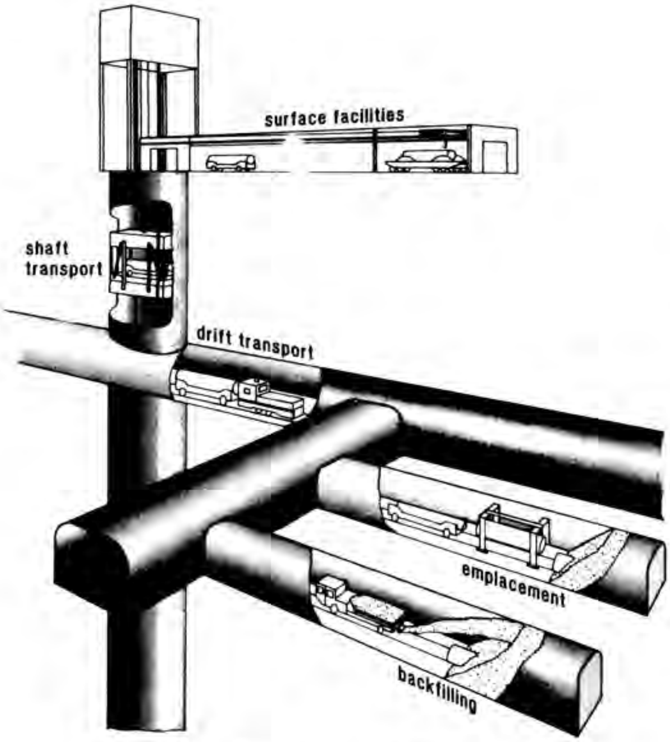


Fig. 1. Emplacement Proceure (DT).

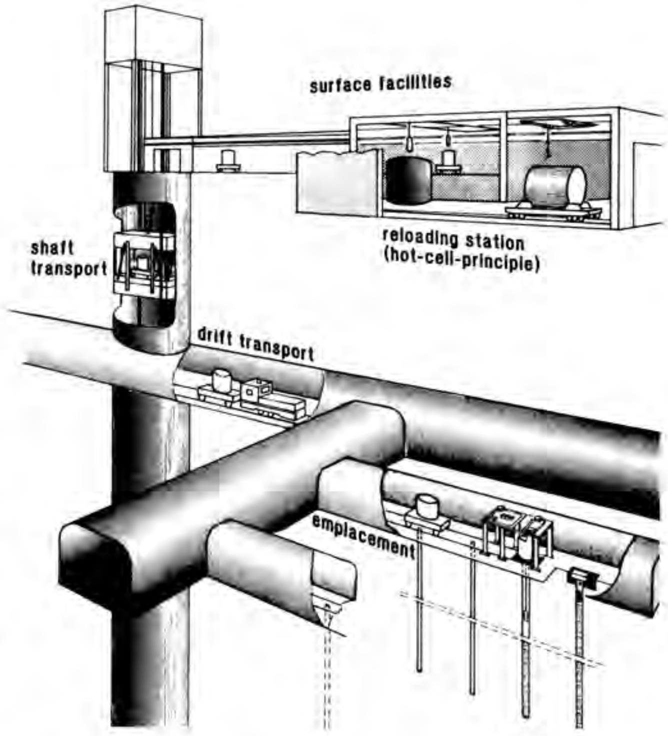


Fig. 2. Emplacement Procedure (BL).

conventional mine. The results of the systems analysis dual-purpose respository are derived from this facility area.

In addition to the delivery rate pattern of wastes, the dimensions and weights of the various containers (repository containers type 1, type 2 and shipping casks, facility transfer cask) are important boundary conditions for the planning of the transfer facility. This necessitates that three different system planning projects which cover the following cases are be undertaken for the systems analysis:

- only borehole emplacement (only containers type 2: BL)
- only drift emplacement (only containers type 1: DT)
- joint borehole and drift emplacement (containers type 1 and also type 2, BD1, BD2)

A comparison of the waste quantities did not indicate any need for further differentiation between the planning projects. The waste material quantity delivery pattern of five different types is shown in Table II.

All emplacement concepts are based on the assumption that 500 t/a are generated by reprocessing, i.e. the HAW vitrified in canisters and the ILW conditioned in 400 litre drums. 200 t/a are emplaced directly (3). The transfer facility for concepts BD1 and BD2 covers all operating procedures (including concepts BL and DT) and is explained in short detail below.

Transfer Facility for Joint Borehole and Drift Emplacement (BD1, BD2)

The functional areas of the facility are shown in Fig. 4. The transfer facility consists of the transfer hall, social and laboratory building and also the technical service facilities. The shaft hall and shaft winding equipment were integrated into this building complex.

