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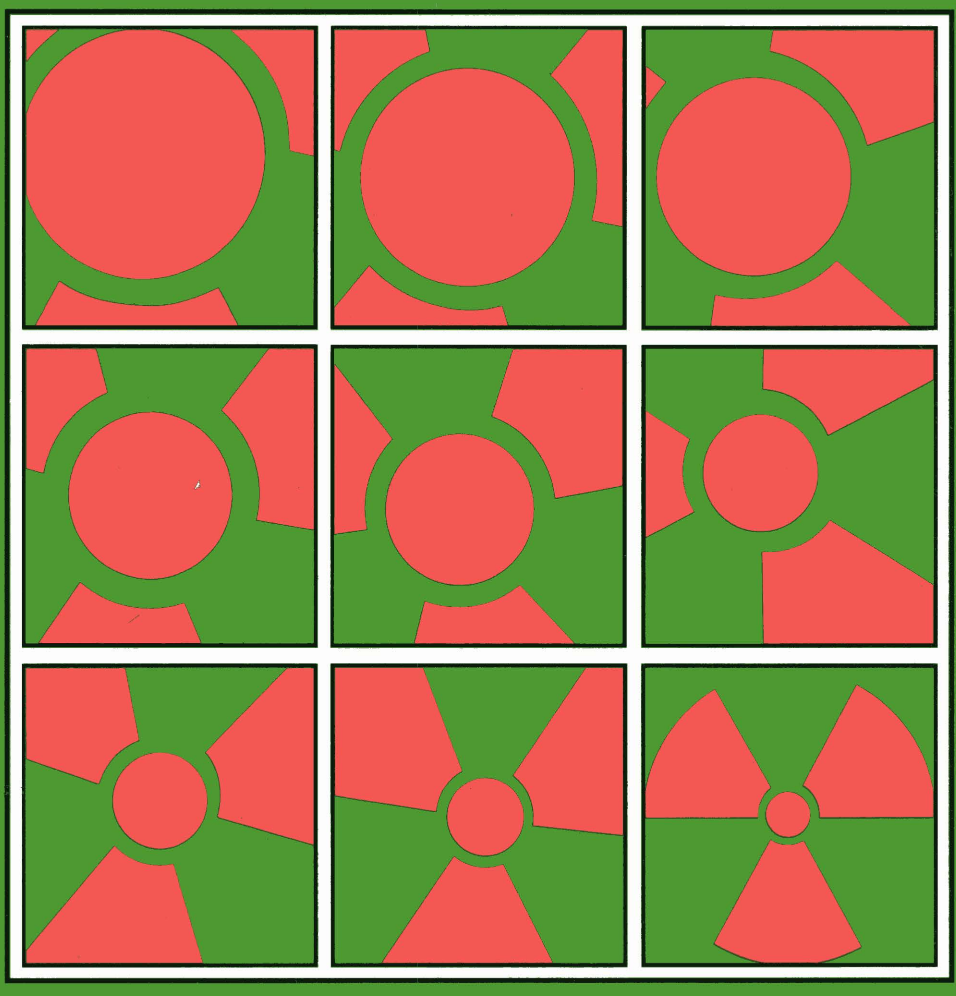

Report

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The HAW project: Test disposal of highly radioactive radiation sources in the Asse salt mine Documentation and appraisal of the disposal system

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Topical report

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ABSTRACT

The primary objective of the HAW-project was to investigate the interaction of high-level radioactive waste canisters with the final repository medium, rock salt. A further major objective of the research project was the prototype development and trial of a technical system for the disposal of highly radioactive canisters in deep disposal boreholes.

The disposal system encompasses all components which are necessary for safe handling of canisters. Moreover, technical-organizational measures were developed for the execution of the emplacement and retrieval.

In the present report the components of the final disposal system are described; their position and function within the overall handling sequence are explained. Special emphasis is placed on questions of radiation protection and accident prevention, on functional and operational safety, on quality assurance and examination of documents, materials, preparation, and function, and on documentation.

As far as planning of the disposal technique for a final repository mine is concerned, the experience gained from the development and operation is recorded in this report, and recommendations are made for further developments. Problems which occurred during work on the HAW-project were due partially to test-specific causes and will not occur in this manner, or at all, in a final repository mine.

Foreword

During the reprocessing of spent LWR fuel elements, fission products and actinides to be treated as radioactive wastes are fused in borosilicate glass and consolidated in stainless steel canisters. The primary objective of the HAW-project was to investigate the interaction of such high-level radioactive waste canisters with the final repository medium, rock salt. A further major objective of the research project was the prototype development and trial of a technical system for the disposal of highly radioactive canisters in deep disposal boreholes.

For the simulation of real high-level radioactive waste, special highly radioactive radiation sources were prepared for the tests in the Asse salt mine by the Battelle-Pacific Northwest Laboratories in the United States within the scope of a German-American cooperative contract. The radiation sources were doped with high contents of the radioisotopes, caesium 137 and strontium 90, in order to obtain representative test conditions with respect to thermal power and gamma dose rates.

In a final repository the canisters or waste casks must only be deposited. During the HAW-project, in contrast, the retrieval of the radiation sources upon completion of the test, or in case of events which render premature retrieval necessary, had to be taken into account.

The disposal system encompasses all components which are necessary for safe handling of canisters. Moreover, technical-organizational measures were developed for the execution of the emplacement and retrieval.

In the present report the components of the final disposal system are described; their position and function within the overall handling sequence are explained. Special emphasis is placed on questions of radiation protection and accident prevention, on functional and operational safety, on quality assurance and examination of documents, materials, preparation, and function, and on documentation.

As far as planning of the disposal techniques for a final repository mine is concerned, the experience gained from the development and operation is recorded in this report, and recommendations are made for further developments. Problems which occurred during work on the HAW-project were due partially to test-specific causes and will not occur in this manner, or at all, in a final repository mine. In this report they are considered only to the extent that they appear significant for future planning.

The beginning of the test disposal had originally been planned for 1987, and its realization would ultimately have been possible in 1993 after appropriate preparation, after approval of the disposal system by the mining authorities and TÜV Hannover in May 1991. In December 1992, however, the German Federal Government decided to discontinue the project and to discontinue all preparatory operations because of the uncertain licensing situation.

Despite the premature termination of the test, useful results have been obtained. With the disposal system, which was available as of December 1989, quarter-annual test and training runs were performed with simulated sources. Weaknesses were thereby recognized and eliminated. This is likewise described in detail in the report.

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1 Introduction

The German concept for the final disposal of high-level radioactive wastes (HAW) from reprocessing of spent nuclear fuels provides for the final disposal of high-level radioactive waste canisters in boreholes 300 to 600 m deep, to be drilled in disposal galleries at a depth of about 800 m in a final repository mine. The design value of the maximum borehole wall temperature in the final repository is 200 °C at ion dose rates in the range of about 1 kGy/h at the canister surface.

In conformance with the safety criteria of the German Federal Ministry of the Interior, dated 20th April 1983 (BMI, 1983), for the final disposal of radioactive wastes in a mine, the recognized codes of practice shall be applied to the construction, operation, and decommissioning of a final repository; that is, only well-proved methods shall be applied in the genuine final repository. For the HAW project, therefore, the development and testing of a technical system for the disposal of highly radioactive waste canisters was also intended, besides the investigation of the interaction of high-level radioactive wastes with the host rock, salt.

The essential objectives of the HAW-project were:

* Investigation of the release of water and gas components as a result of the heat input, the gamma radiation, and the interaction with the candidate canister materials, as well as the resulting gas pressures in a disposal borehole

* Investigation of the thermomechanical effects of the disposal of heat-generating canisters on boreholes, galleries, and pillars with respect to the validation of analytical models

* Development of a transport and handling system for real high-level radioactive waste packages

A survey of the disposal system is presented in Fig. 1.

In the course of the development of the disposal system a "Guideline for hoisting devices at the Asse mine" has been developed as a company standard in agreement with the Mining Authority, TÜV Hannover, as well as an independent expert, and has been approved by the Supervising Mining Inspectorate in Clausthal (GSF, 1988).

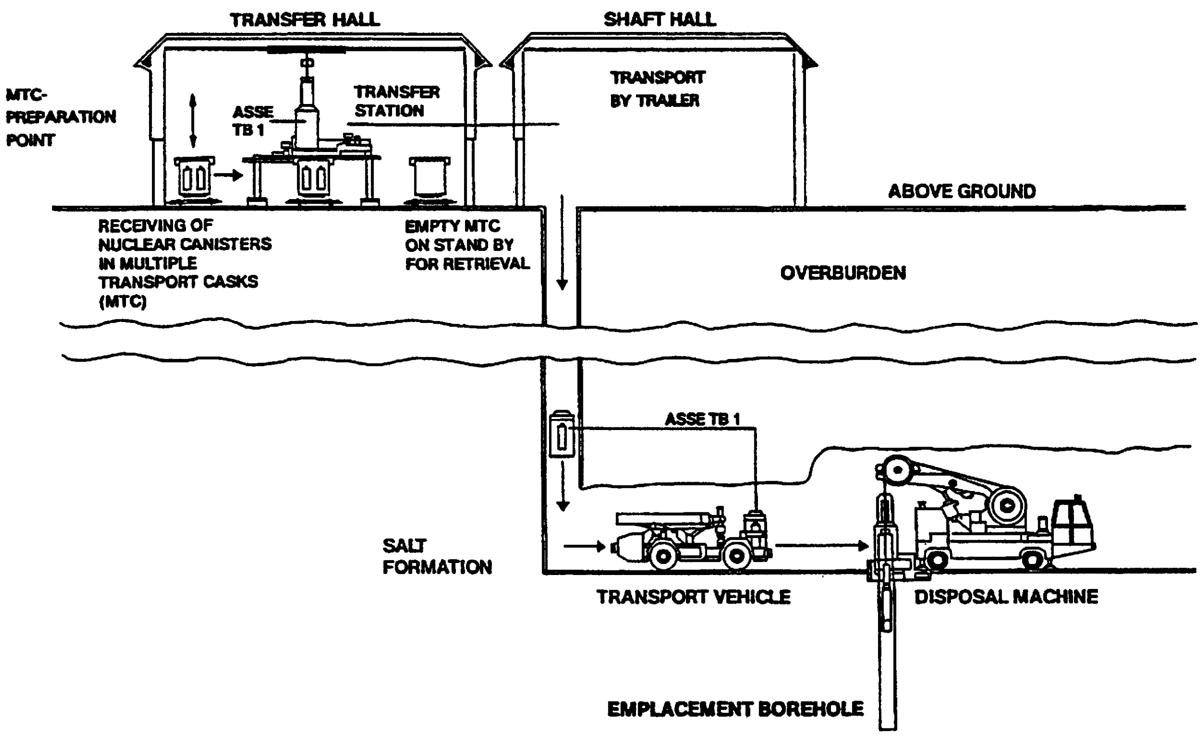


Fig. 1: Survey of the Disposal System

2 Objectives, and Boundary Conditions to be Observed

The disposal system has been conceived for the test disposal, and has reached the operational stage, comprises components for the execution of all handling steps from the arrival of the sources at the Asse mine to forwarding and dispatching to an interim storage facility after completion of the test.

The radiation sources to be considered during the development of the system were prepared by the Battelle Pacific Northwest Laboratories (PNL) (Holton et al., 1989) within the scope of a German-American contract on the "Technical exchange and cooperation in the field of treatment and disposal of radioactive wastes".

With these types of radiation sources (see Table 1) the temperature and dose or dose rate ranges of interest can be generated with a sufficient bandwidth in the disposal boreholes. Moreover, the fission products in real high-level radioactive disintegration waste which are decisive for the major share of the gamma radiation and heat generation during the first 200 years of final disposal are represented with the use of the radionuclides, Cs 137 and Sr 90. In the radiation sources, Cs 137 essentially provides the desired gamma dose rate, whereas Sr 90 is employed as a pure beta emitter for providing the desired thermal power of the radiation sources. Deviations from the standard values and contents are associated with manufacture.

Table 1: Average Values of the Radiation Sources with Reference to the Filling; Preparation of the Canisters between February 1986 and March 1987

Type	Radionuclide Content Cs 137 [PBq]	Sr 90 [PBq]	γ-Dose Rate (in Air) [kGy/h]	Thermal Power [W]	Calculated Maximum Salt Temperature [°C]
I	2,83	5,34	0,93	1335	160
II	7,15	3,10	2,28	1490	190
III	7,64	4,83	2,51	1860	230

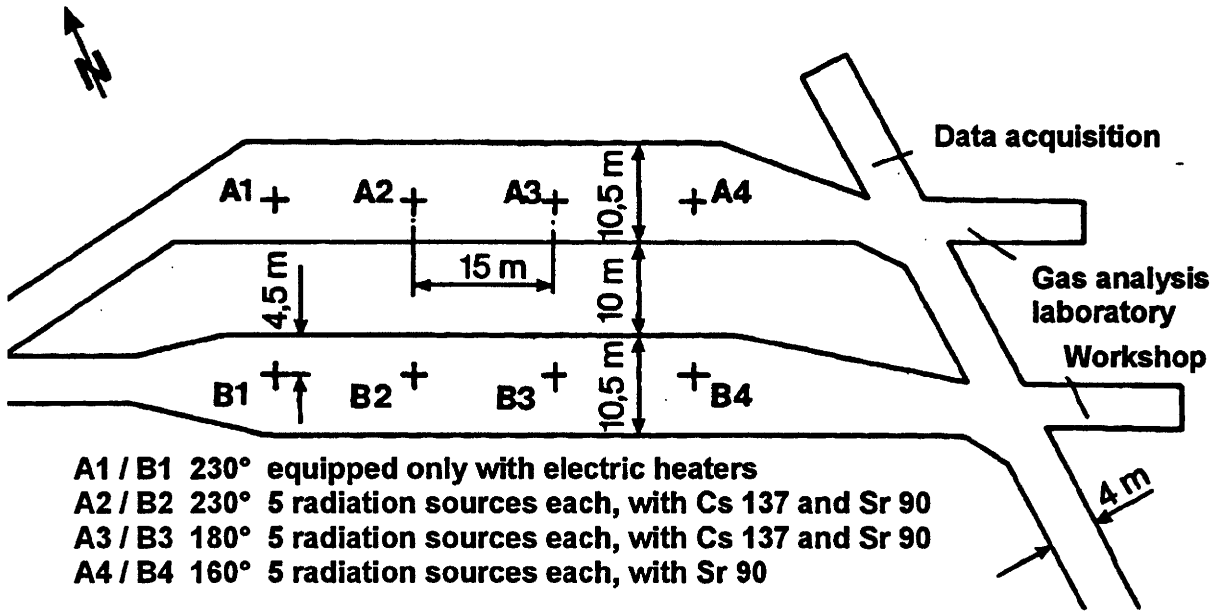


Fig. 2: Layout of the HAW Test Field at the 800 m Level of the Asse Salt Mine

Five radiation sources of the same type each were intended for installation in six disposal boreholes 15 m deep (Fig. 2). Furthermore, two additional test boreholes were equipped only with electric heaters for comparison; the intended maximum borehole wall temperature was 230 °C (as with radiation source type III). The maximum dose rate at the canister surface is 2.8 kGy/h; after attenuation by the borehole liner a local dose rate as expected for the disposal of real HAW is thus attained at the salt. With reference to the height of the canister column the thermal power of the radiation sources is approximately relevant to a final repository; however, the dose rate at the canister surface is about five times as high.

The canisters (see Fig. 3) consist of stainless steel (material no. 1.4571) and are provided with gas-tight welded lids. These lids have a mushroom grip for handling the canisters. Each canister contains about 60 l of vitrified radionuclides. They have a height of 1154 mm, an outside diameter of 298.5 mm, and a wall thickness of 8 mm (see Table 2).

The canister with lid represents the "tight enclosure" for the licensing procedure for the single transport cask, Asse TB1, and for the overall test. As far as the multiple transport cask of type Castor GSF-5 and GNS-12 are concerned, no credit is taken for the "tight enclosure" by the canister mantle. In this case the "tight enclosure" is formed by the lid of the transport cask as well as the sealing and monitoring system installed there.

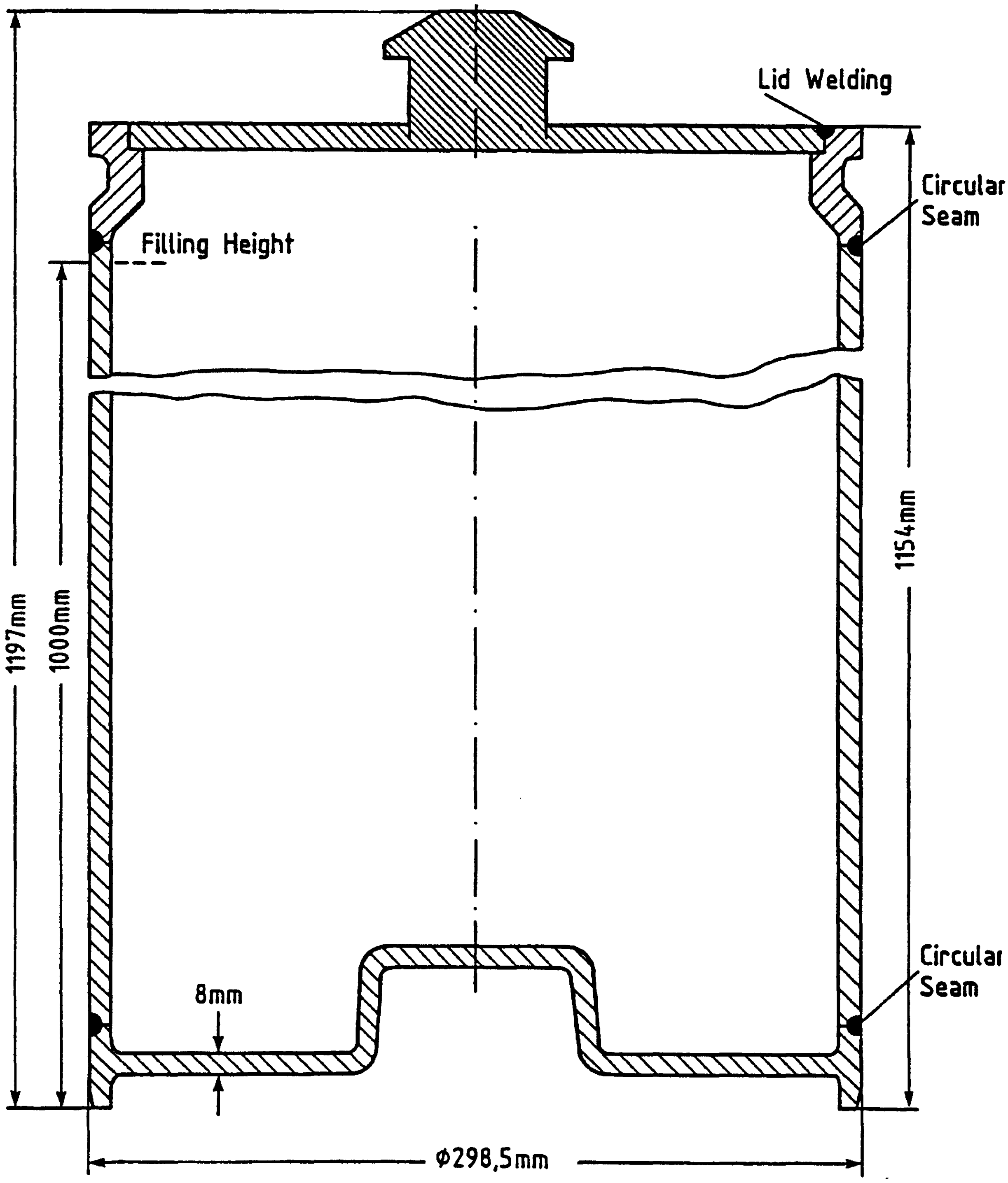


Fig. 3: Canister

Table 2: Canister Data

Dimensions (at 20 °C) [mm]	
Overall Height	1197
Height without Mushroom Grip Pintle	1154
Outside Diameter	298,5
Wall Thickness	8
Filling Level	1000
Mass [kg]	
Total Weight	250
Glass Weight	165
at Glass Volume ~ 60 Ltr.	
and Glass Density ~ 2,8 g/cm^3	

For the design of the shielding the radiation source with the highest activity is decisive. The source manufacturer, PNL, indicates the following maximum activities:

Caesium 137: 8,77 PBq/canister
Strontium 90: 5,88 PBq/canister

In the design calculations for the shielding different assumptions were made for the maximum inventory of the individual radiation sources. In each case the respective assumed inventories are higher than the values just given. The highest inventory (reference inventory) is for

Caesium 137 with 10 PBq/canister, and for
Strontium 90 with 7,7 PBq/canister

for the multiple transport cask (MTC) of type CASTOR GSF 5 and for the transfer station.

Satisfaction of the requirement for permanent retrievability of the radiation sources could be ensured only by lining the disposal boreholes. Since the outer diameter of the liner should be identical with that of the waste canisters intended for a genuine final repository, a smaller diameter resulted for the radiation sources, and a comparatively higher dose rate resulted from the shielding effect of the liner to be compensated, for otherwise identical thermal power per unit of source height.

Even from these details it is obvious that the transport and handling system thus realized is not directly applicable to a final repository. Furthermore, requirements which had to be satisfied for the licensing procedure would have differed for routine operation in the absence of the retrievability requirement, especially since the specifications and techniques prevailing at the date of licensing of a final repository will be decisive.

Therefore, it was not possible to assume the applicability of individual components of the disposal system employed at the Asse mine to a future final repository without more or less extensive modifications. Consequently, the disposal system was examined (Engelmann et al., 1988) by the Deutsche Gesellschaft zum Bau und Betrieb von Endlagern für Abfallstoffe (DBE) on behalf of the GSF-Institut für Tieflagerung (IfT) to determine the extent to which the modifications necessary for application to a genuine final repository are recognizable at present. This examination revealed that some modifications will of course be necessary for application in a final repository, but that the experience gained is valuable and applicable.

Besides the radiation sources to be transported, the conditions at the Asse mine as well as requirements on the safety and permissible duration of retrieval were the decisive factors for the development of the disposal system. This development started with the single transport cask with integrated grapple for use at the plant only. The entire system was then developed, component after component. In this process the operating sequence for handling the radiation sources was continueously revised and improved. This iterative procedure had to be continued throughout, since each modification had to take into account the effects on other components, on the operating sequence, the approval and licensing procedure, quality assurance, and documentation.

The most important events of the HAW-project are compiled in Table 3.

Table 3: Major Events of the HAW-Project

Preparation of the Test Plan	1982 - 1985
Mining of Test Galleries	March - October 1985
Beginning of Geotechnical Measurements	20th March 1985
Application in Compliance with § 3 StrlSchV (Radiation Protection Ordinance)	March 1986
Drilling of Disposal Boreholes	October 1986 - February 1987
Installation of Borehole Liner	April 1987 - August 1988
Installation of Data Acquisition System	April/May 1988
Start of Operation with Heaters A1 und B1	8th November 1988
Procurement and Delivery of Disposal System	December 1988 - December 1989
Cold Training and Approval of the Disposal System by TÜV and Mining Inspectorate	December 1990 - May 1991
Application for Interim Storage in Compliance with § 6 AtG (Atomic Energy Act)	January 1991
Application for Test Execution in Compliance with § 9 AtG	March 1991
Decision on Premature Discontinuation of the Project	3rd December 1992
Cancellation of the Application in Compliance with § 9 AtG	9th December 1992
Gradual Phase-Out of Heater and Shut-Down	1st March - 26th August 1993
Termination of In Situ Operations of the HAW-Project	31th December 1993

3 Conception, Development, Construction, and Approval of the Components

The conception of the overall system was the responsibility of IfT.

The design, construction, and manufacture of the components were performed by external partners (especially qualified specialized companies of the industry).

Further participants in the development of the disposal system were the licensing authorities and their experts. These were

- the mining inspectorate in Goslar, with its expert TÜV Hannover, and
- the Bundesamt für Strahlenschutz (BfS) with its expert, the Bundesanstalt für Materialprüfung und -forschung (BAM) in Berlin.

The Niedersächsisches Umweltministerium (NMU) and the BfS were responsible for the approval of the test and interim storage of the radiation sources after completion of the test, in accordance with the Atomic Energy Act (AtG).

For the normal case, the component development can be described as follows:

1. Definition of relevant key data and functional principles, preparation of the specification and encumbrance catalogue by IfT.
2. Preparation of a description of the respective component as a basis for a delivery quotation. For this purpose planning orders were in part awarded to engineering offices or competent suppliers. As a rule the concept had to be submitted to the approval authorities in order to determine whether additional requirements had to be taken into consideration.
3. Initiation of procurement procedure: Procuring quotations, performing technical and price appraisal, as well as awarding of delivery order.
4. Preparation of manufacturing documents including the quality assurance system by the suppliers as well as control by IfT.
5. Preparation of an operating plan.
6. Approval of the operating plan (usually after expertise by TÜV) subject to imposition of stipulations.
7. Manufacture, delivery, installation in conformance with the approved documents, with due consideration of stipulations imposed.

8. Examination by TÜV of the documentation prepared by the manufacturer and (partial) approval by TÜV, as well as approval for testing, subject to stipulations by the mining inspectorate.
9. Awarding of the ultimate permission for operation by the mining inspectorate.
10. Licensing of the test start (by NMU in conformance with AtG in agreement with the mining inspectorate in compliance with the German Mining Ordinance (ABVO)).

As already expressed, the "normal operation" as indicated in item 9 was not realized. The steps in items 4 to 8 are mutually interlocked. In part they proceeded simultaneously or iteratively, or both.

An important feature is the partially new technical achievement in the design and manufacture of the components. Of course, this resulted in problems with the controlling of the cost and time schedules.

3.1 Single Transport Cask, Type Asse TB1

The key component of the disposal system was the single transport cask, Asse TB1 (STC) only for in-plant transports of the radiation sources at the Asse mine; consequently, its development already began in 1983/84. The grapple system (see section 3.2), the shielding bell (see section 3.3), and the borehole slider (see section 3.12) were thereby developed in parallel.

Boundary Conditions for Development

The following boundary conditions had to be observed for the single transport casks, or were specified for the initial design:

1. Because of the load bearing capacity of the shaft hoisting system, the transport weight of the STC was limited to a maximum of 10 t.

2. Because of the cage dimensions, the maximum outside diameter of the STC is limited to 1.15 m. The maximum permissible height of 3 m never presented any problem.

3. As the authority competent for approval the mining inspectorate was informed that the licensing procedure for type B(U) shipping casks in conformance with the Ordinance

Relating to Hazardous Goods on the Road" (GGVS) (German Federal Law Bulletin, 1979) should be applied to the STC.

4. The STC should be suited for both the transport of the radiation sources used for the test and the transport of real neutron-emitting waste canisters.

This implies that the following vital specifications had to be satisfied or solved for the purposes of the legal regulations:

a) Sealing requirements (so-called tight enclosure of the radionuclides)

b) Thermal design
   - upper limiting temperature for the source
   - upper limiting temperature for the cask surface in conformance with the legal ambient conditions to be taken into account
   - consideratios in case of fire, and corresponding proofs

   A thermal power value of 2.53 kW per canister was initially specified; it was later modified to 2.065 kW, or 2.40 kW (including a safety allowance of 10 percent).

c) Radiological design for the maximum possible source strength of a canister (10^{10} n/s and $9.5 \cdot 10^{15}$ gamma/s). For the safety report (TN, 1989) the reference inventory already mentioned is decisive.

d) Proofs of the cask behaviour upon dropping, in compliance with the legal requirements, by calculation or test, or both. This includes, for instance, the use of approved materials or the associated expertise test and approval of "new" materials.

e) Cask with devices for inward or outward transfer of the canister through a bottom aperture. The design requires no intrinsic drive and additional electrical devices such as switches, cables, etc.

f) Easy handling (for instance, also for underground application).

Moreover, until the beginning of the project in 1985 it was assumed that the following radiation sources were to be employed for the experimental disposal (see Kessels et al., 1985):

a) PNL-canister with the vitrified radionuclides, Cs 137 and Sr 90, canister diameter 300 mm, canister height 1200 mm

b) WA-350-canister with a diameter of 430 mm and a height of 1360 mm (Planning basis for the year 1983)

c) Later possibly also Cogéma wastes in canisters with a diameter of 430 mm and a height of 1335 mm

An appreciable share of neutron radiation was deliberately taken as basis for the cask design (Kessels et al., 1985: Table 1d, WA 350 waste), and appropriate shielding was provided in the cask. Epoxy resin shielding with thermally conductive metal sheets was envisaged as moderator material.

Single Transport Cask, November 1983 Status

The STC has been developed for transporting highly radioactive canisters. In the development special emphasis was placed on final repository relevance; that is, for designing, the reference data on the canister to be transported were chosen to meet the requirements for the planned final repository. The cask constitutes a transport device which is optimized in weight and dimensions and which complies with specifications with respect to radiation shielding, heat dissipation, and mechanical stability.

In Fig. 4 the structure of the transport cask is illustrated.

The requirements with respect to radiation shielding, heat dissipation, mechanical strength, and fail-safe design resulted in the design of the STC described in the following.

Shielding against gamma radiation from the canister is accomplished primarily by the lead layer which surrounds the canister. The remaining cask materials likewise contribute to the gamma radiation shielding.

For neutron shielding epoxy resin with thermally conductive metal sheet serves as moderator. Finally, an insulating layer (fusion insulation) is provided for preventing melting of the shielding materials in case of fire and ensuring effective heat transfer during normal operation. All layers are mutually separated by steel. These steel layers ensure the mechanical strength of the transport cask both during normal operation and in an accident situation in conformance with the requirement specifications for approval of type B(U) packages.

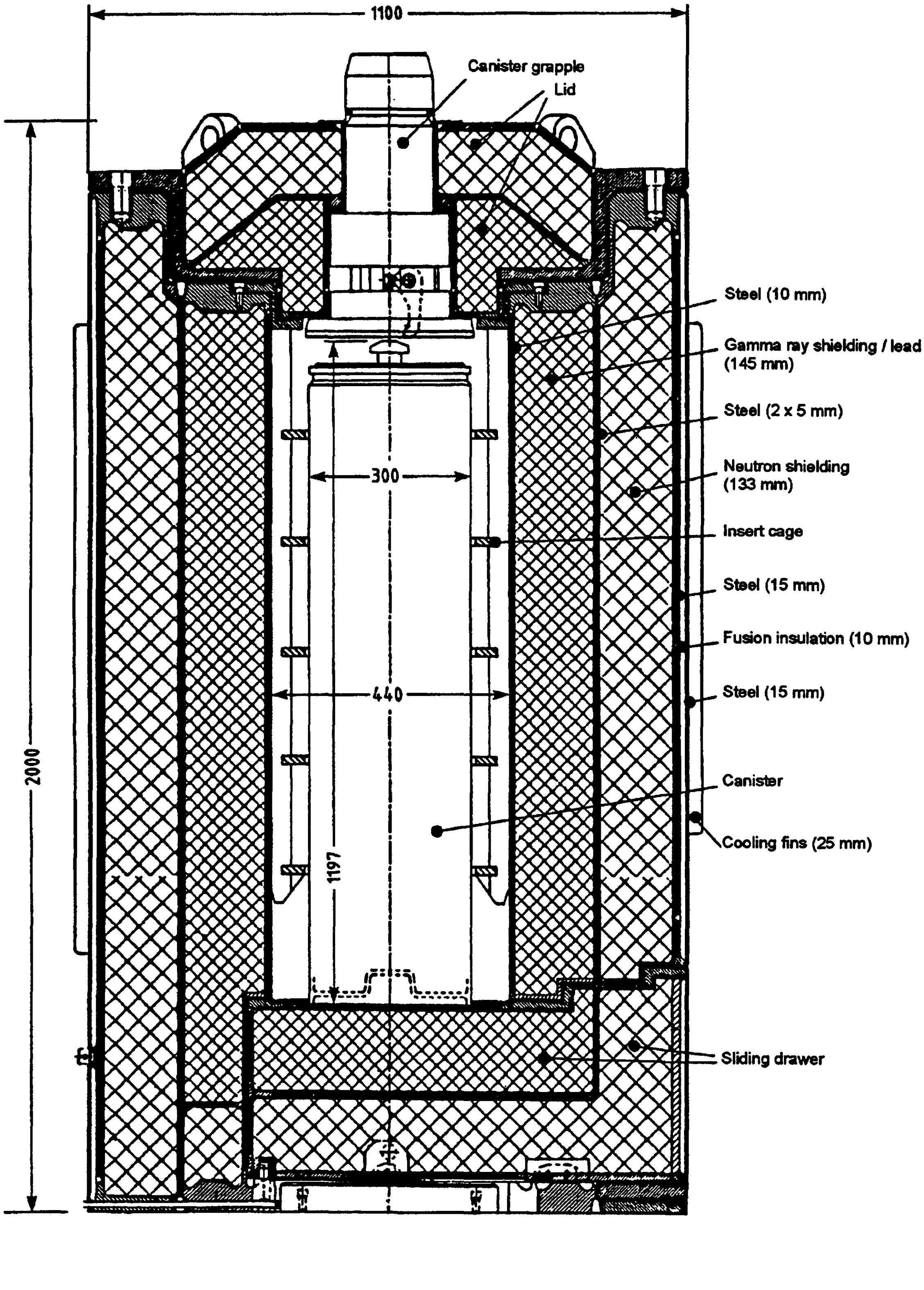


Fig. 4: Structure of the Single Transport Cask, Asse TB1, with Canister

In 1983 the basis for planning of the disposal system comprised the enclosure systems described in the following.

Top closure: Shielding plug, which simultaneously serves as canister grapple
The grapple claws are actuated mechanically or electromagnetically; the retaining function must thereby receive priority.

Bottom closure: Flat slide which constitutes a radiation-proof closure in the closed state
In the open state (disposal process), the possibly emerging gap radiation via "gaps" is shielded by devices on the borehole slider.

As far as radiation protection is concerned the top and base areas are in principle designed in analogy with the cylindrical layers of the mantle. Shielding is achieved by means of offsets at the critical joining zones of the cask components.

The STC is loaded in a hot cell (planning status: 1983!), either from above by removal of the head, or from below with the open flat slide by means of the grapple integrated in the head.

Transfer from multiple trasport casks to the STC is possible with the use of appropriate inward or outward transfer and manipulating devices, as later realized with the transfer facility at the Asse mine (see section 3.9). (Loading in a hot cell was later considered only for the case of a malfunction.)

The canister is transferred from the STC to the borehole after opening of the flat slide and of the borehole closure with the grapple and the associated winch system. (Reverse loading from the borehole was of no importance at that time because of the final repository relevance).

Single Transport Cask, Current Status

The single transport cask (STC) of type Asse TB1 consists of the following major components (see Figures 4 and 5):

- cask body
- lid
- canister grapple with latching device
- bottom sliding drawer with latching device

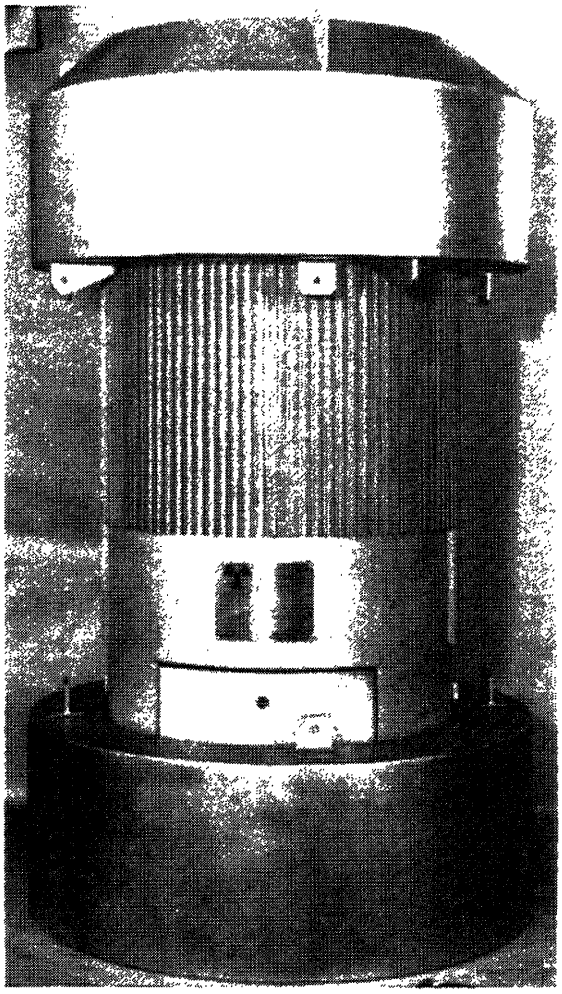


Fig. 5: Single Transport Cask, Asse TB1

- insert cage (basket) for the test canisters (see Fig. 3)
- top and bottom shock absorber, only for transport outside of the Asse plant (see Fig. 5)

The cylindrical cask body consists radially of a multilayered wall. The layering sequence from the inside to the outside is:

- 10 mm stainless steel (material no. 1.4541)
- 145 mm cast lead (Pb 99.9) as gamma ray shielding
- 5 mm stainless steel (material no. 1.4541)
- 2 mm air
- 5 mm stainless steel (material no. 1.4541)
- 133 mm bisphenol-A epoxy resin from the CIBA-GEIGY Company as neutron shielding
- 15 mm stainless steel (material no. 1.4541)
- 10 mm soft solder (L-Sn 50 PbCd 18)
- 5 mm stainless steel (material no. 1.4541)

For improving the heat dissipation 36 meander-shaped, thermally conductive aluminium sheets (4 mm thick) are distributed within the epoxy resin layer, and 98 steel cooling fins (cross section: 25 x 5) are welded to the outer surface of the cask body.

The function of the soft solder is to melt in case of fire, escape through holes closed with fusible plugs in the outer metal sheet, and thus leave behind a thermally insulating air gap.

The useable inside diameter of the cask body is 440 mm; the outside diameter over the cooling fins is 1150 mm. At the top and bottom ends the cask body is closed with welded flanges between the inner and outer metal sheets. At the bottom end the cask is designed in such a way that the so-called sliding drawer can be pushed inward from the side.

The function of the lid (see Fig. 9) is to close and shield the interior from above. The shielding thickness and layering of the lid are equivalent to those of the mantle.

The lid is fastened to the cask body with twelve M 36 screws. Three supporting eyes are welded to the lid for handling the cask and the lid itself. An opening for accommodating the canister grapple is located at the centre of the lid.

The purpose of the canister grapple is to handle the canisters and provide shielding at the head end of the cask. Moreover, the cask should be handled with the grapple. The canister grapple is locked with the lid during transport.

At the bottom the cask body is closed with a slide, the said sliding drawer. As with the lid, the purpose of the sliding drawer is to close and shield the interior of the cask. Its wall structure is of multilayer design, as in the case with the cask body and lid. The layer sequence from the inside to the outside is as follows:

- 12 mm stainless steel (material no. 1.4541)
- 145 mm cast lead (Pb 99.9) as gamma ray shield
- 15 mm stainless steel (material no. 1.4541)
- 133 mm bisphenol-A epoxy resin from the CIBA-GEIGY Company as neutron shield
- 15 mm stainless steel (material no. 1.4541)

During transport the sliding drawer is locked with the cask body with two bolts.

The STC is dimensioned for the transport of canisters of WA 350.

In order to transport canisters of smaller diameter (300 mm instead of 430 mm) for test disposal, an insert cage is necessary for centring the canisters in the interior.

The top and bottom shock absorbers completely surround the cask ends. They are required only for road, rail, or sea transport, which are not intended for the HAW-project. Their purpose is to decrease the mechanical and thermal stresses on the cask in the event of a transport mishap. Furthermore, the bottom shock absorber serves as a receptacle for the cask during transport. The shock absorbers consist of an external stainless steel (1.4541) sheet construction and a balsa wood filler as energy absorber and insulator.

The shock absorbers are tensioned in mutual opposition with four straps each, and thus held on the cask body.

The essential cask data are compiled in Table 4 to provide a better survey.

Handling of the STC

The STC has been conceived for dry loading and unloading. In the present case, that is, within the scope of the HAW-project, its purpose is the shuttle transport of canisters from the multiple transport cask above ground to the borehole located underground, and back again.

For loading, the STC is placed above the multiple transport cask on the transfer station (section 3.9.1).

The coupling grapple (1 t hoisting gear of the crane facility) and shielding bell (2 t hoisting gear of the crane facility) are subsequently placed on the cask. By means of the 1 t hoisting device the manipulation and lifting of the canister is controlled with a precision measuring unit. Two drive units for actuating the canister grapple locking device are attached to the shielding bell (section 3.3). Appropriately, the logic of the monitoring system corresponds with that of the disposal machine employed underground.

For loading and unloading, the sliding drawer at the bottom is then unlocked, opened by remote control by means of a servomotor, and the canister is lifted or lowered. The sliding drawer is subsequently closed and locked.

After loading with a canister and removal of the shielding bell, the STC is lifted from the transfer station and placed on a heavy-duty trailer (section 3.4).

Table 4: Essential Data on the Single Transport Cask, Asse TB1

Cask Capacity	1 Canister
Thermal Output Power (nominal)	2065 W
Maximum Thermal Power (Design Value)	2300 W
Mass of Loaded Cask, Approximate	
- Without Shock Absorber	10000 kg
- With Shock Absorber	11200 kg
Cask Geometry	
- Useable Inside Diameter	440 mm
- Useable Inside Height	1214 mm
- Outside Diameter	
· Through Cask Body	1100 mm
· Through Cooling Fins	1150 mm
· Through Shock Absorber	1600 mm
- Cask Height	
· With Shock Absorber	2657 mm
· Without Shock Absorber	2000 mm
- Ribbed Length, maximum	1150 mm

After lashing of the STC, a traction engine (Unimog) pulls the heavy-duty trailer into the shaft hall.

With the use of a specially designed fork lift the cask in the suspended state is placed on the hoisting cage. After arrival underground the cask is removed from the hoisting cage by the gallery transport vehicle (section 3.14), transported to the intended borehole, and placed onto the borehole slider (section 3.12).

For loading or unloading, the disposal machine (section 3.13) located at the borehole is employed; with this machine the canister can be lowered into the borehole or drawn into the STC by means of appropriate drive and monitoring systems in the shielding bell and borehole slider.

Besides handling for the purposes of the test disposal, the cask has been designed for transport over public thoroughfares. This matter need not be discussed further here. The lid can be handled by means of the three hooking eyes welded thereon, for instance, for removing the insert cage.

During transport the locking device prevents opening of the sliding drawer. The drawer can be opened only if the locking device has been disengaged and, furthermore, the canister has been raised a little bit.

Licensing

The basis for licensing of a package by the BfS (formerly the PTB) is the BAM inspection certificate, which is granted after examination of the documents with the aid of an external expert, such as TÜV.

In the safety report the applicant summarizes the data, descriptions and test results necessary for the approval. In particular the safety report includes information on:

- cask contents
- cask design
- proofs of strength (for transport and handling, as well as in the event of a transport mishap)
- thermal considerations
- nuclide release considerations
- shielding
- criticality
- quality assurance

For the STC of type Asse TB1 the following data can be mentioned:

- beginning of development	1981/82
- Application for type test	March 1984
- filing of order for construction of 2 casks	end of 1986
- updated safety report	May 1988
- examination of documentation	June 1989
- inspection certificate of BAM	December 1989

The following cask models have been constructed:

- 1:4 model, for dropping impact tests in October 1986 and March 1988
- 1:1 disk model, for fire tests in March and July 1987
- Original canister with inactive fill, for dropping impact tests of the tightness in April and October 1989 and for a water pressure test in November 1989

The STC was available as of 1989 and was employed for adjustment work, test runs, and training purposes.

Since December 1989 a total of 8 constructive modifications of class 3 have been performed.

No licensing was granted by the BfS because of the premature discontinuation of the project (see foreword), although all prerequisites were satisfied.

Recommendations for Future Cask Development

1. In general, limitation of the approval procedure to as few different source types and categories as possible is recommended. That is, if no neutron radiation is expected, the corresponding moderator material should be omitted. This offers advantages in case of fire, for shielding, and of course, in terms of construction costs.

   No advantage results from designing the cask for different canister dimensions. In the absence of exact knowledge of the packages to be transported there is no justification for ultimate development.

2. Exact state-of-the-art performance of the proofs demanded by the regulations is expedient, in order to avoid the risk of highly time-consuming investigations.

3. If at all possible, only materials and dimensions for which materials standards exist should be employed; that is, these standards must correspond to the "state of the art". The same applies to analytical procedures.

4. It must be considered that transport casks are employed under highly corrosive ambient conditions in a final repository sited in rock salt. Only stainless materials should be employed; however, it must be recalled that austenitic steels may present problems here (chlorides, such as sodium chloride, may cause pitting corrosion).

5. The temperatures to be expected during operation (not applicable to type B(U) licensing) and the limiting temperatures as specified in the regulations for transport must be taken into account.

6. If several casks of the same type are to be employed, it must be ensured that they are of identical design and conform with the drawings when manufactured. In part, a

dimensional check is feasible only with severe restrictions. In this case the manufacturer must be extremely careful and, for instance, perform small machining steps on large machines (because of the size of the cask) and without changing fixing.

7. During docking at loading and unloading facilities, cooling fins are unfavourable for minimizing gap radiation; hence, cooling fins should be provided only where they are really necessary.

8. Use of the same element for two functions should be avoided. Example: Use of the coupling grapple - canister grapple interface as interface for the load hooking device as well.

9. Devices for securing against inadvertent opening of loaded casks should be provided with redundancies:
   - at the sliding drawer, for instance, by means of shock absorbers, locking bolts, and the canister itself;
   - for safe disengaging of the canister grapple in the lid, if falling of the canister grapple is prevented by the canister itself.

10. Guiding devices must be provided for preventing catching and impact, especially with a suspended load in the case of pendulating.

11. Salt dust and salt pieces may present problems for disposal in unlined boreholes; that is, the canister grapple should be free of level surfaces at the top.