The delivery and despatch of shipping casks and containers with lost shielding is either by truck or by rail on a through roadway for both means of transport. All necessary measuring equipment for incoming and outgoing controls (radiation protection rating) is located in buildings adjacent to the roadway.

The wall heights of all function rooms are designed so that there is adequate clearance for the hall crane. The rail system for internal container transport runs along the centre area of the transfer hall. It consists of the following tracks:

1 shaft loading track
2 return track (transport vehicle)
3 loading track, canister reloading station
4 loading track, drum reloading station
5 loading track, containers with lost shielding
6 side track, dead end for transport vehicle
7 track to workshop
8 track to decontamination rooms

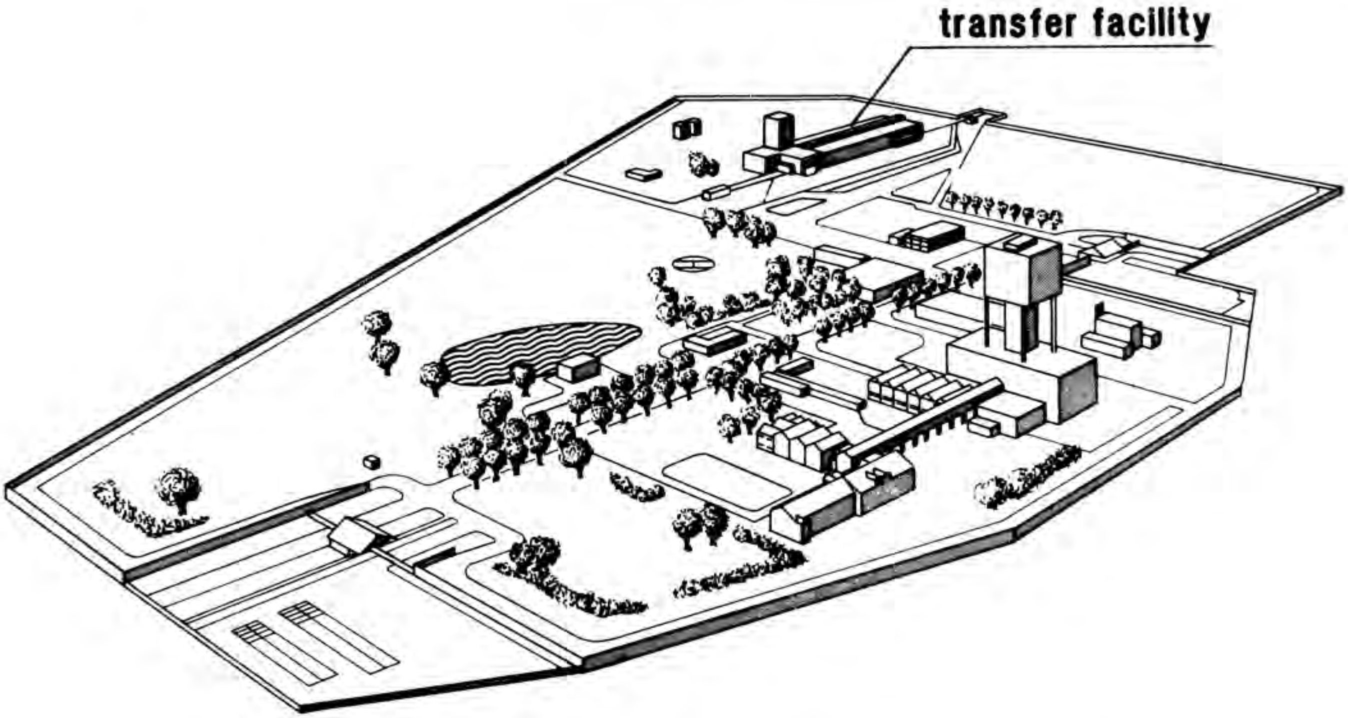
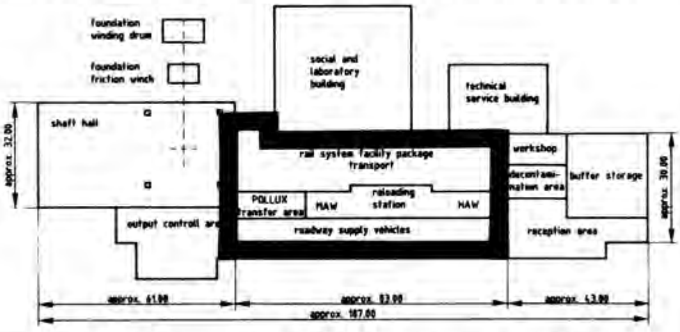
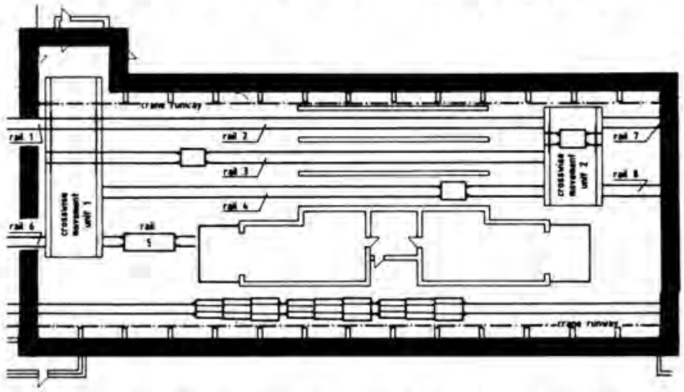