12. The approval and licensing of the transport cask shall be performed in compliance with transport regulations by the BfS, BAM, and its experts, for instance, TÜV Berlin. For handling as inward-outward transfer and transport cask the authorized approval office (for instance, the mining inspectorate and its experts, such as TÜV Hannover) are responsible. Both approval procedures proceed independently, and the cask must satisfy both; the regulations for transport are thereby especially binding.

13. Verification of shielding in compliance with transport regulations shall be unambiguous and shall be easy to perform for the closed cask because of the clear-cut geometry; the limiting values are easier to ensure.
    For use in a final repository (mine) it shall be taken into account that
    - residence times of personnel in the proximity of the cask are longer, and the distances are shorter that in ordinary nuclear installations,
    - other (lower) limiting values may possibly apply (StrlSchV),

- more complicated geometry must be taken into account: inward-outward transfer device open, grapple lowered, position of source possible at any point of the axis, and especially the importance of shielding against additional radiation from the open multiple transport cask above ground.

14. The "tight enclosure" of the radionuclides which must be guaranteed in conformance with transport regulations can be ensured only by integrity of the cask. An inward-outward transfer cask quite certainly cannot be constructed so "tightly" that the "tight enclosure" can be ensured for the purposes of GGVS.

3.2 Grapple

The grapple system consists of three mutually corresponding components:

- the canister grapple (Fig. 6)
- the coupling grapple (Fig. 7)
- the load hooking device (Fig. 8)

The canister grapple is part of the STC and remains associated with same. On the other hand, it is a part of the handling system. For this purpose it is actuated by electromagnets in the coupling grapple. During the process of inward ad outward transfer the fixation of the canister grapple in the lid of the STC is released (see Fig. 9); thus, it can leave the lid zone of the cask while suspended from the coupling grapple. The coupling grapple fits through the hole thus resulting in the lid.

Further lowering (with or without a canister) results in a large gap between the lid and the cable - on which the coupling grapple is suspended - for which a special shielding device, the so-called shielding bell (see section 3.3) is necessary. The crane facility above ground and the disposal machine underground constitute the hoisting equipment for handling the canister and the shielding bell.

The coupling grapple (see Fig. 7) is permanently and firmly attached to the cable of the winches provided for this purpose. It includes an electromagnet with several (3) windings
a) for coupling with the canister grapple, that is, grasping the canister grapple,
b) for actuating the canister grapple, that is, grasping the canister, and
c) for disengaging, that is, releasing the armature of the magnet (locking magnet).

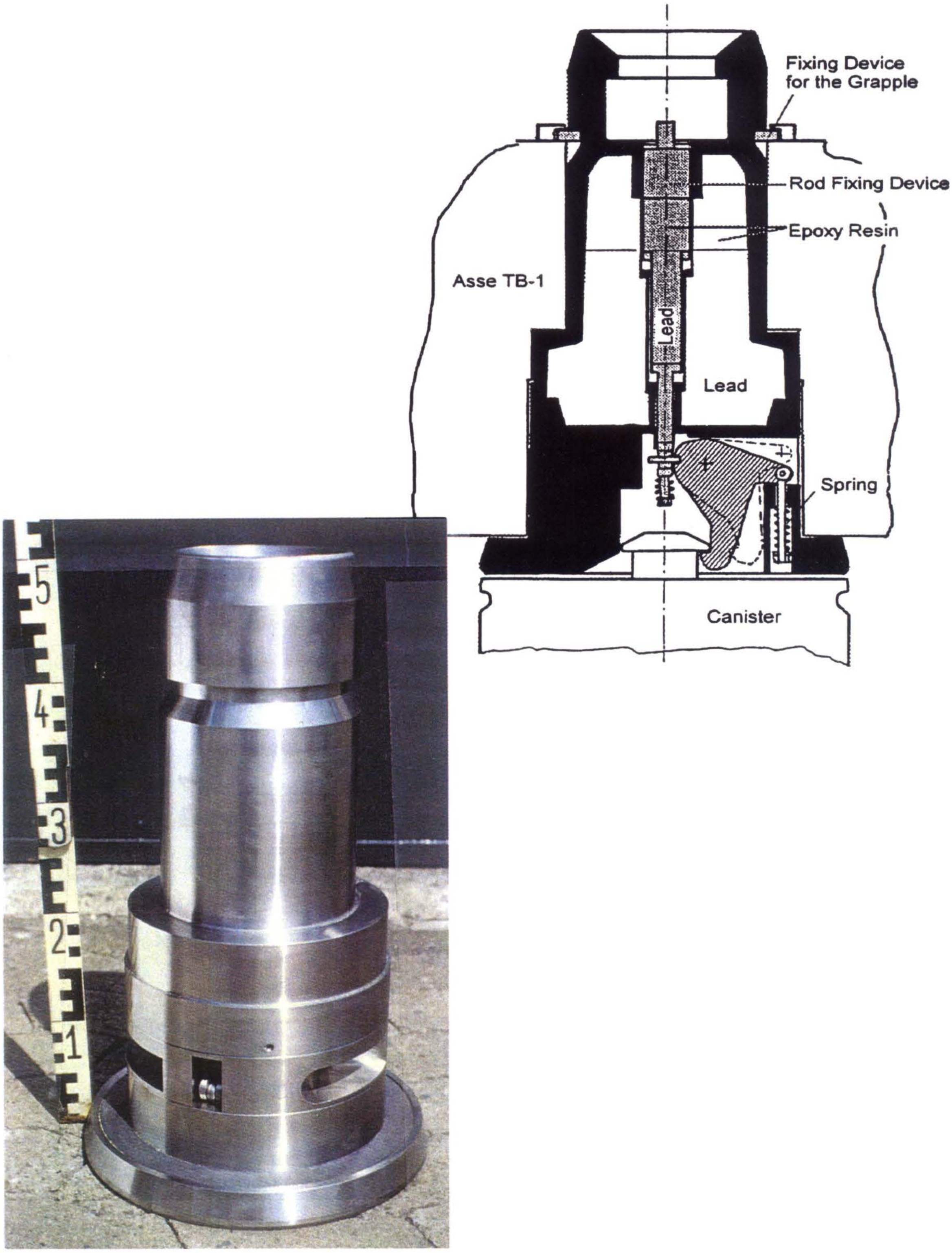


Fig. 6: Canister Grapple

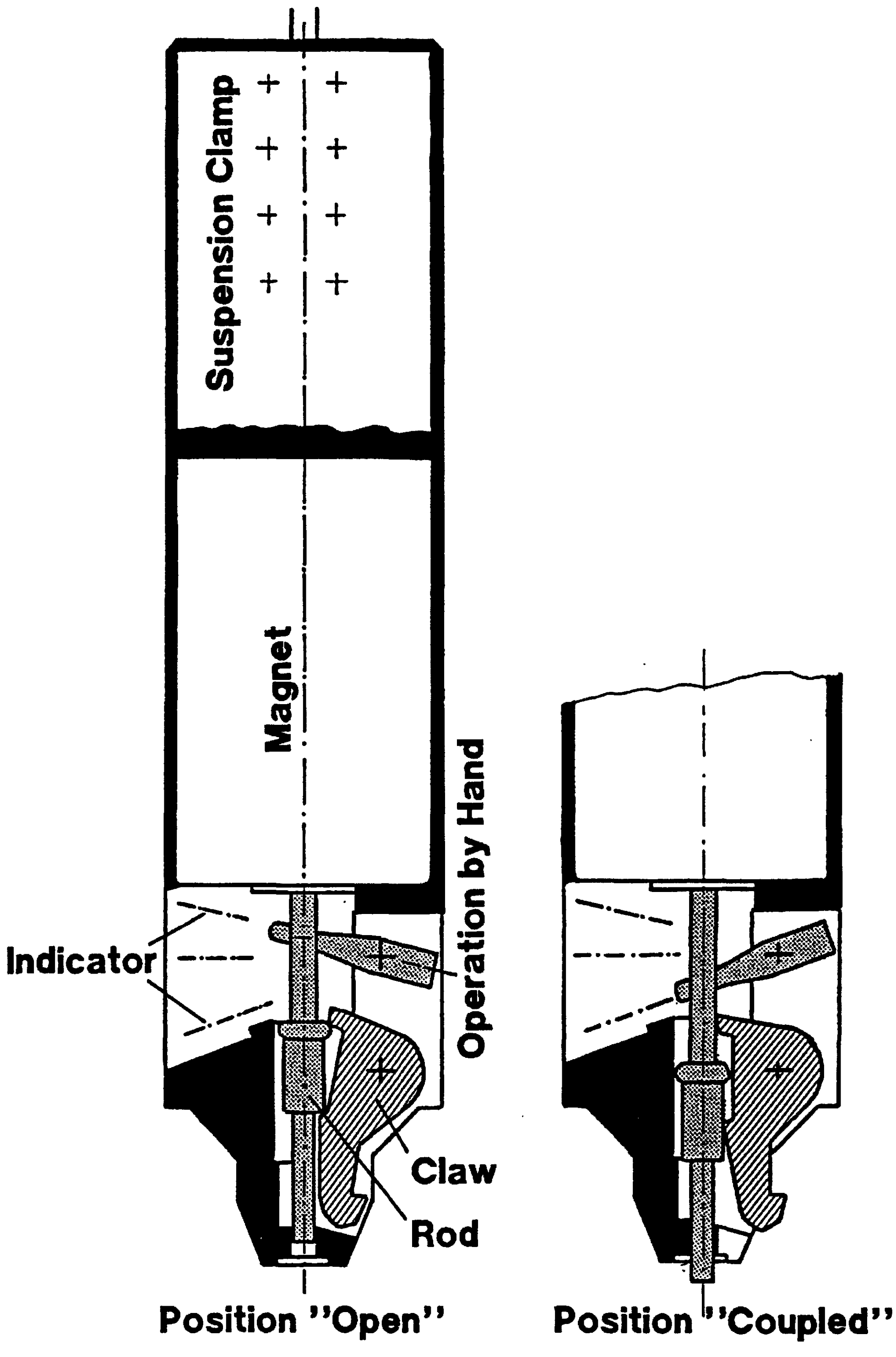


Fig. 7: Coupling Grapple

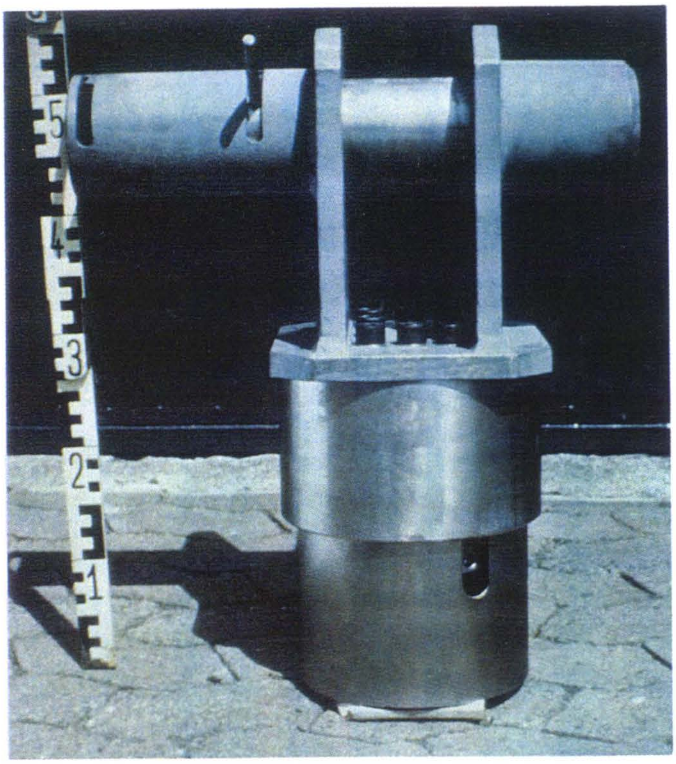


Fig. 8: Load Hooking Device

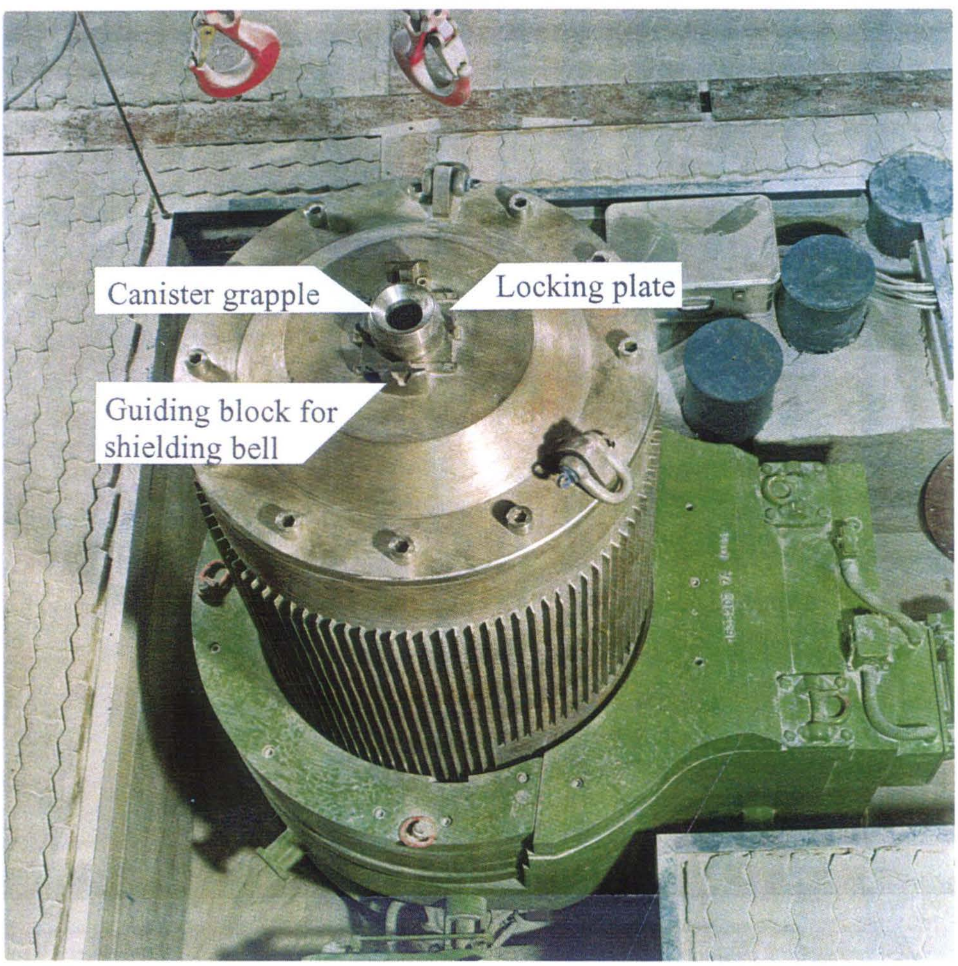


Fig. 9: Top Area of the Single Transport Cask, Asse TB1

The cable core contains seven conductors for electric power supply and for signalizing the position of the magnet armature. The cable itself serves as grounded conductor. The magnet is controlled by way of the suspension cable of the disposal machine or of the surface crane facility.

For opening the grapple claws, both windings c) and a) or b) are always actuated; for return motion, in contrast, only b) or a). The plunger (or armature) in the coupling grapple then engages in midposition. Hence, if the canister grapple has been actuated (winding b), voltage must subsequently be impressed on winding a). In the event of a power failure or a defective magnet, for instance, the armature of the coupling grapple can also be brought to midposition manually, provided that the coupling grapple is accessible.

The canister grapple (see Fig. 6) consists of a housing in which three grapple claws are supported. A concentrically positioned plunger is fixed at the upper end of the grapple housing in its resting position. Otherwise, the plunger might inadvertently move downward, the grapple claws might open and thus release the grasped canister in the event of shock load (for instance, sudden touch-down during lowering). Springs return the grapple claws and the plunger to the resting position. The spring at the lower end of the plunger allows the claws to give way to the mushroom grip of the canister and thus prevent damage in case of an accident during transport. The housing of the canister grapple and the plunger in the canister grapple contain lead and an epoxy resin insert (neutron shielding) for ensuring sufficient shielding against radiation.

The coupling grapple contains the electrical system for actuating the claws and for three position detectors. The cable is clamped. The cable and suspension clamp have been tested by an independant expert.

The grapple system also includes the so-called load hooking device (Fig. 8). This is a purely mechanically actuated grapple for handling the STC itself. For this purpose three claws engage from the inside into the contour of the canister grapple, into which the claws of the coupling grapple also engage.

For opening the manipulating claws, that is, for disengaging the load, the load hooking device must hit the canister grapple; the claws thus move along the slanted contour of the canister grapple and open until they are retained by the spring-loaded arresting devices. The arresting device is disengaged by the sleeve. A relaying mechanism ensures security against inadvertent opening; that is, opening is possible only after the load hooking device has hit three times in each case.

The design of the grapple system was developed together with the STC. The presence of shortcomings to be corrected then became evident; consequently the consignee (Noell Company, Würzburg) had to modify the design before the beginning of construction. Prototypes were available as of March 1987. The functional test in the presence of the approval authority proceeded flawlessly. The quality assurance and a few details for the ultimate design were then specified with the expert, before the grapples intended for the test were constructed.

Of the three load hooking devices in operation, that which was fastened to the telescoping jib of the gallery transport vehicle failed in the summer of 1991. During handling of the STC at the shaft at the 800 m level, the STC became detached from the load hooking device. It was decided not to employ the load hooking devices further. Instead, bridle moorings were procured. However, a considerable personnel effort is now necessary for hooking and unhooking the STC.

It was decided to develop of a new load hooking device. A prototype of this new development is not yet available.

An important innovation is the engagement of the claws of the new design in an external groove of the canister grapple. Overloading can thus be avoided. A modification of the canister grapple would be necessary and would have been performed in the case of favourable testing of the new load hooking device.

Experience and Recommendations

1. The load hooking device has failed (August 1991); the following recommentations can be derived from this failure:

   - With (grappling) claws which act from the inside toward the outside (as in the load hooking device and the coupling grapple) the spatial conditions are so limited that adequate dimensioning of the claws is difficult or impossible.

- Both claws (those of the coupling grapple and those of the load hooking device) engage with the same surface of the canister grapple. The surface contact pressure for the claws of the load device was too high. The collar contour in the canister grapple was deformed, since

  a) the speed of the rotary drive on the top of the jib of the gallery transport vehicle was too high, or the accelerating and braking action was too abrupt, and the additional stress associated with the inertia moment could not be transmitted without causing damage, and

  b) it had been assumed for designing that the load is distributed uniformly over the three claws. This is true only if the STC is positioned exactly perpendicularly (at the instant of load acceptance), or if the tension of the hoisting device is perpendicular. Both were defective in the case of the transport vehicle (contact surface not sufficiently horizontal) and the fork lift above ground. With both vehicles the resilience of the tyres and the associated horizontal variations of the hook position in relation to the load application point on the STC are evident during load acceptance from the floor. On the other hand, resilient elements also offer advantages during load transmission: the impact factors are lower for the calculation!

Conclusion: If not absolutely necessary the concentration of several functions on one component or detail should be avoided. This necessitates compromises which in turn render an operationally safe solution more difficult, especially if modifications are necessary. If experience is available, the problem i not quite so urgent.

2. Moving parts must be supported and guided with sufficient clearance. Differences in expansion coefficients must be taken into account. (For instance, sufficient spare volume must be present for accepting a material such as the excess epoxy resin in the plunger of the canister grapple upon heating to elevated temperatures.) It must be recalled that emerging material (epoxy resin) may block moving parts by sticking.

3. For operation with longer electric power cables, possible voltage drops and the effect of elevated temperatures on the Ohmic resistance must be taken into account.

4. An inductance current must be expected upon switching the exciter current for an electromagnet winding off; this inductance may in turn affect the power supply and control. With AC the tractive force of the electromagnet is weaker; consequently, DC was employed.

5. If several grapples (canister as well as coupling grapples) are provided, identical design must also and above all be ensured, in addition to manufacture in conformance with the drawings. The manufacturing tolerances must in part be set very closely; the assembled condition is especially vital. The interfaces with the mushroom grip of the canister, with the lid of the cask, and with the coupling grapple are of special importance.

6. Since the grapples must be inspected at regular intervals, a design capable for inspection must be ensured. The performance of an inspection in the assembled state is beneficial to all concerned. For instance, the preparation of the specifications for the design inspection, the approval by an expert, and inspections at regular intervals, as well as agreement with the expert on same, regulations at the design stage are recommended.

7. For operation in a final repository with deep, unlined disposal boreholes, the following must be ensured:

   - Salt dust and dislodged salt chunks may be deposited on the grapple. This must be avoided, for instance, by sufficiently large oblique surfaces, cleaning possibilities, or cavities into which the salt can be driven away (the latter impairs decontamination).

   - Severe pendulating of the grapple is highly probable; impact with the wall of the disposal borehole is inevitable. During retraction of the grapple into the inward and outward transfer cask, the grapple may touch structural components of the borehole slider or of the cask. The following remedial measures are possible:

     a) decrease in hoisting velocity;
     b) oblique insertion guides;
     c) flexible guiding elements (brushes, springs, etc.).

8. At a final repository a "hot cell" will possibly be available above ground; thus, the removal of foreign matter from canisters should be possible if they are still stored in the multiple transport cask. Grappling of a canister in the multiple transport cask is not possible if the canister grapple fails to locate the pintle of the canister (guiding elements in multiple transport cask, oblique guiding surfaces) or cannot be lowered sufficiently

(dirt on the canisters). Oscillation of the grapple (with or without a canister) must be taken into account above ground, too.

9. It should also be taken into consideration that the grapple design must be capable of decontamination (completely or only in relevant areas). Perhaps jettisoning, that is, "direct disposal" of a contaminated grapple, can be envisaged for the case where cleaning is not feasible.

3.3 Shielding Bell

The shielding bell (Fig. 10) is necessary for shielding against the radiation which escapes upward from the single transport cask (STC) when the canister grapple and coupling grapple, with or without canister, are lowered into the borehole or, above ground, into the MTC. Altough not necessary for use during HAW test disposal, the shielding bell is equipped with neutron shielding.

The shielding bell has the shape of a hollow body open at the bottom. Detectors (proximity initiators), which indicate correct touch-down of the bell on the STC, are installed at the lower rim. Moreover, it is equipped with the drive units for releasing or fixing the canister grapple in the lid area of the STC.

The cable to which the coupling grapple is attached is routed coaxially through the head zone of the bell and separately shielded with specially designed lead components.

Two shielding bells are necessary:

- in the transfer facility above ground (see section 3.9);
- on the disposal machine at the respective disposal site underground (see section 3.13);

Both are of identical design, with the exception of the different suspension devices. The overall height is 1553 mm, and the weight is 1650 kg.

The application of the shielding bells is described in the sections just mentioned.

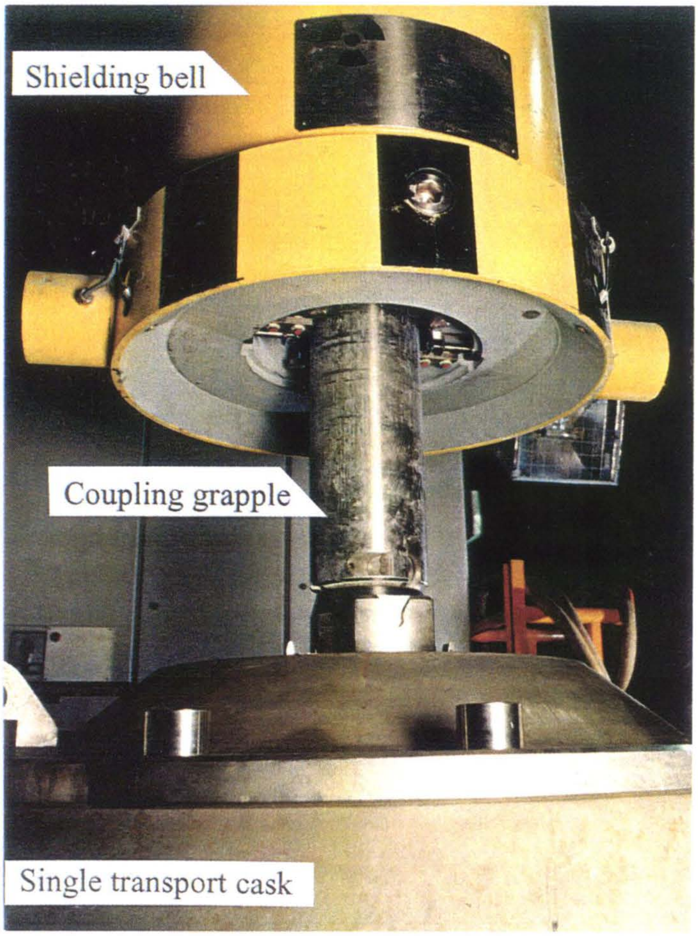


Fig. 10: Shielding Bell over the Single Transport Cask, Asse TB1, with Coupling and Canister Grapples Visible between these Components

Experience and Recommendations

At this point it suffices to mention that these components functioned without problems.

For designing appropriate components in a final repository the following recommendations can be made:

1. Switches for signalizing correct positioning must be protected against damage; that is, they must be recessed sufficiently from the contour.

2. Attention must be paid to the switching characteristic of proximity initiators: With inductive proximity switches, for instance, the opposite components should be

magnetizable. (Stainless steels can be provided by spot welding at the corresponding position).

3. Slight insertion of the coupling grapple in the bell for guidance is always recommended. Otherwise oscillating motion and insufficient oblique guiding surfaces may cause problems during insertion into the bell or lowering of the bell.

4. The motors for actuating the canister grapple locking device in the transport cask lid operate very quietly. A possibility of acoustically or optically observing the rotation of the motors would be advantageous.

5. The touch-down can - or rather should - proceed very slowly. The distances are short; consequently, the time required is only of subordinate importance. The inertial forces are not negligible.

3.4 Heavy-Duty Trailer

For the necessary transport of the single transport cask from the hoisting cage to the transfer station above ground, a heavy-duty trailer has been procured (Fig. 11). This trailer is to be drawn by an existing traction engine (Unimog).

The following conditions had to be satisfied:

- load bearing capacity: 10 t
- good manoeuvrability
- stability of the vehicle, especially when running in curves
- braking system (service and parking brakes)
- safe travel characteristics upon coupling with the standard trailer coupling of the traction engine (Unimog)
- antiskid device for the load on the platform, lashing device

A heavy-duty trailer with the following special features was ordered from the MAFI Company:

- vehicle with four-wheel steering
- no swing axle; hence, 16 t load-bearing capacity, that is, 4 t per wheel (load of 8 t on two diagonally positioned wheels on uneven terrain)

Fig. 11: Heavy-Duty Trailer with Lashed Single Transport Cask, Asse TB1

- equipped with dual-circuit compressed air braking system, braking force adjustable in correspondence with load
- draw-bar attachable on both ends of the trailer
- vehicle shortened in comparison with standard version
- draw-bar lengthened because of oblique upward traction, in order to decrease the angle with respect to the horizontal
- maximum velocity 6 km/h (stepping speed)
- special approval inspection of the entire assembly by TÜV

Experience and Recommendations

The experience gained from operation and from the approval procedure is as follows:

1. Contrary to the original plan, only the rear trailer coupling of the traction engine could be employed. The front coupling is mounted on the (removable) bumper of the vehicle. Fastening of the bumper on the vehicle was judged by TÜV as inadequate.

2. A single-circuit braking system, or a combined single- and dual-circuit braking system was not approved by TÜV.

3. Repulsing of the trailer requires special skill. The short vehicle and the four-wheel steering are the reason for manoeuvring problems. Reversing of the draw-bar was not necessary; no simplification would have resulted during operation.

4. Shortening of the vehicle (shortening with respect to the manufacturer's standard version) caused problems with the Bowden cables of the braking system. When driving with the maximum angle of turn the Bowden cables were too short and not sufficiently flexible; consequently, buckling could be avoided only by conversion with appropriate guide plates.

5. The functional performance, including that in curves, was good.

6. For operation in a final repository, however, consideration should be given to the possible advantage of a special vehicle, for instance, a two- or three-axle vehicle on a Unimog basis (motor, drive and steering axles, driver's cab) with a small loading surface area (springless, hard rubber tyres).

3.5 Fork Lift Above Ground

For transferring the STC from the hoisting cage to the heavy-duty trailer, an existing fork lift equipped with a jib-type crane (fork lift I) was employed. The jib-type crane is approved for a load of 10 t; the fork lift itself has a load-bearing capacity of 15 t.

No problems were encountered during operation. Only the resilience of the tyres under load must be taken into account: When the tyres give way, the position of the load hook is displaced in a circular arc. The horizontal component is detrimental. If the fork lift is unbraked during load acceptance, that is, if it can "roll away", this effect can be counteracted. Of course, this is feasible only on level terrain.

A necessary condition is that loads always be accepted and set down on level terrain. This also applies to a final repository.

3.6 Shaft Transports

For shaft transports, the existing hoisting facility was available. The hoisting cage was merely provided with a shock absorber for accepting the STC; the purpose of this shock absorber is to decrease loads on the hoisting cage and hoisting cable by shocks due to incorrect placement of the STC.

Marks on the shock absorber indicate the middle of the hoisting cage. From an administrative standpoint it was ensured that the STC was not raised any higher than absolutely necessary.

It must also be recalled that only the hoisting cable can serve as elastic element in the event of shock on the cage. The hoisting cable is comparatively short during loading and unloading in the shaft hall. Underground, in contrast, the hoisting cage sinks by almost 1 m when the load is accepted. Sudden loading of the hoisting cage is then less critical.

On the other hand, the lifting devices which raises the STC from the hoisting cage underground, or sets it down, has to raise this height in addition if the hoisting engine is not activated to compensate the elongation or shortening of the cable by charging or discharging the cage.

3.7 Multiple Transport Cask, Castor GSF-5

For the delivery of the thirty radiation sources and for use as receptacles for same after completion of the tests, a total of six multiple transport casks (MTC) of type Castor GSF-5 (Fig. 12) are available. These casks are constructed as type B(U) packages. They were converted only later to storage casks with a dual lid system for intermediate storage of the radiation sources after completion of the tests in the Asse mine. This also includes the possibility of attaching a so-called joining lid as a third lid in the case of failure of a seal. The purpose of this lid is to ensure the "tight enclosure" with the application of a welded seam (joining). The design of this weld had not yet been ultimately appraised by the approval authorities at the time of discontinuation of the HAW-project (welding method tests still had to be performed).

The multiple transport cask is a combined transport and storage cask. It consists basically of a thick-walled body of GGG 40 with a lead insert for improving the shielding. This cask body is closed with a lid system (two lids): the so-called primary lid on the inside, and the

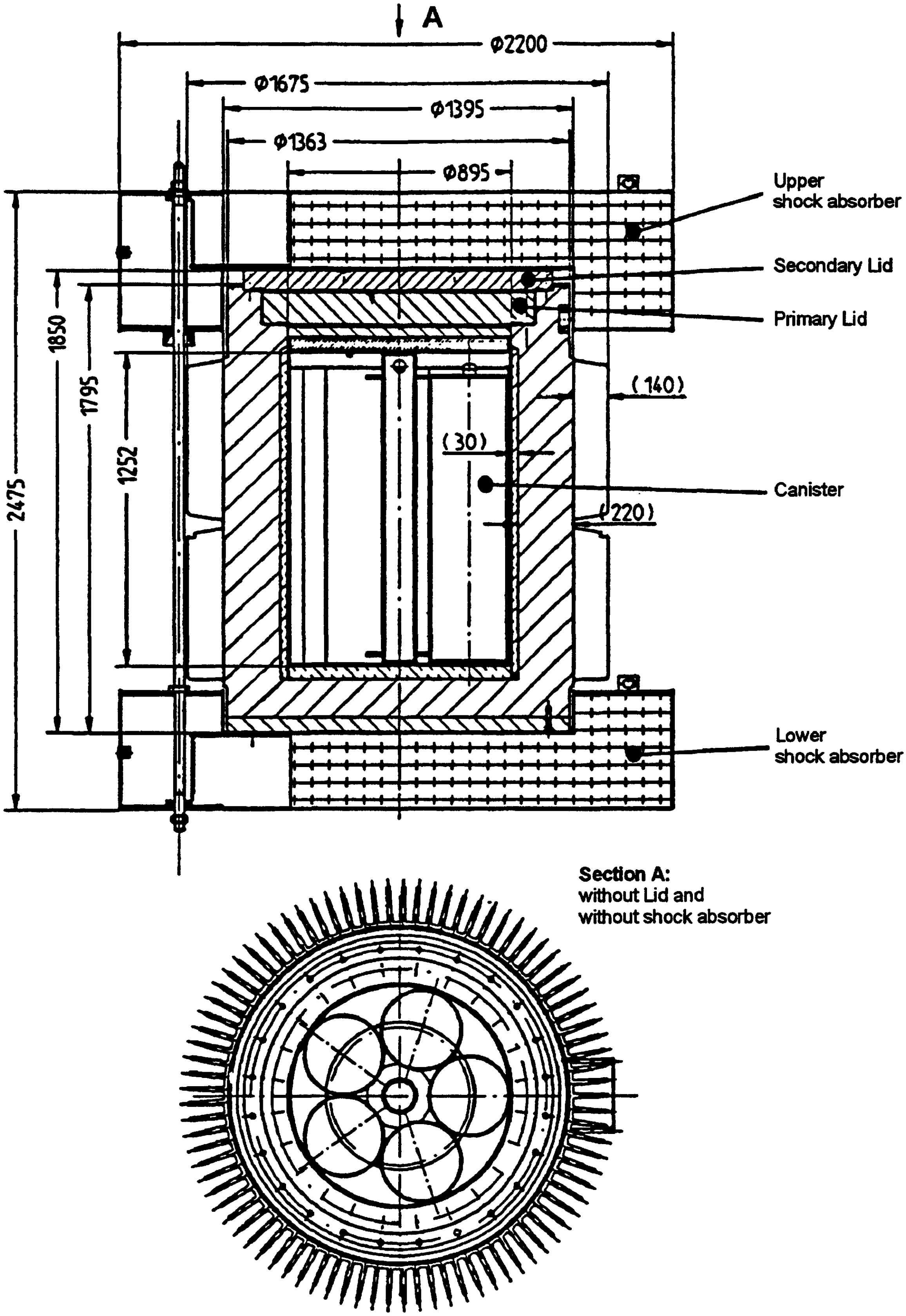


Fig. 12: Multiple Transport Cask, Castor GSF-5 (dimensions in mm)

secondary lid on the outside. Both lids are equipped with an inspectable sealing system for ensuring the "tight enclosure".

For fixing the contents in position, a basket with five chambers is located in the shaft of the cask for accepting the radiation sources. The details of the cask design are not discussed further in this report.

The joining lid as third lid is intended for use as a repair lid when the cask is employed for storage. It must be placed on the cask and welded to the cask body if the primary or secondary lid becomes leaky and the lid seals cannot be replaced (for instance, in a hot cell). Further details, such as

- additional details of the lid system
- protective plate for covering the lid and
- shock absorbers,

are beyond the scope of this report.

A few data on the cask are compiled in Table 5.

Application of the Multiple Transport Cask within the Handling System

In the original plan the procurement of two MTC had been intended, and three transport operations to the Asse mine, each with two multiple transport casks containing a total of ten radiation sources from Hanford/USA had been planned.

When the approval authorities later demanded the availability of sufficient cask capacity for accepting the radiation sources after completion of the test, four additional casks were manufactured. For accepting the radiation sources in an interim repository, the transport casks had to satisfy the requirements for storage. For this purpose, an order was placed for the conversion with a second lid (and a third lid in case of failure of a seal).

The casks satisfy the conditions imposed on type B(U) packages.

A nationally awarded approval is usually validated by the states which are concerned with the transports. This was not the case here: In the United States nodular cast iron (GGG 40) has not yet been approved as a material for transport casks. Since time did not permit a sufficiently reliable survey of the validating process in the United States, and to avoid jeopardizing the delivery, it was decided to proceed with transport in the United States and

Table 5: Essential Data on the Multiple Transport Cask of Type Castor GSF-5

Cask Capacity	5 Canisters
Heat Dissipation Power (Design Value), [kW]	11,5
Mass of Cask, Loaded, [kg]	
- with Primary and Secondary Lid	17700
- with Shock Absorber and Joining Lid (Transport Weight)	21500
- with Protective Hood and Joining Lid (Storage Weight)	20600
Cask Geometry	
- Outside Diameter, [mm]	
· over Cask Body	1345
· over Cooling Fins	1675
· over Shock Absorbers	2200
- Cask Height, [mm]	
· with Primary and Secondary Lids	1850
· with Protective Hood (Storage Version)	2140
· with Shock Absorbers (Transport)	2525

at sea in steel-lead casks (see section 3.8) of type GNS-12 in compliance with a concept capable of validation in the United States. Since the transfer station had been specially designed for the multiple transport casks of type Castor GSF-5, the sources had to be transferred (from the GNS-12 casks to the Castor casks). This transfer was intended to be performed in a hot cell facility at the Nuclear Research Centre (KFK) in Karlsruhe. This procedure did not result in any changes for handling of the radiation sources at the Asse mine.

The delivery to the Asse mine proceeds by rail. After removal of the shock absorbers the multiple transport casks are placed on railway carriages assigned to the casks with a leased 60 t mobile crane with the aid of a crosshead (Fig. 13). At the end of the tests the casks are placed again on the car by the mobile crane.

Experience gained with the further handling of the casks is discussed in conjunction with the transfer station (see section 3.9).

Fig. 13: Delivery of the Empty Multiple Transport Cask, Castor GSF-5

Licensing Procedure

The application for the licensing of the MTC as a type B(U) package in conformance with GGVS was filed on behalf of the IfT by the Gesellschaft für Nuklear Service mbH (GNS) in Essen and processed by BfS all the way to the submission of the BAM test certificate.

In the absence of licensing for disposal of the sources in the Asse salt mine, however, the BfS did not grant any type testing approval for the cask.

The construction of the six casks was conducted in compliance with the documents contained in the safety report; there was no objective barrier preventing the licensing as a package.

The situation was somewhat different for the licensing as storage casks which must be granted in conjunction with the licensing procedure in conformance with § 6 AtG for the interim storage of the radiation sources after completion of the test. In this case the approval of the joining lid design, or more precisely, the test on the method for welding the third lid, was lacking.

Of course, the subsequent conversion to a storage cask resulted in a supplement to the safety report for the procedure for approval as a transport cask, for instance, because of the replacement of one of the two elastomer seals by metal seals on each lid.

3.8 Multiple Transport Cask, GNS-12, and Transfer Facility in Karlsruhe

The multiple transport cask of type GNS-12 (Fig. 14) and the transfer facility in Karlsruhe (as is the case with the facility in Hanford) do not constitute a part of the handling system. Hence, they are mentioned only briefly here.

The multiple transport cask of type GNS-12 was intended for transporting the canisters from the United States to Germany. The canisters were to be transferred to the multiple transport cask (MTC) of type Castor GSF-5 at the Nuclear Research Centre (KFK) in Karlsruhe, and then transported further to the Asse salt mine.

Because of the poor thermal conductance and heat dissipation associated with the design (lead/steel compound), the GNS-12 cask is designed for only three radiation sources at a time. Four casks were constructed; hence, twelve sources would have been transported each time. Three transports had been planned for all thirty sources, the last with only two casks.

The cask body of the GNS-12 is constructed in a sandwich design; a lead filling is thereby present between an outer and an inner stainless steel cylinder. The cask body is tightly closed with a lid; hence, the "tight enclosure" and thus the integrity of the package design (that is, the radiation sources) are ensured.

For fixing the canisters in position, a basket is installed in the cask chamber. The cask is handled with the use of supporting pins. The transport cask itself is protected during transport by shock absorbers at the bottom and top ends. Further data are presented in Table 6.

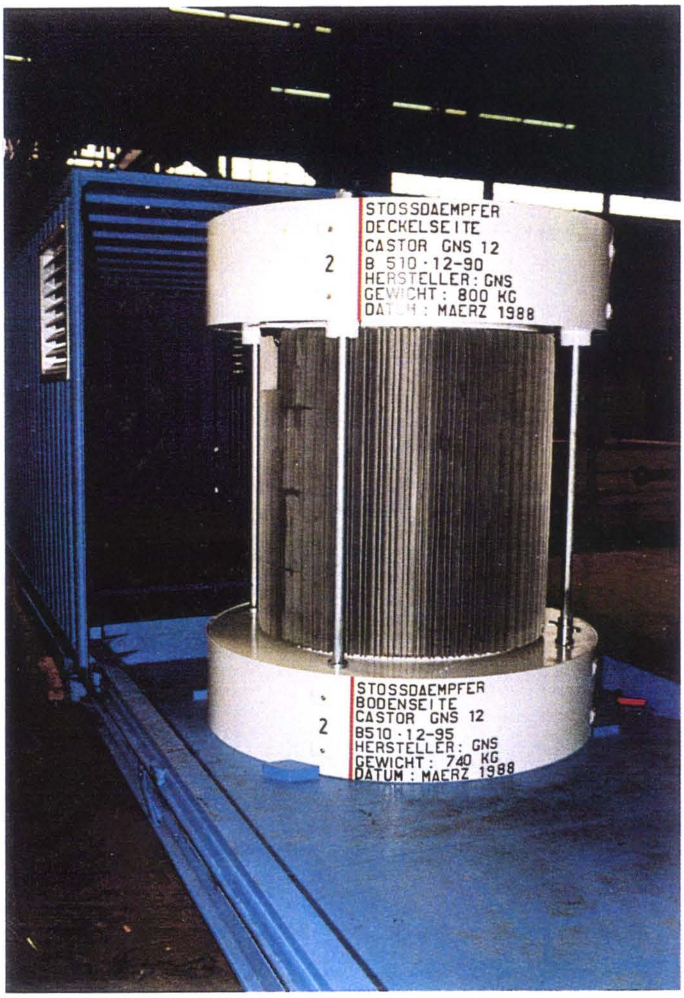


Fig. 14: Multiple Transport Cask, GNS-12

Because of its conceptional similarity to GNS-11, for which a licence existed, the GNS-12 got also a licence at short notice by the BfS (in November 1989). A validation for Canada and for the United States were likewise obtained.

The technical installations for the transfer in Karlsruhe were present, or were specially procured, for instance, an electromechanical grapple for use in the hot cell.

3.9 Transfer Facility (Transfer Station and Crane System)

The transport of the radiation sources to the Asse mine was intended with the use of the multiple transport casks, Castor GSF-5 (see section 3.7); the subsequent shaft transport was planned with the single transport casks, Asse TB1 (see section 3.1).

For transferring the radiation sources to the STC, a transfer station (Fig. 15) was therefore necessary; it was commissioned in December 1988 and approved by TÜV in June 1989.

Table 6: Essential Data on the Multiple Transport Cask of Type GNS-12

Cask Capacity	3 Canisters
Heat Dissipation Power (Design Value), [kW]	6,855
Mass of Cask, Loaded, [kg]	
- without Shock Absorbers	11100
- with Shock Absorbers	12500
Cask Geometry	
- Outside Diameter, [mm]	
· over Cask Body	1050
· over Cooling Fins	1210
· over Shock Absorbers	1650
- Cask Height, [mm]	
· without Shock Absorbers	1636
· with Shock Absorbers	2065

Besides the construction of the transfer hall with the necessary infrastructure, two purchase orders were placed for the transfer facility:

- to GNS/Essen for the delivery of a transfer station;
- to Noell/Würzburg for the delivery of a crane facility.

The transfer facility offers the possibility of transferring the thirty radiation sources while maintaining the necessary operational safety (including radiation protection) for disposal, and especially for retrieving all radiation sources within a reasonably short time.

The purposes of the transfer station are

- to install and remove the primary lid of the MTC,
- to mutually couple the two transport casks in such a way that adequate shielding is ensured at all times, and
- to open and close the STC and to mechanically lock and unlock this closure.

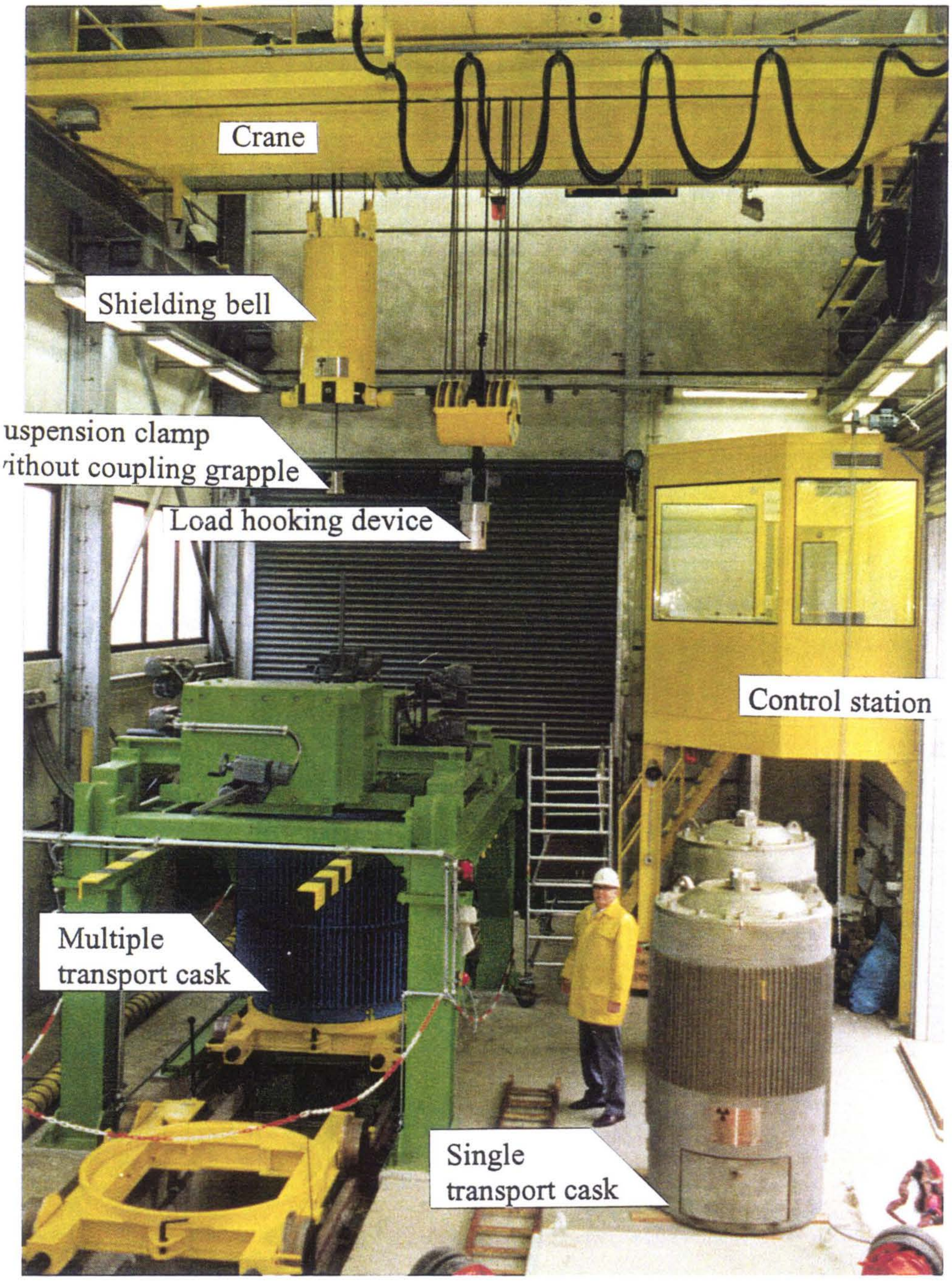


Fig. 15: Transfer Facility Above Ground: The Photograph Provides a View of the Transfer Hall with the Transfer Station and Crane System During Commissioning Work

The purposes of the crane system are

- to raise the secondary lid of the MTC,
- to place the STC on the transfer station and to remove it,
- to raise or lower the canisters within the transport casks,
- to set down and to deposit the shielding bell, and to control the servomotors integrated in the shielding bell for locking the canister grapple in the lid of the STC.