Fig. 3. Surface Facilities of an Underground Repository.



functioning areas of transfer facility



layout of the transfer hall (level 0-0)

Fig. 4. Transfer Facility With Joint Borehole and Drift Emplacemtent (BD).

Two inter-track transfer units are planned for a space-saving wagon transfer between parallel tracks.

The transfer stations for canisters and drums are also placed in the centre area of the transfer hall. The design of the reloading stations is based on the hot cell principle. Accordingly, both the shipping casks and internal facility transfer casks can be docked from below up to the cell. The reloading stations cover tracks 2,3 and 4 and also the area between track 4 and the roadway for the delivery vehicles (Fig. 5). The transfer casks can pass beneath the docking entry point standing upright on a transport vehicle.

The transfer hall bridge crane is used for the transfer of the shipping casks from the delivery vehicle into the transfer station. The cell crane is used for removal of the containers from the shipping cask and placing them in the facility transfer cask. The crane lifts the canister or drum out of the shipping cask, travels inside the cell, over the docking entry point of the single transfer casks and lowers it into the cask.

A loading track for the transfer of containers with lost shielding runs parallel to the roadway for the delivery vehicles in the area between the reloading stations and the shaft hall. The facility transport vehicles planned for the transport of these containers will be parked on track 6 in the shaft hall and, when necessary, will be transferred to track 5 on the inter-track transfer unit.

Transfer Facility for Pure Borehole Emplacement (BL)

In comparison with the transfer facility BD, in this case there is no area for transfer of containers with lost shielding. Accordingly, the transfer hall is shorter in length by approx. 12 m. Otherwise, the structure is principally the same as shown in Fig. 5, quite simply, tracks 5 and 6 are absent.

Transfer Facility for Pure Drift Emplacement (DT)

Only the transfer of containers with lost shielding is undertaken in the transfer facility DT. The transfer hall is considerably smaller and more compact on account of the absence of the reloading stations (Fig. 6.). The length reduces from 126 m with transfer hall BD to 48 m, this is

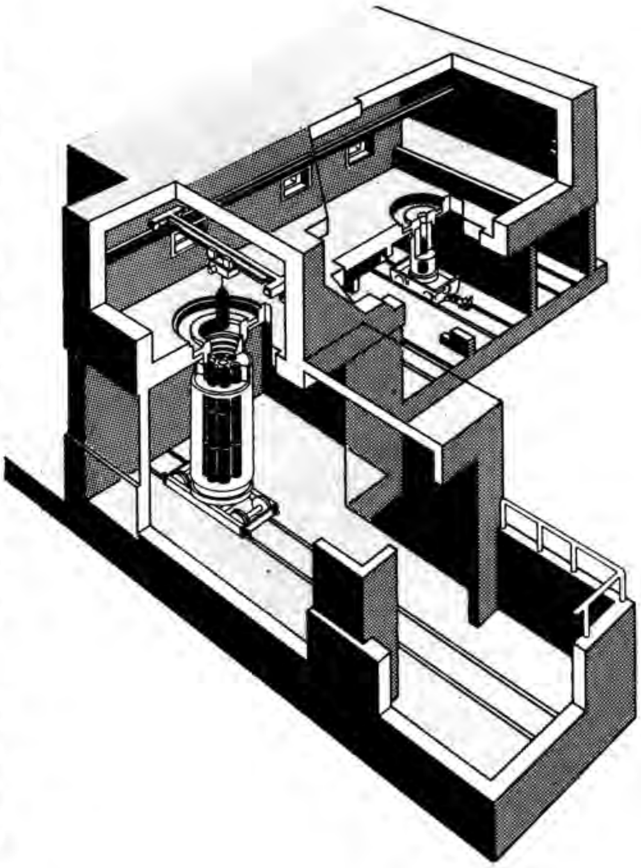


Fig. 5. Reloading Station.

TABLE II

Waste Material Quantity Delivery Pattern for the Investigated Variants

emplacement concept	container type 1 per year	container type 2 per year canisters	drums
BD 1	47	433	2086
BD 2	47	433	2086
BL		1183	2186
DT	624	-	-
DT*	245	-	-

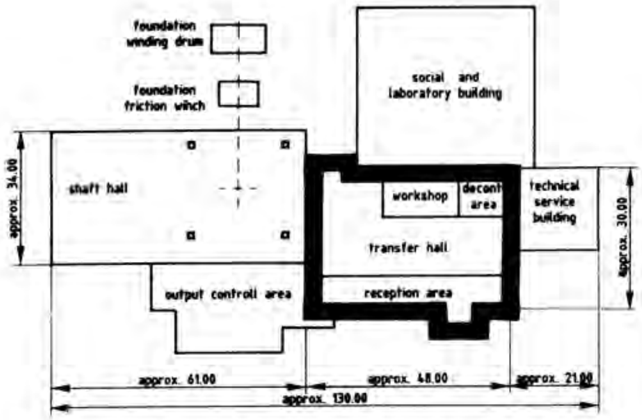
* advanced conditioned ILW(Q) /3/

TABLE III

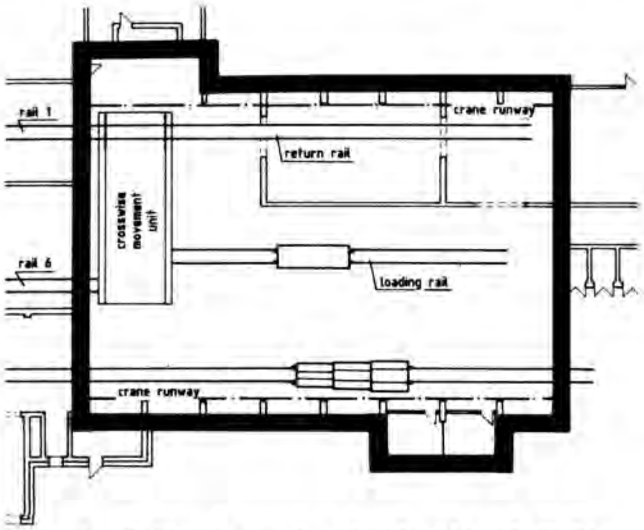
Characteristics of Transfer Facilities

	BD	BL	DT
area approx. m^2	8,750	8,350	5,850
volume approx. m^3	159,000	137,000	90,000
costs approx. Mill $*	40	39	24

* DM/$ parity 1.75/1



functional area of the transfer facility



layout of the transfer hall (level 0-0)

Fig. 6. Transfer Facility with Pure Drift Emplacement (DT).

equivalent to a reduction of the covered area of around 60 %.

COMPARISON OF FACILITIES

A comparison of the characteristics of the buildings of the transfer facilities, excluding the installed equipment, is given in Table III.

The design of the shaft halls, social and laboratory building and the technical amenities are virtually identical. When related to the BD concept, their proportions in terms of cost and area of the total transfer facility are around 30 %. This shows that the transfer hall alone is the crucial building for the facility comparison.

Table IV shows some technical data for the transfer hall equipment. The differences in costs for these items of equipment result from the differences in the transfer stations, crane installations, inter-track transfer units and rail haulage roads with the respective rail transport equipment. Items of equipment for radiation protection for the delivery and despatch control and also radiation monitoring have not been included. The different load carrying capacities of the crane installations are, on one hand, attributable to the weight of container type 1 (max. 65 tons) and, on the other, to the weight of the shipping cask for canisters and drums (max. 130 tons). The number of inter-track transfer units and the length of the rail haulage roads is dependent upon the number of handled containers. It is also influenced by the "reloading concept".

Additional quantifiable parameters for the different transfer facilities are the handling times and the expected occupational doses for the operatives. The occupational doses are determined on the one hand by the handling operations and on the other hand by the total number of the containers.

The handling times and collective dose commitments as shown in Table V and VI for the operatives in the surface facilities were determined in the course of a handling study. In this case, a differential was made between the container types: lost shielding, canisters and drums.