Transfer Process

In the following the process of transferring a canister from a MTC of type Castor GSF-5 to the STC of type Asse TB1 is briefly described for the case of disposal. These processes are illustrated in detail in the flow diagrammes in the "Instructions for the disposal and retrieval sequence with HAW canisters" (GSF, 1992).

- The MTC with five canisters is transported on its carriage by rail into the transfer hall.

- At an initial stop the secondary lid is removed. Subsequently, the fastening screws of the primary lid are loosened and removed, and three threaded guide bolts are installed. When performing this the cask is secured against tipping, and the carriage is braked.

- At the next stop (under the transfer station), the carriage is immovably fixed in position.

- The MTC is raised from the carriage into the shield of the transfer station; the hoisting and rotating device is available for this purpose. The lid is raised from the cask, but remains in the slide of the transfer station. The canister to be unloaded is selected and rotated to the unloading position. The device just mentioned is available for this purpose and rotates the entire MTC.

- Without displacing the slide, the STC is set in place (with the 10 t winch of the crane system) and then transported with the slide from this initial position over the canister to be transferred.

- The grapples are then coupled (1 t winch), and the shielding bell is set down on the STC (2 t winch).

- The sliding drawer of the STC is opened, the canister is drawn from the MTC into the STC, and the STC is closed.

- The shielding bell is raised, and the grapples are decoupled.

- The slide of the transfer station returns the STC to the initial position.

- The STC is raised and set down on the floor of the hall or on the heavy-duty trailer. The transfer process is thus complete.

- After the last of the five canisters, the lid is lowered onto the empty MTC. The MTC is rolled from the transfer station. It remains on its assigned carriage until reloading.

Reloading proceeds accordingly.

3.9.1 Transfer Station

The transfer station supplied by GNS is illustrated in simplified form in Fig. 16. In Fig. 17 the crane system is shown too.

The transfer station consists essentially of the following subassemblies:

- support structure,
- slide, consisting of lid recipient and STC recipient (guidance, frame, base plate, face plates, and shields),
- hoisting and rotating device for lifting the MTC into the shield (cask centring) and for rotating to the respective canister positions,
- actuators for the individual locking and slider systems.

Furthermore, the GNS Company constructed the carriages for transporting the MTC into the transfer station, with carriage guidance.

The design and construction proceeded in conformance with the usual regulations (UVV, VDE, DIN, StrlSchV), to the extent applicable.

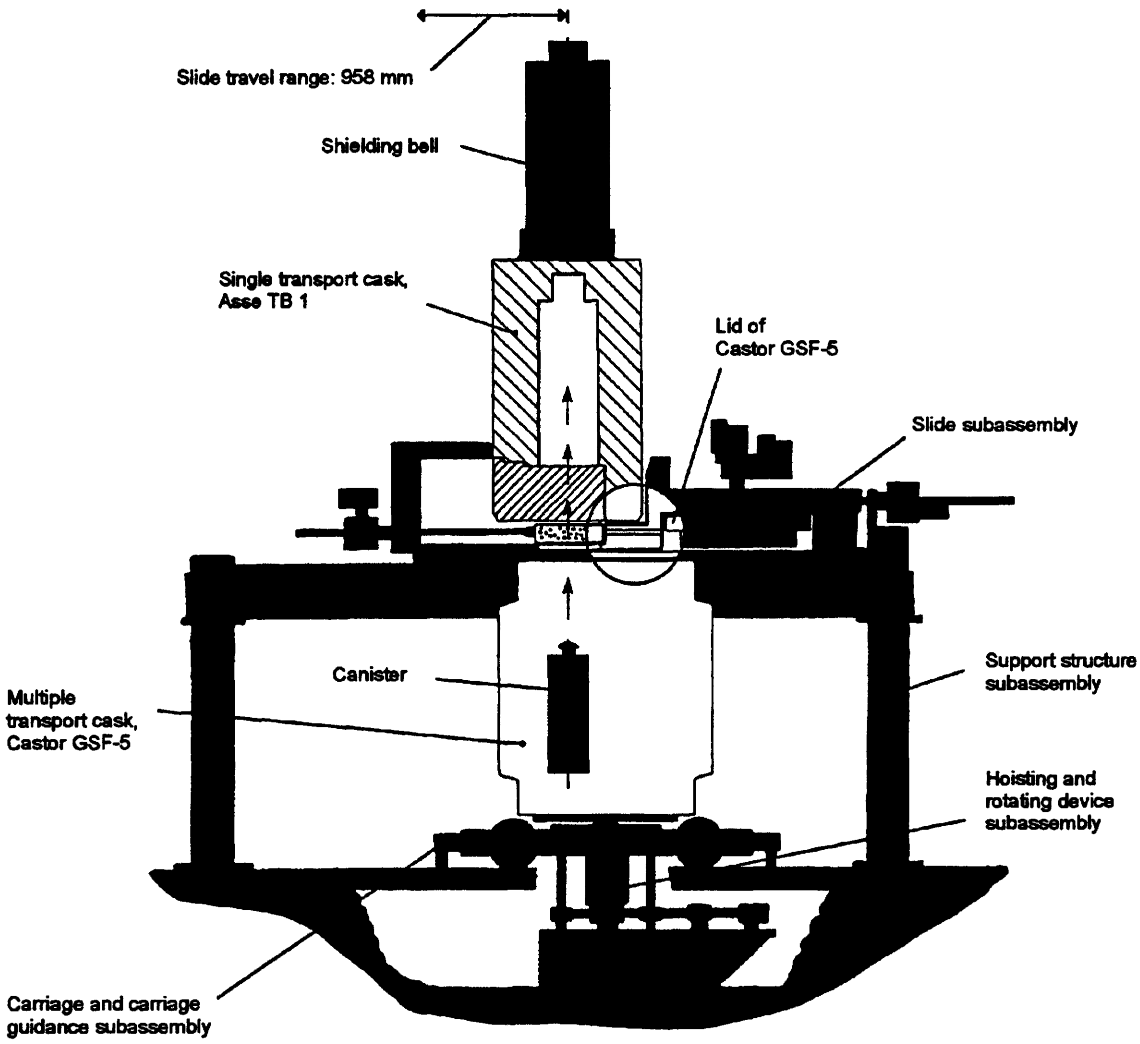


Fig. 16: Simplified Diagramme of Transfer Station with Transport Casks and Shielding Bell; Slide in Transfer Position; Sliding Drawer of STC Still Closed

Fig. 17: Transfer Station

"Support Structure" Subassembly

The "support structure" subassembly includes all stationary structural components above the hall floor.

A spandrel-braced frame structure is equipped with slide rails for the so-called slide, with the sections which secure the MTC against tipping, and a device for centring the MTC. This centring device serves mainly as a shield in the upper area of the MTC.

The spindle drive unit for the slide motion is mounted on one of the cross pieces.

"Slide" Subassembly

The slide consists of the receptacle for the primary lid of the MTC as well as the components for accepting the STC. The necessary shielding is ensured for every handling phase.

The slide is driven by means of a threaded spindle with an electric gear (see Fig. 18).

The lid receptacle is provided with a device which raises the detached primary lid from its position, or lowers it into position, by remote control; thus, the cask aperture is accessible or closed by displacement of the slide.

The device consists of an electric gear with a spindle which is engaged and disengaged on the lid adapter of the primary lid by remote control. The lid adapter is fastened with screws to the freely accessible primary lid of the MTC before unloading or reloading. Three guide bolts are screwed into the cask body of the MTC for guiding the lid during removal and placement. Guide bolts (2 pieces) which correspond with the circular arc of the guide bolts on the cask are also located in the lid receptacle; thus, the entire path over which the lid is raised is secured by guide bolts against displacement without interruption. The components just described are shown in Fig. 19.

The STC is positively accepted by the slide. The so-called sliding drawer of the STC is pulled by the sliding carriage of the slide and supported in the slide.

In the "primary lid park position" the STC recipient component is in the unloading or reloading position; that is, the aperture for canister passage in the slide is situated centrally over the canister position in the MTC (situation is shown in Fig. 16).

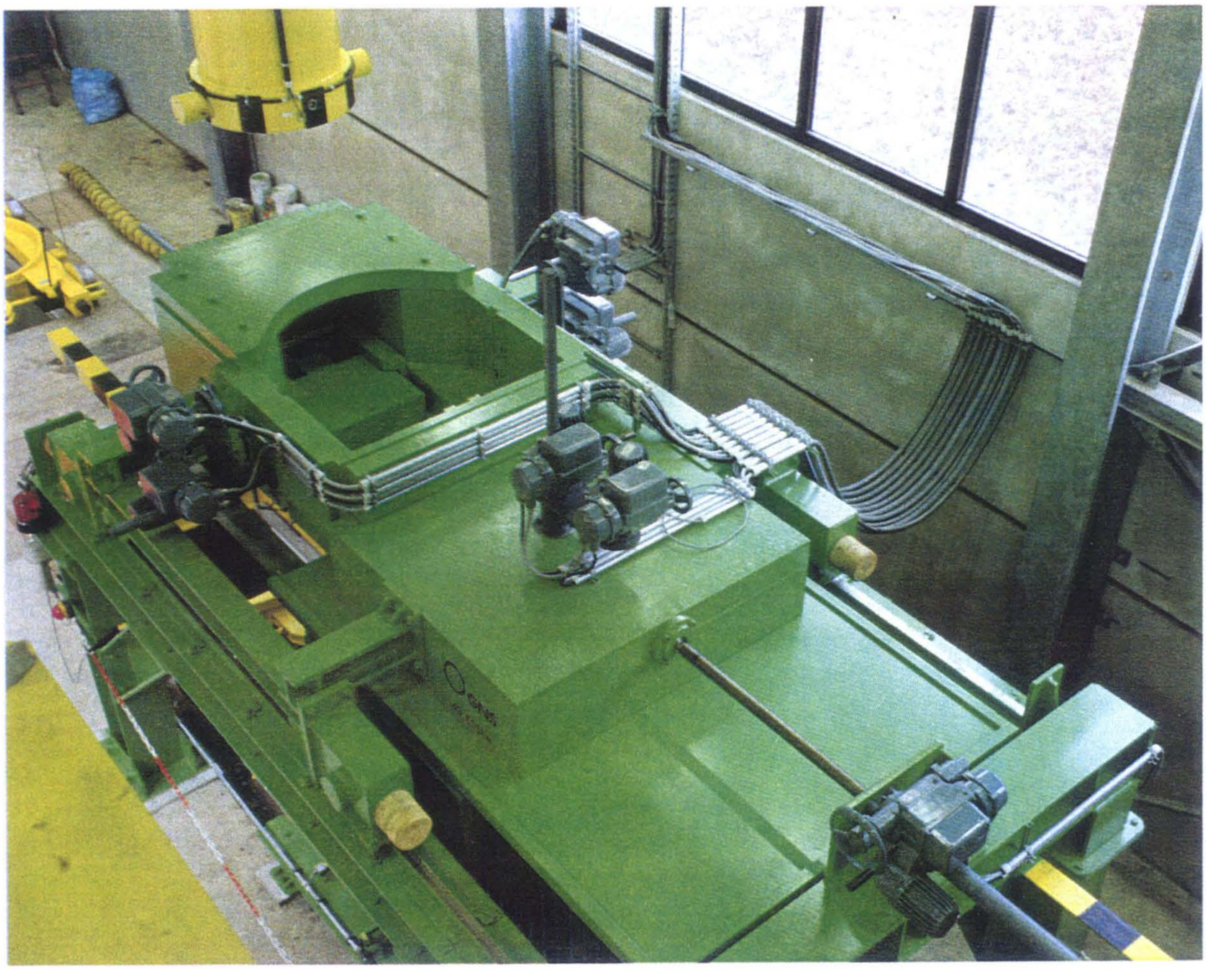


Fig. 18: View of the Transfer Station: in the Foreground the Spindle Drive Unit and the Spindle for Moving the Slide

"Hoisting and Rotating Device" Subassembly

A standard-gauge rail siding, on which the carriages can travel, leads into the transfer hall. In the area of the transfer station there is a pit between the rails. In the pit the hoisting and rotating device is mounted centrally with respect to the lid hoisting position and centrally with respect to the centring device already mentioned in the support structure. Its purpose is to raise the MTC from its position on the carriage into the cask centring device and to rotate the turntable of the hoisting and rotating device (and thus the MTC) to any desired cask position by means of a rotary drive system. This situation is illustrated in Fig. 20.

The respective canister positions and the position for raising the primary lid are approached by means of actuating pins on the MTC and proximity switches on the support structure.

The lifting gear of the said device is provided with an electromechanical drive system, a brake for preventing inadvertent lowering, as well as a possibility of manual operation. The rotary drive unit for the turntable (supporting for the MTC) is likewise equipped with an electromechanical drive system with a brake for limiting after-running and a manual operating device.

Actuators

Electrical actuators are installed on the transfer station for performing the following motions:

- one actuator for displacing the slide (support structure),
- two actuators with two motors each for pulling or setting the locking bolts of the STC sliding drawer (slide),
- one actuator for displacing the sliding carriage, and thus the sliding drawer of the STC (slide),
- one actuator with two motors for raising and lowering the primary lid of the MTC (slide),
- actuator on the hoisting and rotating device for raising and lowering the MTC, and
- actuator on the hoisting and rotating device for rotating the MTC.

The electromechanical actuators consist essentially of a motor and transmission gear. The drive units include two torque switches and two limit switches in each direction. The displacement switches also signalize the end positions.

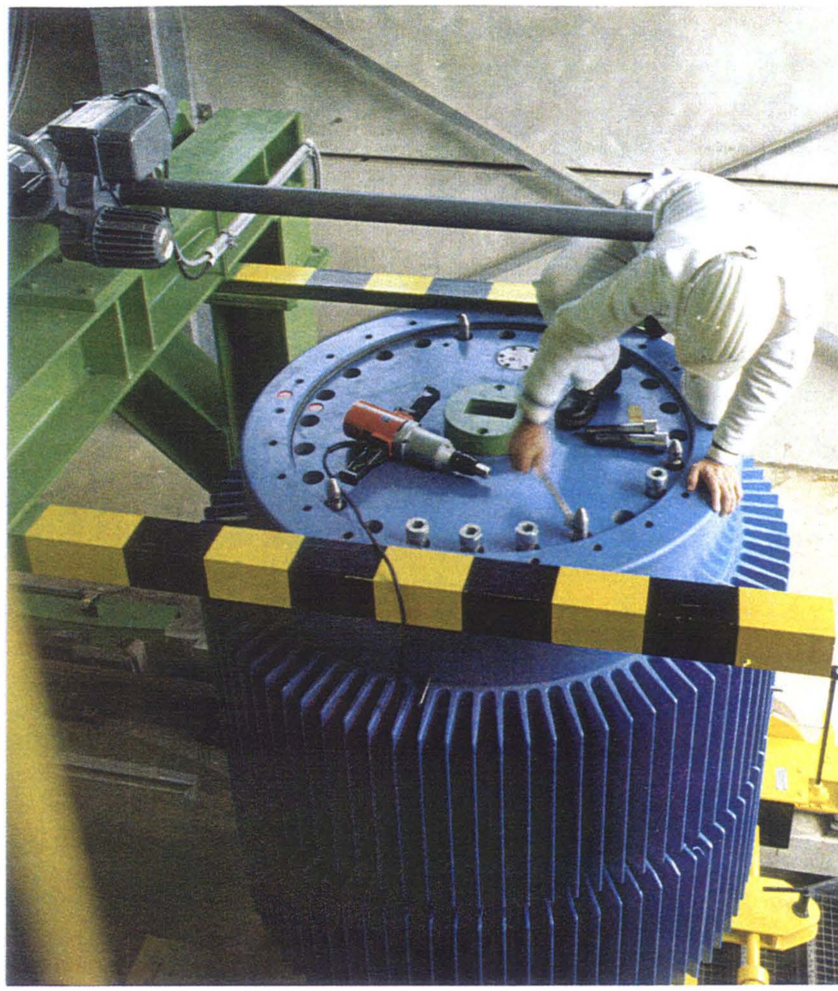


Fig. 19: Preparation of the Multiple Transport Cask, Castor GSF-5 for Raising of the Primary Lid

In case of failure of an electric motor or the power supply, the positioning operation can be finished manually.

Carriages and Carriage Guide (see Fig. 20)

The carriages consist of a frame structure with a ring for accepting the MTC and are equipped with track wheels. For the unloading or reloading position, carriages are positioned below the cask centring device.

Two wheels of the carriage are individually attached to the frame with extensible axles; the other two are mounted on the frame with a continuous axle, which is equipped with a parking brake. The axles are connected with the basis structure by pedestal bearings (roller bearings). The carriages are designed for travelling over industrial railway switches installed at factory-plants. They are provided with a trailer eye for a drawbar on the front and rear ends and diagonally with crane buffers.

The loading surface of the carriages is provided with a recess in the middle (ring). The hoisting and rotating device located in the assembly pit at midposition between the rails raises the MTC through this recess into the cask centring device. Positioning of the carriage is ensured by the guide rollers attached to the carriage and by the carriage guide. In the operating position the carriage is secured against rolling away by two extensible bolts between the carriage guide and carriage.

Quality Assurance

The "Großer Eignungsnachweis" was necessary for performing the welding operations. Moreover, the following steps were necessary:

- dye checking of the welds at a stength utilization of 50 percent,

- certification of the materials used, at least in compliance with DIN 50 049, 2.3,

- dimensional checks for certain manufacturing dimensions, and

- preparation of documentation with records of tests performed.

3.9.2 Crane System

In this section the crane system is described only with reference to the construction and design of the steel structures and machinery.

The crane system (Fig. 21) supplied by the Noell Company, Würzburg, is a bridge crane with three hoisting gears; two of these are mounted on a stationary frame on the bridge (gantry), and one is mounted on a trolley.

Fig. 20: Docking of the Multiple Transport Cask, Castor GSF-5, at the Transfer Station; Hoisting and Rotating Device Visible in the Pit between the Rails; MTC Raised from its Seat in the Carriage

The frame just mentioned with 2 t winch for the shielding bell and 1 t winch for the canisters is displaceable by $\pm$ 30 mm transversely to the longitudinal axis of the hall, and thus exactly positionable with respect to the transfer station during installation.

The crane has a wheel base of about 2850 mm, a mid-gauge dimension of 7155 mm, and runs on A 55 crane rails. The traval path length is abut 15.5 m and is limited by two buffer blocks in each direction of travel.

The trolley has a wheel base of about 1700 mm and a mid-gauge dimension of 1100 mm. The travel path length is 4950 mm and is limited by a buffer stop in each direction of travel.

The crane and trolley are equipped with an automatic control system. For attaining the desired accuracy of approach of ± 10 mm, the crane and trolley are provided with angular encoders which positively transmit the displacement paths by way of toothed racks. The crane and trolley are each guided by idler rollers on one side.

Electric power is supplied to the crane and trolley by way of trailing cables. By means of the automatic control system the travelling motions of the crane and trolley are controlled in such a way that acceleration and deceleration result in only slight oscillation of the load.

The following specifications applied to the calculation (for this purpose, compare the "Guideline for Hoisting Devices at the Asse Mine", GSF, 1988, issued in parallel with the processing of the order):

- All shafts, axles, and drawbars are to be designed for fatigue strength in accordance with Niemann (1981).

- The transmission gear for the 1 t winch is to be designed as follows:
  nominal moment x 2.35 with respect to fatigue strength, with a safety factor of 1.35 against tooth fracture, and a safety factor of 1.25 with respect to pitting.

- The cable winch is to be designed in accordance with Ernst (1973).

- In general the calculations are to be performed in conformance with the pertinent DIN standards for hoisting gears.

Gantry, Trolley Frame, Frame for 1 t and 2 t Hoisting Gears

The gantry consists of a welded box girder with a trolley rail, a sectional girder with a trolley rail, a sectional girder with a side girder, and two head girders. These components were welded to form a unit. The trolley rails were continuously welded for preventing corrosion.

The trolley frame and the frame for the 1 t and 2 t winches are welded structures of steel sections.

The classification was based on loading by the 10 t and 2 t winches in H2/B3, DIN 15 018, and for loading by the 1 t winch in H3/B3, DIN 15 018. During loading by the 1 t winch, the maximum sag of the crane bridge shall be 1/1000 of the mid-gauge dimension.