With the values as shown in Tables V and VI, the handling times and occupational doses which occur during handling of the shipping cask have been related to the container. Most of the handling stages are undertaken remote controlled or under the protection of simple shielding measures. The handling operation with the maximum dose effect is the transfer of the containers onto the

TABLE IV

Data of Equipment in the Transfer Halls

variants	BD	BL	DT
total costs of equipment approx. million $*	18.0	17.5	3.0
load carrying capacity			
of main crane installation in tons	130	130	70
number of intertrack transfer units			
single track	1	1	1
double track	1	1	0
length of rail haulage roads with rail haulage equipment in m	300	285	125
number of reloading stations	2	2	0

* DM/$ parity 1.75/1

TABLE V

Handling Times in the Surface Facilities Per Container

	Type 1 min. approx.	type 2 canister min. approx.	drum min. approx.
container delivery	15	0.5	1
delivery control	3	0.5	0.5
transfer onto the repository internal transport system	32	10	28.5
positioning for shaft transport, winding cage loading	20	20	20

repository internal transport system. The listed values are conservative and based on realistic but simplified assumptions. More detailed planning are not presented in this summarizing paper, but the principle results are shown.

If the container-related values of the occupational doses are compared with the waste quantity patterns (see Table II), a value for the collective dose commitments in the surface facilities of the repository is then obtained. With particular reference to the comparison between the facilities, one arrives at the conclusion that the emplacement of containers with lost shielding has considerable advantages Table VII).

In addition to the quantifiable factors, which can now be given for these three different transfer facilities, for a final evaluation aspects such as state-of-the-art and approval likelihood must be taken into consideration.

Only type-B(U)-tested containers are handled in the transfer facility DT. The handling procedures are comparable to those in an intermediate storage for spent fuel elements as in the interim storage facility at Gorleben (FRG). Some non Type-B-(U)-tested containers are handled in transfer facilities BL and BD. Procedures similar to those practiced at the waste handling facility of the German Pilot Reprocessing and Waste Management Plant (of the HBD/WAK) are implemented. A virtually identical facility is planned for the pilot encapsulation facility at Gorleben (FRG).

Both facility types are covered by a licensing procedure for the repository (par 9b AtG, German Atomic Law). Potential approval is demonstrated by the operation or planned operation of comparable facilities in the Federal Republic of Germany.

Based on experience gained at comparable facilities, it is obvious that the costs for safety technology and safety certifications for transfer facilities BL and BD are higher than the transfer facility DT.

The possibility of technical realization for all facility concepts (DT, BL, BD) is demonstrated by the operation of

TABLE VI

Ocupational Doses in the Surface Facilities

	type 1 Sv approx.	type 2 canister Sv approx.	drum Sv approx.
container delivery	2.6 - 6	0.2 - 6	0.6 - 6
delivery control	0.6 - 6	0.01 - 6	0.03 - 6
transfer onto repository internal transport system	16.5 - 6	5.0 - 6	10.4 - 6
positioning for shaft transport, winding cage loading	1.7 - 6	1.7 - 6	1.7 - 6
total	21.1 - 6	6.9 - 6	12.7 - 6

TABLE VII

Collective Dose Comittment in the Repository Surface Facilities

emplacement concept	occupational doses in the repository surface facilities man mSv/a approx.
BD1	30
BD2	30
B2	36
DT	13
DT*	5

*advanced conditioned ILW(Q) /3/

comparable facilities.

CONCLUSION

With in the next six months a decision-analysis will be under-taken. The outlined differences in this report will be compared under the aspects of technical feasibility, radiation protection, long-term safety, safeguards aspects and costs with all other parts of the investigated waste management systems, so that the final evaluation may lead to different significant values, which result in decision-making guidelines for the responsible planning institutions.

From the current aspect the differences between variants BD and BL are within the area of uncertainty of the evaluated data (costs). However, the total number of drums and canisters can be restricted to below 1,200 per annum so that, it is only necessary to erect one reloading station in the transfer hall which would result in a considerable cost reduction. The reloading station can then be designed so that both drums and canisters can be handled.

REFERENCES

1. K.D. Closs et. al., "Systems Study Alternative Entsorgung", PAE Final Report, Karlsruhe, FRG, Dec. 1984, Main Volume, Karlsruhe Nuclear Research Center.
2. German Federal Ministry for Research and Technology, Press release 8/85 (22.01.1985)
3. R. Papp et al., Preliminary Results of the Systems Analysis Dual-Purpose Repository, Waste Management '89, Tucson, Arizona, 1989 to be published
4. H.-J. Engelmann et al., Thermal Simulation of Drift Emplacement for Direct Disposal of Spent Fuel Evaluation of the Backfilling Technique -, Int. Symposium on Uranium and Electricity "The Complete Nuclear Fuel Cycle", Procee- dings of the Conference, Saskatoon, Canada 'Sept. 18-21, 1988