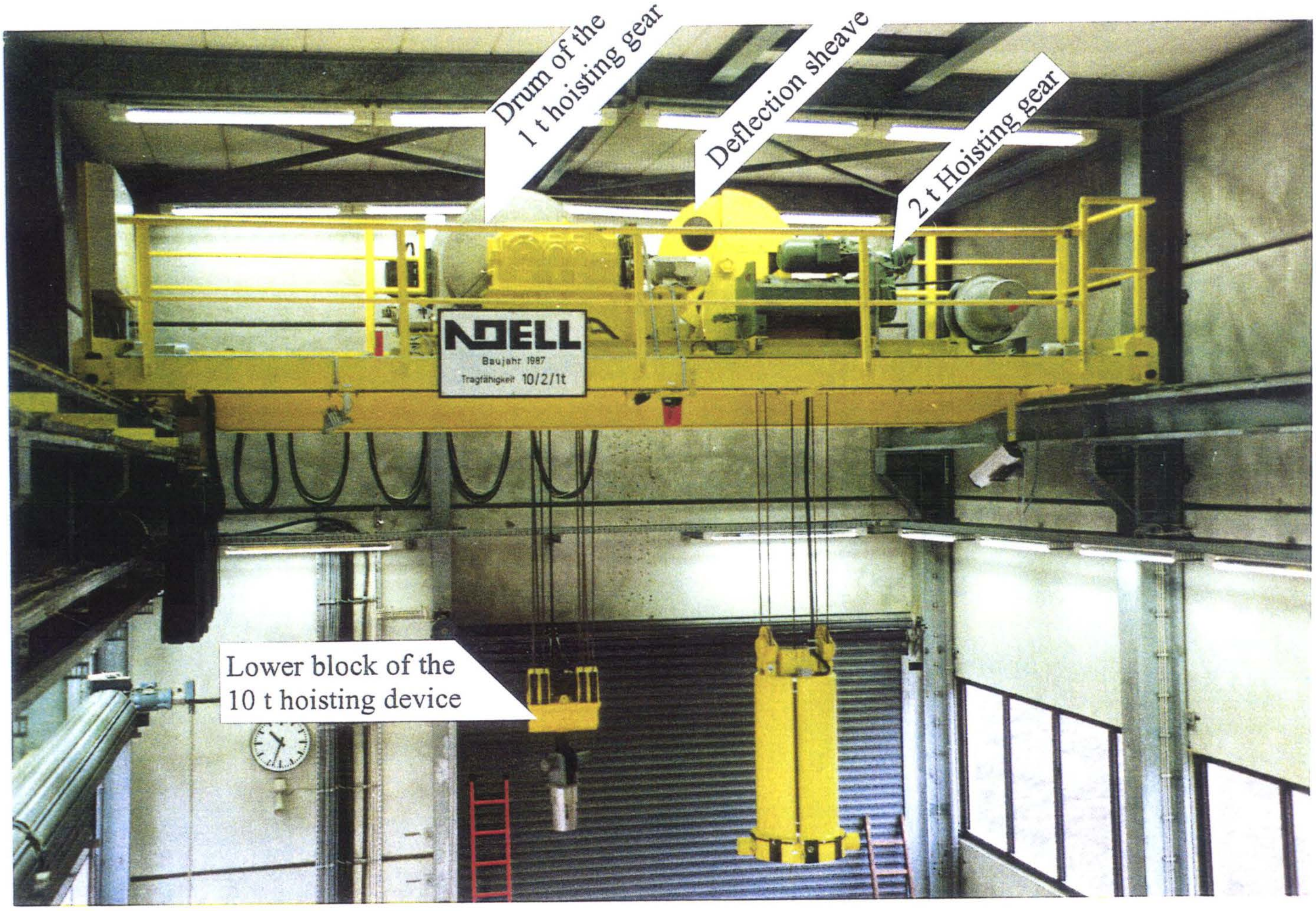


Fig. 21: Crane System of the Transfer Facility

For load-bearing components, exclusively fully killed cast, general-purpose structural steels (RSt37-2 and St52-3) were employed; the materials were thereby verified by certification in compliance with DIN 50 049, 2.2.

10 t Hoisting Gear for Asse TB1

The 10 t winch is an 8/2 reeved hoisting device, from the SWF Company, series BS, with a load capacity of 2500 kg. The standard version of this hoisting device has been design-tested. The cable drive of the winch has been designed in compliance with DIN 15 020, drive system group 1 Am; the winch is classified in group 2 m.

The two cables running from the drum are each routed over two sheaves of the four-sheave lower block and deflection sheaves mounted on the trolley frame to the cable fixation points. These cable fixation points make a length compensation possible between the two cable lines.

The winches are equipped with a four-sheave lower block; the simple hook, no. 8 DIN 15 401, can be endlessly rotated by means of a rotary drive unit. No hook migration occurs.

The winches differ from the standard version in the following respects:

second limit switch as emergency limit switch in the control circuit,
second brake on input drive shaft of the transmission gear,
no sliding armature motor,
maximum cable strength: 1770 N/mm^2,
cables torsion-free, galvanized version,

brake:	disc brake with automatic brake lining adjustment and lining limit indication; brake disk corrosion-proof,
auxiliary brake:	disc brake with corrosion-proof brake disc and limit switch for the "brake lifted" position.

The limit switch integrated in the auxiliary brake provides contact if the brake is lifted. The hoisting motor can be switched on only in this case. Upon switching off, the brake falls later than the main brake because of a current-independent delay element. Wear of the auxiliary brake is thus precluded.

Both brakes have manual lifting devices.

The components which are not included in the standard type testing of the hoisting devices have been verified by means of a component type testing or series component certifications.

The cable ends are fastened at the cable fixation points with wedge-type dead line anchors similar to those specified in DIN 43 148.

<u>Technical Data:</u>

Technical Data:	v_{lift}	0,2 to 6 m/min, controllable
	lifting height	8 m
	hook rotation	0,05 to 1 l/min

2 t Hoisting Gear for Shielding Bell

The 2 t winch is a 4/2 reeved hoisting device from the SWF Company, series BL, with a load bearing capacity of 1000 kg. The cable drive unit of the winch has been designed in compliance with DIN 15 020, drive system group 1 Am; the winch is classified in group 2 m.

The two cables running from the drum are each routed over two sheaves which are attached to the shielding bell by articulated bolts, to the cable fixation points. The cable ends are fastened here with wedge-type dead line anchors similar to those specified in DIN 43 148.

The cable fixation points make a length compensation possible between the two cable lines. The design of the hoisting device prevents the occurrence of load migration. In the event of failure of one cable line, the other can handle the full load.

The hoisting gear differs from the standard version in the following respects:

second limit switch as emergency limit switch in the control circuit,
second brake on input drive shaft transmission gear,
hoisting motor not sliding armature motor,
maximum cable strength: 1570 N/mm^2,
cables torsion-free, galvanized version,

brake:	disc brake with automatic brake lining adjustment and lining limit indication; brake disc corrosion-proof,
auxiliary brake:	disc brake with corrosion-proof brake disc and limit switch for the "brake lifted" position.

The limit switch integrated in the auxiliary brake provides contact if the brake is lifted. The hoisting motor can be switched on only in this case. Upon switching off, the brake falls later than the main brake because of a current-independent delay element. Wear of the auxiliary brake is thus precluded.

Both brakes have manual lifting devices.

The components which are not included in the standard type testing of the hoisting device have been verified by means of a component type testing or series component certifications.

<u>Technical Data:</u>	v_{lift}	8/1,7 m/min (pole changable)
	lifting height	5,5 m

<u>1 t Hoisting Gear for Coupling Grapple</u>

The cable drive unit of the 1 t winch has been designed basically in compliance with DIN 15 020, drive system group 2 m. The drive motor with disc brake drives the cable winch by means of the transmission gear. The disc brake is equipped with an emergency manual lifting device and automatic brake lining adjustment as well as an indication when the lining thickness has attained the permissible minimum. The brake disc is corrosion-proof. A flexible shaft coupling with a hard chrome plated brake drum is fitted between the motor and transmission gear; a dual-shoe brake acts on ths drum as auxiliary brake. The cable drum is supported unilaterally on the output shaft of the transmission gear.

Since electric power is supplied to the coupling grapple by way of the cables integrated in the load cable, the diameter of the cable drum and sheave was specified at 1000 mm. Since the load cable is made of stainless steel, the cable drum and deflection sheave were also manufactured of stainless steel with material number 1.4541.

The cable dispensed from the winch passes over the deflection sheave and is fastened to the coupling grapple by a suspension clamp.

The axle of the deflection sheave extends at one end over the bearing and is supported on a load cell installed there. This load cell provides three switching points:

- overload at 600 kg,
- nominal load at 500 kg, and
- slack cable at 100 kg.

A type-tested load cell which remains functional at an operating temperature from -10 °C to +40 °C and a shelf temperature up to +70 °C is employed.

A chain-driven angular encoder measures the hoisting path; the respective hoisting positions are indicated digitally. The chain is monitored with a chain tensioner coupled with a limit switch.

The angular encoder also functions as an operational limit switch for the winch; a gear limit switch is included in the circuit as an emergency limit switch.

Technical Data:	v_{lift}	0,2 to 6 m/min, controllable
	lifting heigth	8 m

Traversing Gear

Of the four crane track wheels (diameter: 250 mm) with roller bearings, two opposite wheels are each driven by geared motor from the SEW Company, installed on the track wheel shaft.

The calculation for the track wheel support was performed in conformance with DIN 15 070 and 15 071. The geared motors are equipped each with a brake with emergency manual lifting and a corrosion-proof brake disc. A travel limit switch limits the two end positions of the crane. The travel velocity is 0.3 to 9 m/min (continuously controllable).

Trolley Travelling Gear

Of the four trolley track wheels (diameter: 250 mm) with roller bearings, two opposite wheels are driven by a geared motor. The gear is mounted on the track wheel shaft; a transmission shaft provides the link with the opposite wheel.

The drive units of the crane and trolley are identical. A travel limit switch limits both trolley end positions. The travel velocity is likewise 0.3 to 9 m/min.

Quality Assurance

- Welds
  The "Großer Eignungsnachweis" was necessary for performing the welding operations. A welding schedule was prepared for load-bearing welds on the steel structure and lifting devices. The welds were performed in compliance with DIN 4100 or DIN 18 800; the weld quality was thereby specified with classification BS/BK DIN 8563.

All welds on the load-bearing components with a utilization factor higher than 80 percent have been subjected to a 100 percent nondestructive test.

Fillet welds on dynamically stressed components were subjected to a 100 percent surface crack testing procedure if the utilization factor is higher than 50 percent.

The welds were classified in compliance with DIN 15 018 and tested in conformance with quality group B. Before the welding operations, metal plates subject to load in the thickness direction were tested for doubling. Zones of hardening were eliminated by appropriate low-heat methods after acetylene cutting.

- Inspection by Approval Authority

  For the preliminary inspection, drawings of all components and subassemblies in the load sequence were submitted with the associated calculations as well as a welding procedure for the welds on load-bearing components.

  For the 1 t transmission gear, test schedules for the construction and approval inspections were prepared and submitted, in addition to drawings and calculations. The approval by the authorities was performed before assembly. After installation of the transmission gear, a test run was conducted with 1.5-fold drive moment. All tests were recorded and included in the crane test report.

3.9.3 Control of the Transfer Facility

The two contractors for the construction of the transfer facility also had to supply the control system for their respective part. It was the responsibility of IfT to ensure the ultimate realization of functioning control for the overall facility.

At the end of 1985 GNS received the order to deliver the transfer station. The order was placed with the Noell Company in December 1986 for delivery of the crane system. This time difference partially explains the fact that the crane system is equipped with a modern stored programme control system (SPC), in comparison with the transfer station, which is still provided with a contactor control system.

At the time of ordering with the GNS Company the requirements on the control system were still regarded as subordinate. For the total of seven drive units (ten motors), two brakes, and 19 external switches of the transfer station, a contactor control system represented an economical and thoroughly modern control techology at that time.

Additional requirements by the approval authority during execution of the order (for instance, for redundancies and antivalences) revealed that a stored programme control system would have offered advantages for controlling the entire facility.

The requirements on the control system for the crane facility are the following; they would also apply to the control system for a transfer station if it were to be realized today.

- Stand-by reserves (locations in memory, cabinet space, terminal clamps, signal and control conductors in cables): about 25 percent
- Stored programme control systems SPC equipped with self-monitoring (for over- and undervoltage, cycle, posity or ready, completeness) on plug-in printed circuit boards
- Pulse in positive acting direction
- All inputs and outputs on SPC with filters or optocouplers
- Indication of programme crash-down, immediate machine shut-down
- Control console designed in accordance with ergonomic and human engineering standpoints; spatial arrangement of the operating and monitoring components in correspondence with the sequence of successive operating and monitoring steps; ensurance of safety in the event of failure of system components as well as operating errors by personnel
- Adequate lighting, emergency lighting
- Operating modes:

  Interlocked manual control, partially automatic: Motion sequences are initiated manually; all interlocking conditions are active: semiautomatic programmes can be started if the interlocking conditions are fulfilled. All limit switches and detectors which are necessary for the safety of the system are functional.

  Interlocked "test" mode, in keypad operation: This mode is employed for maitenance and testing operations, or for operating the crane facility (traversing gears and 10 t winch). Certain interlocks necessary for safety remain active. The mode can be activated only with a special key-operated switch and under supervision.

- Several drive systems with three-phase asynchronous motors and pulse converters, regulating range, for instance, 1:30
- Locking of brakes for the winch drive systems in such a way that they open or engage only if the motor already has attained, or still provides, the moment necessary for holding the load
- Synchronization for exact approach of bridge and trolley positions

- Load measurement for canister handling, for monitoring the execution of a command (such as grappling of canisters)
- Control of acceleration processes during travel in such a way that oscillation of loads is avoided
- Design of control systems for both components of the facility in such a way that only one component is activated at any time, while the other component is disabled
- Transfer by way of potential-free contacts between the two system components

3.9.4 Transfer of Canister Above Ground for Disposal and Retrieval

As an example, the handling sequence during canister disposal in accordance with specially prepared operating instructions is described in the following:

Preparatory operations, such as

- removal of the protective elements for the multiple transport cask,
- removal of the secondary lid from the multiple transport cask,
- removal of the lid screws for the primary lid,
- all provisions for the radiological release measurements of the facility and of the casks, and for operational radiation protection,
- the provision of equipment (tools, heavy-duty trailer with traction engine, and accessories),

are not discussed here.

<u>Step 1: Switching the facility on</u>

Both components of the facility must be switched on separately; subsequently,
* the crane is released by means of a key-operated switch;
* the transfer station is released by pressing a push-button.

<u>Step 2: Selection of operating mode</u>

* Crane facility: test mode or normal mode

In the <u>test mode</u>, all functions are active: however, no automatic commands are issued. For a command, the release key must be pressed simultaneously. Certain safety-relevant interlocks ar provided in the test mode:

- The multiple transport cask, MTC, shall not be lowered unless the lid is positioned thereon.
- The slide of the transfer station shall not be moved when the sliding drawer of the STC is open.
- The slide of the transfer station shall not be moved unless the STC is in place thereon, if the lid of the STC has been lifted.
- The shielding bell shall not be raised if the sliding drawer of the STC is open.

In the normal mode, two submodes are possible:

Normal crane operation is for testing the emergency limit switches and normal crane functions, such as raising, lowering, trolley travel (for instance, for manipulation of the secondary lid).

Automatic operation is for canister transfer. Only certain functions of the crane can still be influenced by the operator.

* Transfer station: test mode or normal mode (automatic operation)

In the following, only the automatic mode for inward transfer of the canisters is described, as already mentioned.

Step 3: Start

The control of the crane facility and transfer station in the normal mode (crane in automatic mode) is a prerequisite. Pressing the "Inward transfer" key disables the crane and issues the release command for the transfer station.

Step 4: Prepare MTC for unloading

From the preparatory position (in the preparatory position, the secondary lid has possibly been removed, if not before; in particular, however, the lid screws of the primary lid have been removed, three of threse have been replaced by guide bolts, and an adapter has been screwed on, (see Fig. 19)) the carriage with the filled MTC is moved manually under the transfer station and positioned exactly and secured there with two bolts. Two limit switches each (two for the carriage position, two for inserted bolts) determine whether this has in fact occurred. It is now possible to enter the command for lifting the MTC. The hoisting and rotating device lifts the MTC from its seat in the carriage and into the shield of the transfer station frame. If this has been accomplished (position switch), the MTC can be rotated to the so-called zero position. In the zero position the lid lifting device can engage in the adapter of the lid.

Step 5: Prepare MTC for unloading, continuation

The spindle of the lid lifting device is lowered, subsequently rotated through 90° (a T-shaped end piece thereby engages in and under the lid adapter), and again raised. An ultrasonic sensor determines whether the lid has in fact been raised; together with the signal for the attainment of the end position by the spindle, these signals are processed for the release of the crane facility and disabling of the transfer station control system.

Step 6: STC handling

After pressing of the illuminated switch, "Receiving, position 1", the crane travels with its 10 t winch (that is, bridge and trolley) to a preprogrammed initial position, that is, (receiving) position 1. After attainment of this position, the crane hook of the 10 t winch can be moved exactly over the STC. This STC, lashed in place, has been transported on the heavy-duty trailer into the transfer hall and into a position which is attainable with the load-receiving device of the 10 t winch. From "Receiving, position 1", the load hook is thus positioned exactly over the STC, and the load is engaged. This position must be approached very accurately, because it later must be approached very accurately once again for setting the loaded STC down again. This is (set-down) position 3; it is stored in the memory after attainment of the upper hook position.

After pressing the key, "Slide, position 2", the crane automatically transports the load to the preprogrammed position 2 over the receiving point for the STC in the slide of the transfer station. During this travel, the STC can be neither lowered nor rotated. The two traversing gears of the bridge and trolley are actuated in succession: first the bridge, and then the trolley. This offers the following advantage: After braking of the bridge, and while the trolley is in motion, sufficient time is available for the oscillating shielding bell to come to rest, and thus prevent a collision with the STC. (The distance between the two is very short!)

For setting down, the STC must still be rotated as accurately as possible and lowered very carefully into the guides provided for the purpose. The STC is now set down, unhooked, and the hooking device is moved to the upper position.

As soon as the crane hook attains the upper end position, a condition is satisfied for disabling the crane control system and releasing the transfer station control system. Until reacceptance of the load, the crane facility (bridge and trolley) remains in this position (travel is not possible).

Step 7: Transport STC with slide

On the control panel of the transfer station, the push-button switch "Insert tool" must be pressed. The so-called tool consists of two rods for engaging with, and pulling, the locking bolts for the STC sliding drawer. The tools are inserted at this stage of the handling sequence, in order to mechanically lock the STC with the slide of the transfer station, that is, for preventing the STC from "falling" or being raised. The attainment of the end position by the tools is signalized and monitored for antivalence.

Subsequently the command is entered manually (push-button switch) for moving the slide of the transfer station (and thus also the STC and the lid of the MTC) from the crane position to the loading position. The travel path length of 958 mm is the same as the distance in the crane facility between "slide, position 2" and the grapple/shielding bell axis. For this reason further travel of the crane is not necessary.

As soon as "slide, position 2" is attained, the control system of the transfer station is disabled, and the control system of the crane facility is released.

Step 8: Connect coupling grapple with the canister grapple

The next steps are started immediately and automatically upon release of the control system of the crane facility:

- With the 1 t winch the coupling grapple is lowered in fast motion.
- Shortly before attaining the canister grapple, the lowering velocity is decreased, and the grapple claws are opened.
- The coupling grapple moves into the canister grapple, and the winch switches off after placing in position (that is, upon indication of "underload").
- The coupling grapple engages with the canister grapple.
- The winch pulls until the "overload" indication is attained. This indicates that the locking plates for the canister grapple in the STC are now relieved of the canister grapple weight.

Step 9: Place shielding bell in position

This step is initiated by pressing of the flashing push-button for lowering the shielding bell. The corresponding winch (the 2 t hoisting gear) thereby stops immediately when the push-button is released. Placement of the bell on the top of the STC is, of course, signalized by three proximity initiators connected in series, but not further processed for stopping the winch. Termination of the lowering operation must be initiated by the operator by releasing the push-button. The three proximity initiators merely signalize the correct placement of the bell in position. This signal (and the drawworks at rest) are processed for transmission to the control system of the transfer station.

Step 10: Select canister and open STC drawer

By means of the manual control device (switchboard on the transfer station frame, see Fig. 17) the MTC is rotated to the desired position. Since the individual canister positions in the MTC cannot be monitored by a sensor, the rotary device must be restarted if the desired position has not yet been attained. After releasing of the push-button, the MTC rotates further to the next canister position. An exact bookkeeping is necessary, since the canister disposal sequence does not correspond with the order of the canisters in the cask.

The steps for opening the STC then follow:

- Rotate tools, that is, the tools engage with the locking bolts;
- pull tools and thereby locking the bolts;
- open the sliding drawer.

Lifting of a small arresting bolt in the STC is associated with the rotation of the tool; the arresting bolts prevent the locking bolts from falling out during transport of the STC. The rotation of both tools as well as pulling are each monitored for antivalence. The limit switches are redundant. Moreover, proximity initiators signalize that the bolts have really been pulled.

The sliding drawer is pulled by means of a sliding carriage, which originally had no shielding function, but was later filled with lead. This sliding carriage is provided with a pin which engages in a corresponding counterpart on the underside of the STC drawer.

After opening of the sliding drawer, the system switches back to the control system of the crane facility.

Step 11: Pulling the canister into the STC

With the command for unlocking the canister grapple from the lid of the STC, an automatic process sequence with the following partial steps begins:

- Two small servomotors on the shielding bell pull away the locking plates in the head of the STC to permit lowering of the grapple (canister and coupling grapple as a unit).

- The grapple thus leaves the overload area and is lowered, initially at high speed, through the STC and the slide of the transfer station into the MTC.

- Shortly before attaining the canister, the speed is decreased, and the canister grapple is opened.

- When the grapple sets down in place (indication: "Slack cable"), the winch stops, and the claws of the canister grapple close.

- The winch is immediately reversed and pulled slowly at first. The load measurement must now indicate "normal load"; this means that a canister is suspended on the grapple.

- Shortly before attaining its position in the STC, the lifting speed is decreased. The winch stops when "overload" is indicated. (At this point the displacement measurement is synchronized).

All of these manipulations cannot be observed directly. The running noises from the motors, the depth indication, and the load measurement on the winch are advantageous for controlling and monitoring the manipulations.

Step 12: Close STC sliding drawer

The process described under step 10 now proceeds in the reverse direction:
- The sliding drawer is closed.
- The drawer is locked (the tools are inserted), and the tools are rotated (that is, the tool and bolt are decoupled).

Step 13: Disengage the canister, raise the bell, and separate the grapples

The last stage of step 12 results in automatic switch-over to the crane facility and starting of the following sequence:

- "Lower" the canister (that is, the canister is placed on the sliding drawer) until "slack cable" is indicated.

- The canister is disengaged, that is, the canister grapple is opened and raised somewhat; the grapple then recloses. No "normal load" is indicated; that is, the canister has been released.

- The grapple is raised until "overload" is indicated; that is, the grapple is in the uppermost position.

Another manual operation now follows: The push-button for locking the grapple is pressed. After insertion of the locking plates, the grapple is automatically lowered until "slack cable" is indicated.

As long as the flashing push-button for raising the shielding bell is kept depressed, the bell is raised. The process is discontinued by releasing the push-button, or terminated when the bell has attained its highest position.

Afterwards, the canister grapple is automatically decoupled, and the coupling grapple is likewise pulled to the upper limiting position.

The crane is subsequently disabled, and the control system of the transfer station is activated.

Step 14: Transport STC with slide

The slide (and thus the STC) travels to the so-called crane position; the tool is then pulled (see step 7). With the response of the limit switches in the gear motors, the crane facility is activated, and the transfer station is disabled.

Step 15: STC handling

With the 10 t winch the STC is raised from the transfer station. After pressing the push-button, "Set down, position 3", the crane moves to the position where it had accepted the STC in step 6. (This is not the so-called "receiving" position 1!)

After attaining this position, the STC can be set down on the heavy-duty trailer; the load hook is subsequently returned to its uppermost position. The canister count then automatically increases by one digit, too.

After departure from the upper end position (with the STC on the hook), moving the load hook up once more is not permissible if the Asse TB1 has not been previously unhooked. This would cause the counter indication to increase further and thus permit the next step in the programme, although the STC has not yet been set down.

Step 16: Possible options

At this point two options have been provided:

1) All five canisters have been withdrawn from the MTC (that is, the MTC is empty), or the removal of further canisters is not desired for an extended period, or not possible (that is, the lid is to be replaced on the MTC), or
2) the next canister is to be withdrawn.

With the option of "further withdrawal", the process is continued as described as of step 6. This loop is executed until option 1 exists. That is, with fewer than five canisters, "end withdrawal" must be selected manually, or this switch-over proceeds automatically after withdrawal of the fifth canister.

Hence, if the withdrawal is to be terminated, that is, if the MTC is to be closed or forwarded, the further procedure is as follows.

Step 17: Close and lower MTC

By manual control (switchboard on the frame of the transfer station), the MTC is rotated to the zero position. Afterwards, the push-button switches, "Lower MTC" and after completion of this, "Disengage MTC lid", are pressed. The rod system of the lid removal device is thus decoupled from the lid.

The push-button switch, "Raise removal device", is pressed: The removal device (without lid) rises and completely releases the lid. After attainment of the upper end position, the command can be issued for lowering the MTC onto the carriage. That is, the push-button, "Lower MTC/elevating turntable" must be pressed.

Step 18: Preparing the MTC

Once the lifting device has come to rest in the lower position, the two locking bolts for the carriage must be pulled, and the MTC must be pulled out under the transfer station.

The MTC is now prepared for storage (preparatory position, see step 4); that is, the three threaded guide bolts are removed from the MTC top area, the lid is fastened with screws, the adapter is removed, and possible conservation measures are implemented. Measurement of the possible contamination of the (empty) cask, for which the cask lid must be raised again outside of the hall, is also planned.

Reloading proceeds in a similar manner. All manipulations up to step 8, inclusively, are identical. The subsequent steps are prefixed with a distinguishing "1", that is, 109, 110, 111, etc. up to the steps which again proceed in the same manner as for disposal.

Step 109: Place shielding bell in position and engage canister

As in step 9, the shielding bell is lowered and placed in position on the STC. The subsequent procedure differs, however:

- The command to disengage the canister grapple is given (for disposal, this command is issued in step 11!).

After completed disengagement, that is, after response by the two sensors, the following sequence starts automatically:

- The grapple is opened and moves slowly to the canister situated in the STC.
- After the "slack cable" indication, that is, grapple in place, the claws close.
- The winch pulls the canister upward somewhat and thereby determines whether the present weight limit is exceeded, that is, whether the canister is in fact suspended on the grapple.
- The winch pulls the grapple further upward and under the lid of the STC. "Overload" is indicated; this also provides the criterion for switching the winch off. At the same time, the control system for the transfer station is activated, and that for the crane is disabled.

Step 110: Select position in MTC and open STC sliding drawer

Step 110 is identical with step 10.

Step 111: Set canister down

After release of the crane facility by the last action of step 110 the following sequence is automatically initiated:

- The 1 t winch is lowered (slowly at first, then fast, and again slowly shortly before placing the canister in the MTC) until "slack cable" is indicated.
- The claws of the canister grapple open.
- The 1 t winch is raised; no "normal load" must be indicated; this means that the canister has really been disengaged. The claws are closed.
- The 1 t winch is raised further until "overload" is indicated; that is, for the correct depth indication the canister grapple has been moved exactly under the lid of the STC.

Step 112: Close STC sliding drawer

Step 112 is identical with step 12.

Step 113: Raise shielding bell and separate grapple

The control system of the crane facility is released. The command for locking the canister grapple in the lid is given. After completion of locking, the grapple is automatically lowered (only by 1 to 2 mm) until "slack cable" is indicated. The shielding bell is now raised all the way up. As soon as this is attained, decoupling of the canister grapple is automatically initiated:

- The grapple claws open.
- The coupling grapple rises, and the claws close a few seconds later.
- The coupling grapple moves further to the upper end position and thereby extends into the shielding bell.

The remaining steps are identical with steps 14, etc.

Experience and Recommendations

The following summary of experience cannot be complete. Negative experience should also be mentioned in order to avoid repetition as far as possible in the future.

1) Transfer facility or transfer in a "hot cell"

The transfer facility constructed at the Asse mine has been developed on the basis of earlier experience with the transfer of cobalt 60 radiation sources at the Asse mine, and because a "hot cell" was not constructed for economic reasons. A comparison of possible advantages and disadvantages with the two systems is presented in Table 7.

If shaft transports with MTC were feasible in a final repository, there would be a possibility - on the basis of the transfer station principle - of direct withdrawal from the MTC for disposal in the borehole. A patent application has been filled for this solution (Baatz et al., 1990).

Table 7: Advantages and Disadvantages of Possible Transfer Systems

	Advantages	**Disadvantages**
Transfer Facility (HAW-Project)	Comparatively Low Investment Cost for Pure Gamma Emitters	Special Facility, Concept Suited Only for STC and MTC Castor GSF-5 Elaborate Shielding for n emitters
Hot Cell Facility	Universal Applicability Known Technology	Expensive

2) All casks of one type must be of identical design, and their application must be tested inactively at least once before active application.

3) For the analytical proof of sufficient shielding, realistic modelling is necessary (for instance, lid raised, cask open, radiation path, and for all possible emitter positions), scattered radiation is of major importance. Impairment of the shielding in the zone of the cask aparture by the installed seat for the two lids must be taken into consideration.

4) The chambers in the MTC for accepting the canisters must be provided with devices for guiding the grapple during withdrawal. If a canister is accasionally retrieved from a final repository into the MTC, a guiding device for the canister is also necessary.

5) Travel and hoisting velocities should be continuously controllable. A control range of 1:20 to 1:25 is sufficient. It is thus possible
   - to accelerate gently (inertial forces!), on the one hand, and
   - to shorten the time necessary for individual steps, on the other hand.

   Even at relatively low speeds substantial inertial forces are generated because of the large masses.

6) The 1 t winch (for canister handling) is equipped with a load cell at the deflection sheave. Experience has shown that even small deviations of the cable from midposition result in transmission of an appreciable moment of the axle of the deflection sheave, and thus an increased load, or load relief, on the load cell. As an effective remedial measure additional sheaves were provided for guiding the cable.

7) An all-round lighting fixture had been intended for operation during activation of the crane facility. This proved to be very anoying for the operating personnel.

8) A lamp-saving switch must be provided for all control lamps, since the lamp life is limited and the lamps must therefore be used sparingly. Otherwise, defective lamps must be frequently replaced.

9) All components of the facility must be exactly aligned with respect to one another. For alignment appropriate adjustment possibilities (such as oblong holes) must be provided. Moreover, certain design dimensions must be observed very exactly.

   In the present case,
   - the displacement of the transfer station slide was 958 mm, which is equal to the distance between the lines of action of the 10 t winch and the 1 t or 2 t winches;
   - the circular arc diameter on which the canister chambers are situated in the MTC is the same for all Castor GSF-5;
   - all axes (10 t winch, 2 t or 1 t winches, turntable for MTC, axis of MTC, and relevant chambers in the MTC with canister, are exactly at midposition between the rails in the hall;
   - the axis of the MTC turntable is identical with the axis of the MTC on the carriage. (This was not the case; consequently, the MTC stood eccentrically on the turntable, and therefore rotated eccentrically. As a result it was not possible to place some of

the canisters in position in the MTC during reloading. After detection of this error and correction of the carriage position, no further problems occurred.)

10) For selecting the canister position in the MTC, pins by means of which a proximity initiator furnishes contact are screwed into the cask body. These pins can be easily bent. In the future, a solution should be found for avoiding this shortcoming.

11) A spindle is provided for raising and placing the lid in position. During lowering of the lid, that is, motion in the load direction, unpleasant noise and vibration resulted from slip-stick effects. This was avoidable only by considerably decreasing the rotational speed or velocity of the motion, in combination with an improved method of cutting the trapezoidal thread on the spindle. The appropriate speed could be easily set by means of rotational speed regulation. Above all, however, uncritical ranges could be traversed quickly, and this would save plenty of time.

12) A "practice cask" should be employed for training and testing purposes. The use of a MTC intended for "active" handling affects the flange zone (moisture, rust on the sealing surfaces, impairment of seals). More attention should be given to corrosion protection or preservation of the casks, especially of the sealing area of the lid seals, and a practicable procedure should be developed.

13) A stored programme control system for the facility has proved to be very advantageous, especially for commissioning.

14) A fully automatic sequence has not proved to be advisable. The continuation of the programme should be initiated by pressing a corresponding key.

15) Running noises from the drive systems are useful for monitoring and for safety in conformance with UVV.

16) Loads must be suspended vertically (centre of gravity in the geometrical axis).

17) All in all, a well functioning facility is available.

3.10 Mobile Crane, Crosshead

In this section the cranes and load hooking devices for transfer of the MTC from the delivery vehicle (railway car) to the carriage are described.

No suitable hoisting device is available for handling the 20 t MTC at the Asse mine. Since the utilization frequency of such equipment is low, and since availability can be ensured by specialized companies, it was decided to lease a standard mobile crane for the purpose when necessary.

Because of the greater radius of action and for enhancing safety, a crane with a load-bearing capacity of at least 60 t should always be employed for transfer, in conformance with the operating licence and its approval.

The load hooking device (a crosshead) was purchased and made available.

The site for transfer was determined; special features are indicated in the operating instructions for transfer (barriers, site marks, supervision etc.).

During transfer for the first time (see Fig. 13) on the occasion of delivery for five MTC, the proposel procedure was implemented. No problems were encountered.

3.11 Locomotive, Draw Bar

The plan for moving the carriages by means of a special draw bar with the existing Diesel locomotive on the rail road system of the mine was abandoned at a relatively early stage for the following reasons:

- The existing coupling on the locomotive is positioned very high in comparison to the coupling on the carriages; consequently, the draw bar must be very long if a certain angle is not to be exceeded.

- The tractive power of the locomotive appeared to be too high. In the event of faulty operation there is a hazard of damage to equipment components.

- Modifications of the locomotive (installation of an additional coupling) in a manner capable of receiving approval are difficult.

Instead, there was a possibility of purchasing a used railway gang vehicle.

This vehicle has a comparatively weak engine, is light-weight (the wheels can easily slip), and is equipped with a lower truck coupling. With the use of a draw bar, the carriages can be easily moved. These components are shown in Fig. 22.

Problems were encountered with dirty, and in the winter icy rails (grooved rails, or rails with pavement protection, rail type Ph 37 a), because of the low tractive power of the railway gang engine. Rails of this type must also be kept clean. It can then be expected that icing problem will also be less severe, since water can run off more easily.

Moreover, the time-consuming approval procedure presented problems (TÜV - Landeseisenbahnaufsicht (Federal State Railway Supervising Authority) - Office of Mines - Asse Mine).

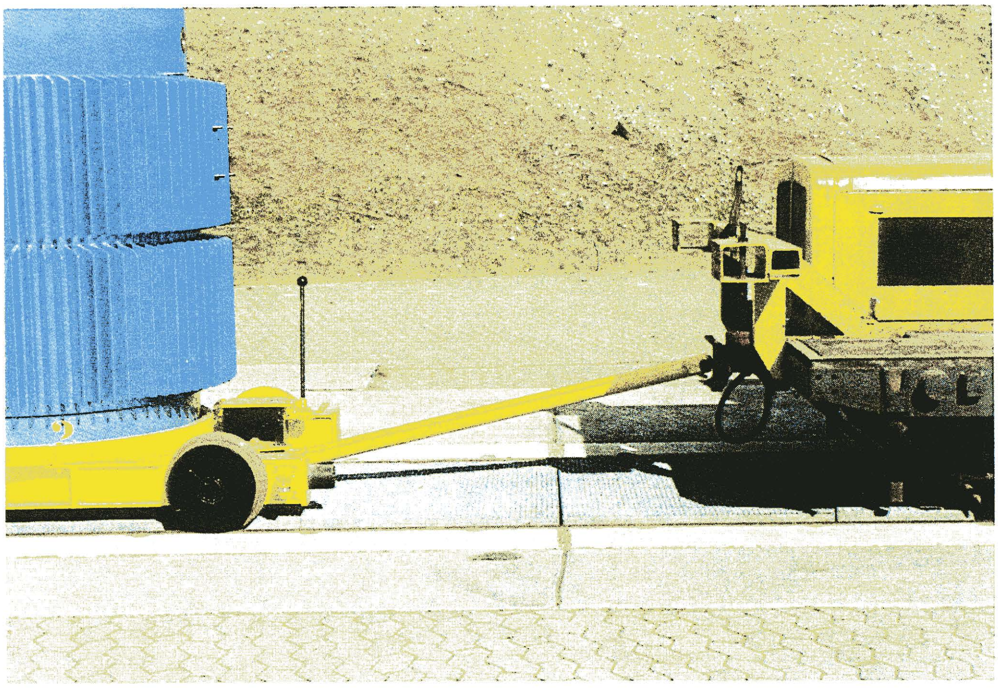


Fig. 22: Carriage with Multiple Transport Cask, Coupled with the Railway Gang Vehicle

3.12 Borehole Slider (with Supplementary Shielding)

The borehole slider constitutes the connecting link between the disposal borehole and the STC during disposal in, and retrieval from, the borehole (see Fig. 23).

The borehole slider (Fig. 24) consists of a thick-walled housing with the slide, the drive system for the slide, the drive systems for locking the sliding drawer in the STC, and the chamber for accepting the slide and the drawer of the STC. The drive systems and switches are supplied and controlled from the disposal maching (see section 3.13) by way of two connecting cables.

Designing of the borehole slider began in parallel with the evelopment of the STC in 1984; in 1985, the order was placed for the construction and delivery of two borehole sliders.

The borehole slider closes the disposal borehole and shields against radiation from the borehole. Furthermore, it performs functions similar to those of the transfer station at the surface.

Its purposes are to
- receive the STC and position it coaxially with the borehole,
- ensure adequate shielding at all times,
- open and close the STC, mechanically lock and unlock the sliding drawer of the STC.

The borehole slider was viewed as a component whose development is relevant to final disposal (as with the STC). Consequently, provision was made for shielding against neutron radiation (from real high-level radioactive waste) although this is not necessary for the HAW-project itself.

This additional shielding of polythene plates had been intended for external cladding of the steel body of the borehole slider. However, equipped with the additional shielding the borehole slider was too heavy for the hoisting device provided underground. Consequently, the borehole slider was finally constructed without neutron shielding. Hence, no test was performed to determine whether the shielding was indeed sufficient for neutron radiation. In principle, the problem of simultaneously ensuring adequate shielding against gamma and neutron radiation at every point is not so easy to solve from a design standpoint.

The shielding on the borehole slider for gamma radiation was determined in a manner similar to that for the transfer station; in the area for receiving the STC, similar dose rates

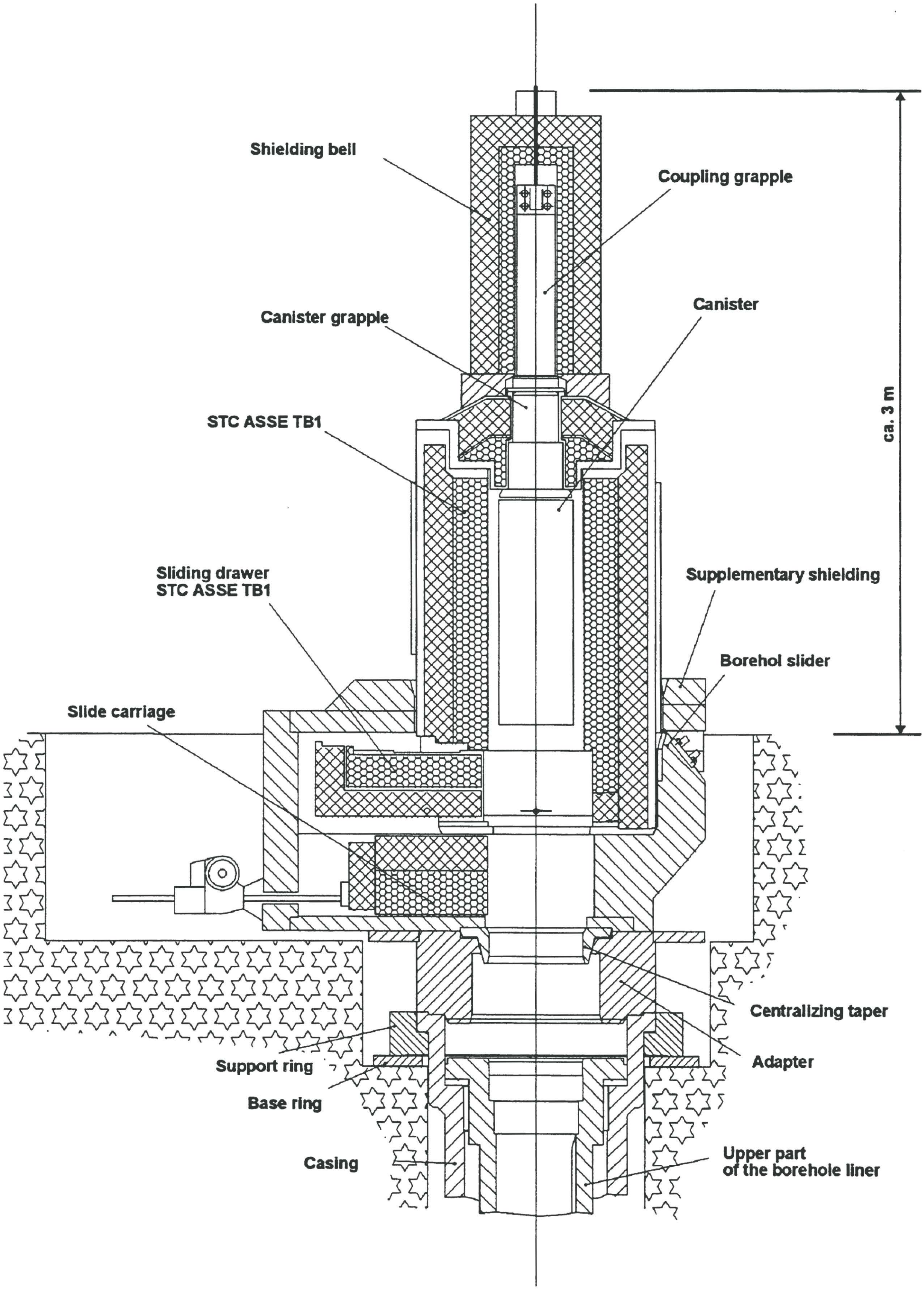


Fig. 23: Situation at the Disposal Borehole; Borehole Slider as Connecting Link between the Borehole and Single Transport Cask

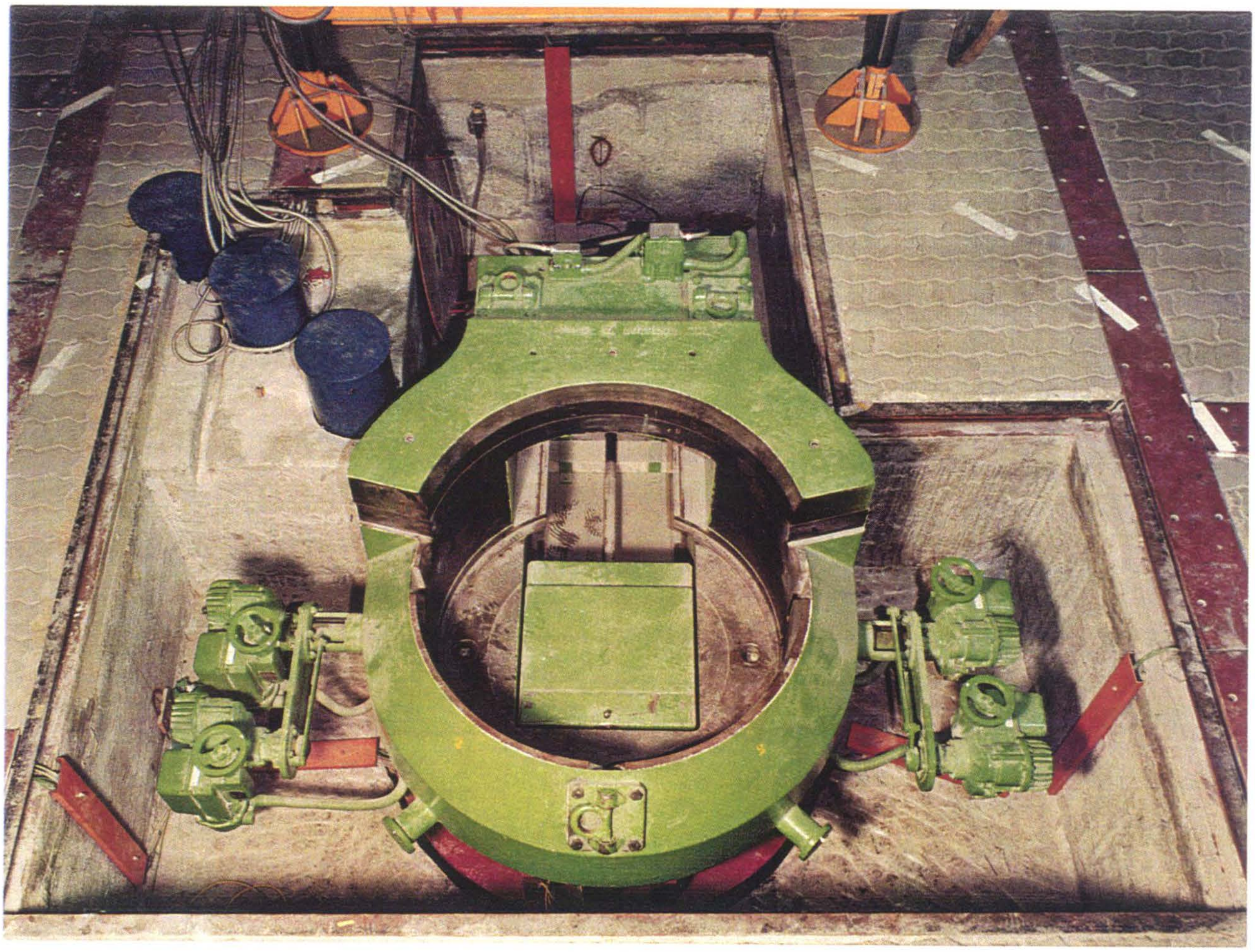


Fig. 24: Top View of the Borehole Slider above the Disposal Borehole; Borehole Slider Shown without Supplementary shielding

can be expected because of the similar geometry and materials. Weakness had been detected during the radiological examination of the transfer station with a Co^{60} source (see section 4.2) in this area, and a modification was therefore necessary; consequently, a similar modification was also provided for the borehole slider.

The supplementary shielding (Fig. 25) is removable for saving weight; that is, the supplementary shielding must always be previously removed for transferring the borehole slider, and then reinstalled at the new location. The check on the shielding with a Co^{60} source, in this case both at the transfer station above ground and at the borehole slider underground, has indicated that no unacceptable dose rates can be expected (see section 4.2).

An important feature is that both borehole sliders are of identical design and correspond in principle with the transfer station at the interface with the STC. (There are differences, however).

At the time of ordering it was not yet clear whether the borehole slider was to be installed on the floor or in a recess in the gallery floor. It was finally decided to excavate a recess for the borehole slider. Several reasons for this decision are as follows:

- Shielding of the personnel is thus improved, since no one normally enters the recess in the gallery floor (the so-called cellar) during disposal of the sources. That is, no personnel are ever present in an area where an increased radiation hazard exists.

- The drive motors are relatively well protected; they cannot be damaged by vehicle traffic in the disposal gallery.

- The hoisting height for the transport vehicle and the disposal machine can be kept shorter.

- The necessary borehole casing was shorter by the corresponding length (economic advantage).

- The gallery height was lower, or did not have to be increased (for installing the borehole liner).

Experience and Recommendations

1. The borehole slider must be positioned exactly horizontal. If the supporting surface for the borehole slider is not exactly horizontal, as is the case at the A4 borehole, compensation must be provided. Otherwise, there is a hazard that the STC and shielding bell are not exactly vertical. As a result, the routing of the cable on which the grapple is suspended is not exactly coaxial with the borehole. Consequently, the grapple or canister, or both, cannot be accurately lowered or retracted.

2. The installation of the borehole slider in a "cellar" offers the advantages just mentioned. A disadvantage is the space limitation for repairs which may be necessary. An enlargement of the "cellar" at appropriate locations and the possibility of assembly from above (in conjunction with a new design) are possible solutions.

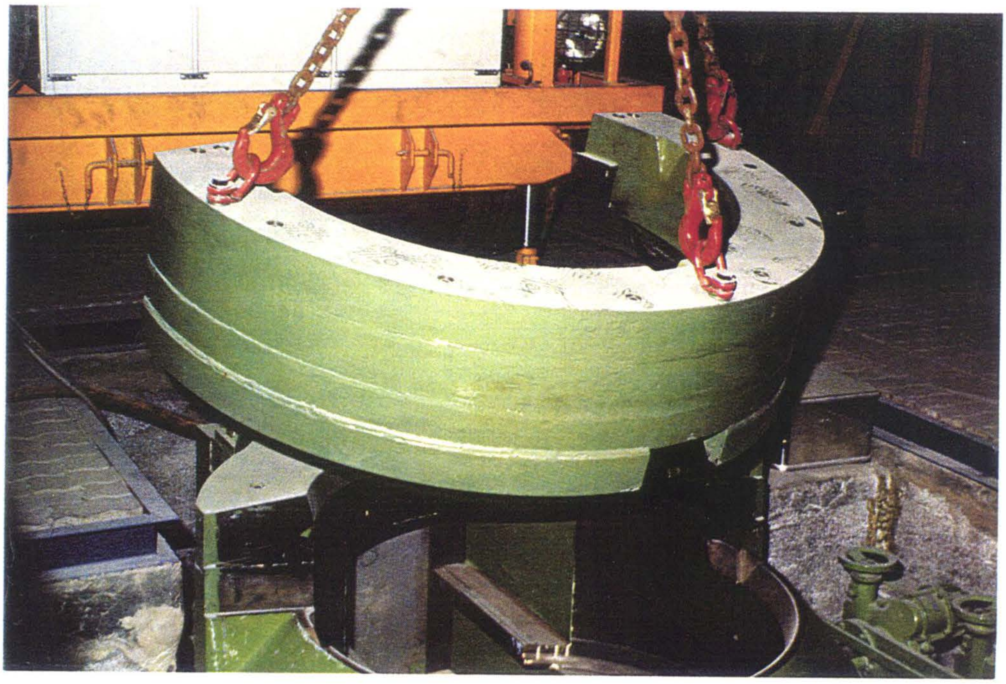


Fig. 25: Supplementary Shielding for the Borehole Slider

3. Earthing or connection to the earth potential of the disposal machine is necessary for the borehole slider. Otherwise, interference occurs in the control system of the disposal machine.

4. Elements which are suitable and approved for mining (for instance, load bracket from the Rud Company) must be employed as load hooking points for transfer from the very start. (Eye bolts are not acceptable for a load direction which deviates from the bolt axis.)
   Three-point suspension with chains has proved its value, but an appropriate test must determine whether a possibility of adjusting the chain length is necessary. An adjustment device is always advisable.

5. The glide rails for the drawer of the STC should be replaceable. With a welded structure such as the STC, considerable welding distortion may occur, and machining of the glide rails for the sliding drawer within the STC is hardly or not feasible at all in the completely welded condition. That is, a slight upward or downward slope of the slideway within the STC must be expected. The slideway within the borehole slider (and also within the transfer station) must continue in this predetermined direction.

Considerable adaptation work is therefore necessary. This clearly illustrates the reason why identical casks are so important.

6. With the originally conceived combination of borehole slider and STC, the borehole slider was provided with a means of accepting the STC with a depth of 470 or 610 mm. These areas of the STC were not provided with cooling fins. The supplementary shielding has now been designed in view of the shielding deficiencies determined; hence, it would have been far better if the ribs had not extended so far downwards. Thus, a large "gap" remained for radiation in the rib zone. The quintessence of the matter is that the ribs are not really necessary at all parts of the casks such as the STC and should not be longer than required for the analysis of the heat dissipation.

7. The subsequent installation of a supplementary shielding for the already constructed borehole sliders (see above) must be avoided from the very start with future designs by a more exact consideration of this subject with respect to protection against radiation.

8. The borehole slider is controlled from the disposal machine. A special control unit was present for tests and functional checks; this unit also permitted operation without the disposal machine (without sources or simulated sources, of course). This feature was very useful and should also be available in a final repository.

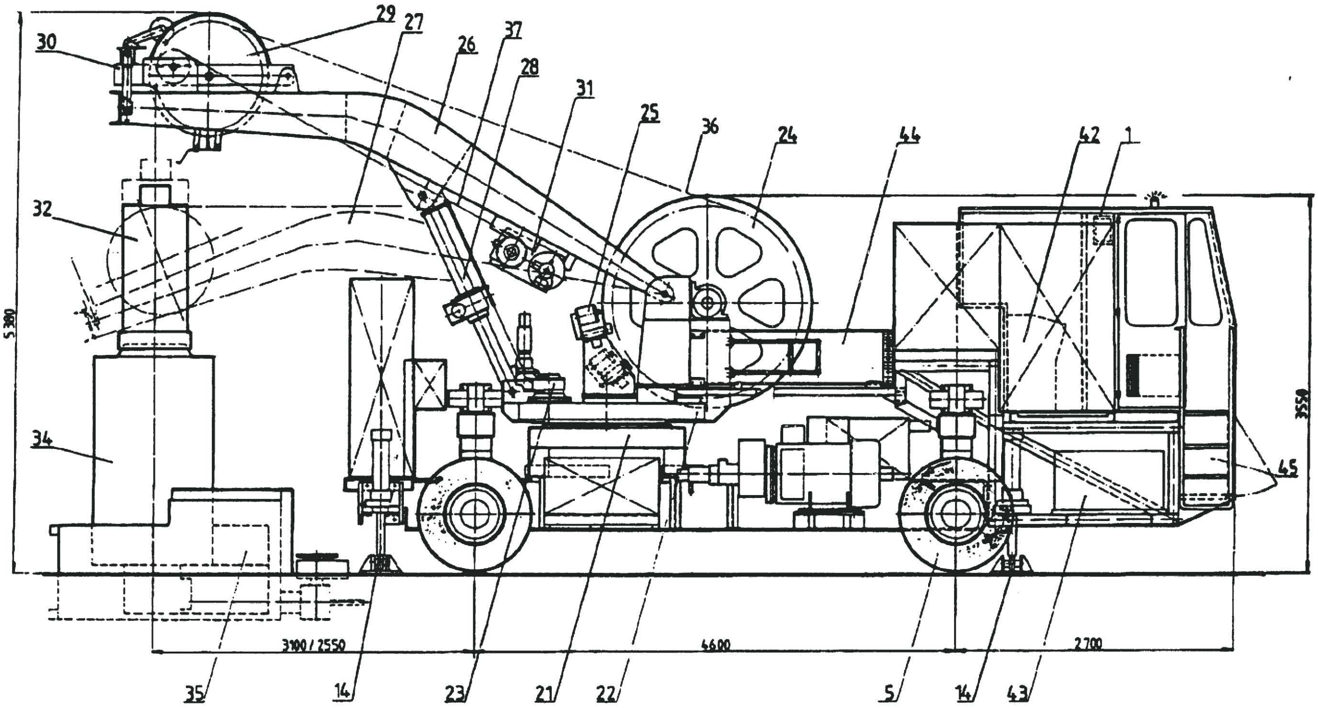
9. In the bottom of the borehole slider, switches are installed for monitoring whether a cask has in fact been inserted. The plunger switches originally employed were replaced with proximity initiators because contamination had resulted in a functional impairment.

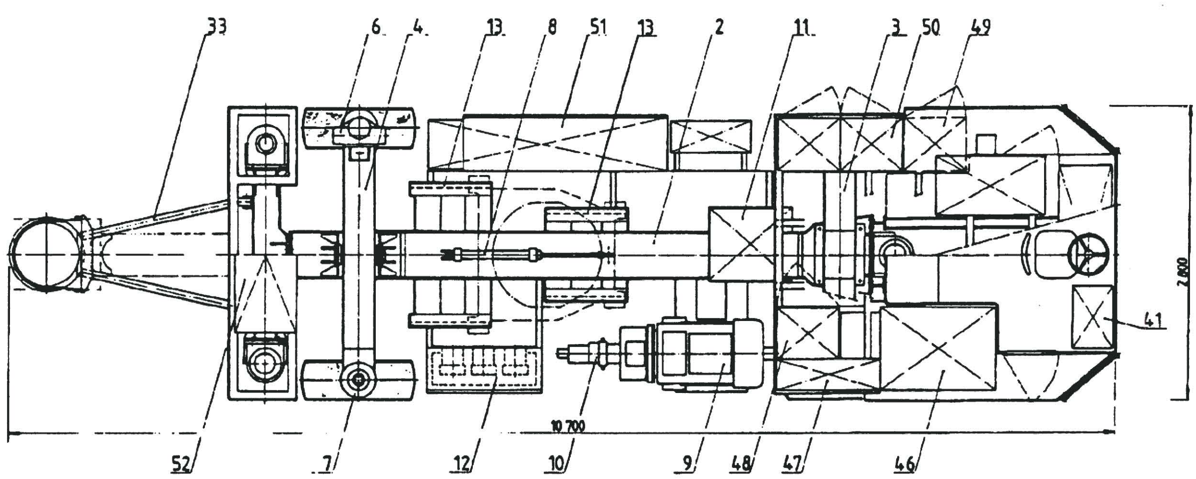
10. Switches with springs (restoring springs) must be designed to interrupt the transfer condition in the event of spring rupture, that is, to detect the spring rupture.

3.13 Disposal Machine

With the use of the disposal machine, a canister made available in the STC is automatically or manually lowered into the borehole, or retrieved from the borehole into the STC, in compliance with all necessary safety measures.

The machine has been designed to allow relocation under its own power. A general survey of the machine is presented in Fig. 26. In Fig. 27 the machine is shown in a test gallery underground.





Vehicle
1 Driver's cab/control station
2 Vehicle frame/machine frame
3 Front axle
4 Rear axle (swing axle)
5 Wheel with wheel hub motor
6 Hydraulic power steering unit
7 Potentiometer for steering control
8 Hydraulic cylinder for displacing 21
9 Motor for driving hydraulic pumps
10 Hydraulic pumps
11 Hydraulic fluid tank
12 Hydraulic valve station
13 Console for upper carriage slide
14 Vehicle support element

Winch System
21 Upper carriage slide
22 Chassis for winch and jib
23 Slewing gear
24 Grooved drum
25 Winch brake system
26 Jib in working position
27 Jib in transport position
28 Jib height adjustment mechanism
29 Cable deflection sheave
30 Device f. load measurement
31 Shielding bell winch
32 Shielding bell
33 Stabilizing fork for 32 in transport position
34 Transport cask Asse TB1
35 Borehole slider
36 Cable for grapple
37 Cables for shielding bell

Electrical Equipment
41 Control console for the vehicle
42 Control console for the winch system
43 Rechargeable battery
44 Cable chain f. elec. power supply to winch
Electrical Switching Cabinets:
45 Outlets for small drive units
46 Inverter
47 Direct current starter
48 Low voltage supply
49 Stored programme control system 1
50 Stored programme control system 2
51 Battery charger
52 Pulse converter

Fig. 27: Disposal Machine in Test Gallery

The individual functions are:

- disposal of HAW canisters, including control of the borehole slider, with extensively automated operational sequences;
- visualization of malfunctions;
- counting and documentation of the HAW canisters in the boreholes by computerized borehole management;
- installation and removal of the borehole plug;
- transfer of the disposal machine from one borehole to another;
- in addition, safe retrieval of the HAW canisters within the scope of the HAW-project for reasons of approval.

The disposal machine was developed and delivered by the Siemag Company. The machine was ordered in September 1987 and delivered in January 1989. The initial test runs were conducted in April 1989.

Technical Data on the Disposal Machine

The technical data are presented in Table 8.

The individual modules are electrically or electrohydraulically powered. Electric power is supplied by way of a cable from the 500 V mains of the mine, or from rechargeable batteries on board of the vehicle.

Vehicle

For relocation, the machine is equipped with four pneumatic tyre wheels with individual swivel bearings. They are driven by hydraulic wheel hub motors and provided with drum parking brakes.

The vehicle frame accommodates the upper carriage slide, a cab (as driver's cab and control station), the hydraulic system, control cabinets, rechargeable batteries, and the telescopic supports for adjusting the vehicle level.

The upper carriage slide is hydraulically displaceable on the machine frame in the longitudinal direction of the machine for fine positioning of the winches in relation to the borehole and borehole slider. The hoisting device is slewable for fine positioning perpendicular to the longitudinal axis.

The shielding bell accompanies the machine during transfer.

Hydraulic System

The hydraulic drive system for all consumer devices of the machine is designed as a compact unit. Two different areas are driven, individually and never simultaneously, by the central pumping unit:

1) the travelling and steering drive system with the brake system;

2) the machine levelling system and positioning of the upper carriage slide.

Table 8: Technical Data on the Disposal Machine

Dimensions:		
- Length		9800 mm
- Width		2800 mm
- Heigth with Jib	in Travelling Position	3800 mm
	in Disposal Position	5300 mm
Total Weight (Distributed over all 4 Wheels)		29.7 t
Travelling Speed		0 to 0.5 m/s
Maximum Road Inclination		15 %
Hydraulic Power for Travelling Operation		37 kW
Winch Slewing Range		2 x 30°
Winch Displacement		550 mm
Disposal Winch (Main Winch)		
- Payload		14 kN
- Break-loose Force, maximum		20 kN
- Depth of the Disposal Borehole		300 m
- Transport Speed During Normal Travel (Three-phase Power) and for		0.1 to 2.0 m/s
Fine Positioning and During Failure of Mine Mains (Direct Current)		0 to 0.05 m/s
- Transport Cable Diameter		15 mm
- Calculated Rupturing Force		120.3 kN
- Cable Strands		7 x 1.5 mm²
- Insulation - Peek-Kapton for Limit Temperature		300 °C
- Cable Drum Diameter		1700 mm
- Diameter of Deflection Sheave		1000 mm
Dual Drum Winch for Shielding Bell		
- Payload		20 kN
- Lifting Height		3 m
- Transport Speed		0.025 m/s
Power Supply		
- for Stationary Winch Operation from Mine Mains		3 x 500 V, 50 Hz
- for Travelling Operation (Rechargeable Battery, Rectifier, Battery Charger), DC		160 V
- Control Voltage, DC		24 V
- Grapple Actuation, AC		220 V

The hydraulic pumps are driven (in tandem) by an electric motor.

Travelling Gear

The drive system for vehicle transfer, that is, the travelling gear, has been designed as a so-called closed system with an independent power supply, that is, with its own pump, for reasons of safety. The wheel hub drive units are thus blocked when the hydraulic system is switched off. (For towing the vehicle, short-circuiting is possible.) The velocity of travel is porportional to the hydraulic fluid flow rate. The flow rate is matched to the demand by servocontrolled variation of the pump displacement. The maximum travelling speed is 0.5 m/s (1.8 km/h). It depends on the resistance to travel. Prerequisites for travelling motion release are:

- that the disposal or retrieval operation has been completed,
- that the shielding bell is in the initial position (that is, raised), that the coupling grapple is retracted, and
- that the jib is positioned along the machine axis and has been lowered.

Steering and Brakes

Four possibilities are available for steering (selector switch):

1) Straight forward
2) Steering (front wheel steering only)
3) Turning on location (circular motion)
4) Lateral displacement (side crawling)

The steering system consists of a distribution gear and a metering pump. When the steering wheel is turned, hydrauic fluid flows from the distribution gear through the metering pump to the rotary piston cylinder of the steering units. The metering pump ensures that the fluid volume supplied to the rotary piston cylinders is proportional to the angle of rotation of the steering wheel. Only a connecting system of pipes and hoses is present between the steering wheel and the four adjusting units over the drive wheels.

"Emergency steering" in the event of steering pump fluid flow failure is feasible only with the use of a hand pump after installation of a hose connection to the front steering units.

The steering and braking systems are supplied from the same hydraulic fluid circuit; the braking system thereby receives unrestricted priority. Both systems in turn receive priority over the vehicle level adjustment system, which is also powered by the same pump. Further details of the braking system are beyond the scope of the present discussion.

During vehicle levelling, the travelling gear is disabled. Levelling of the machine is indicated optically (bubble level) and electrically (pendulum inclinometer). The signal, "vehicle aligned" also is a prerequisite for release of the disposal operation. The level is automatically checked between disposal operations.

Superstructures on the Disposal Machine

The frame of the vehicle (that is, of the machine) supports the upper vehicle carriage. The jib slewing gear is accommodated in the upper vehicle carriage and in turn supports the jib as well as the main winch for handling the canisters. The winch for raising and lowering the shielding bell is also mounted on the jib (see Fig. 28).

Height Adjustment for the Jib

The two necessary jib positions (operating position, "raised", and transport position, "lowered") are assumed by means of a spindle lift device. This spindle lift device is situated between the rotary platform and jib. The worm wheel of the transmissin gear serves as spindle nut. The unit is driven by an electric motor. The motor is braked in the current-free condition.

The two jib positions are doubly monitored at the spindle lift device:
- by an inductive proximity switch each, and
- by limit switches.

The motor is switched on only manually and in push-key operation.

Jib Slewing Gear

The jib slewing gear performs two functions:

- Exact positioning of the jib, and of the coupling grapple (and the shielding bell) over the centre of the borehole (displacement of the upper carriage slide in the longitudinal direction of the vehicle also necessary for this purpose), and

- Slewing of the shielding bell out of the way for unimpeded positioning and set-down of the STC.

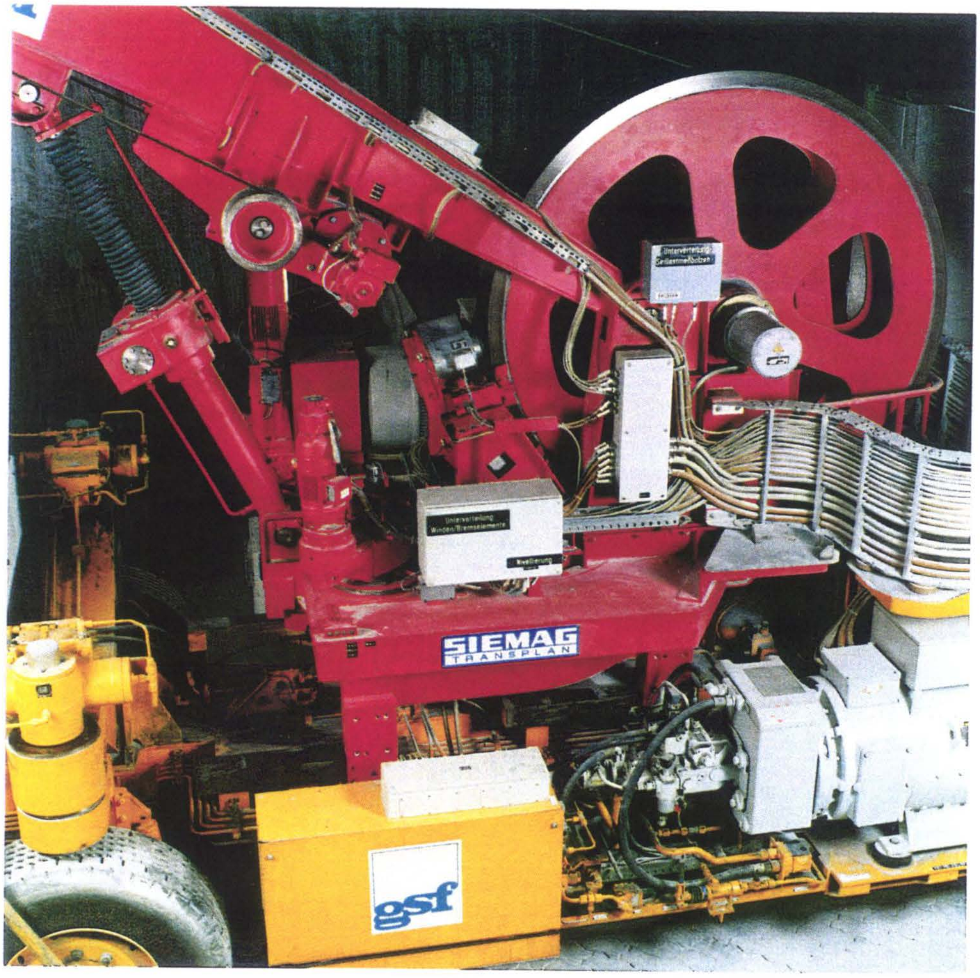


Fig. 28: View of the Jib Height Adjustment Device, Jib Slewing Gear, and Winch System of the Disposal Machine

The slewing gear consists of a standard ball bearing slewing rim with external toothing and geared motor with pinion. The geared motor is equipped with a single-disc spring-loaded brake.

The exact positioning is accomplished by means of a rotational pulse generator on the pinion shaft. (A transmission gear is included for improving the resolution of the pulses.)

For the initial alignment at the borehole and for slewing the shielding bell away, the motor is switched on only manually and by key-press. After slewing away, the position over the borehole is automatically assumed upon command.

Linear Positioning Device for the Upper Carriage Slide

The possible displacement of the upper carriage slide in relation to the vehicle is 550 mm. Positioning is accomplished by means of a hydraulic cylinder between the vehicle frame and upper carriage slide.

Winch System for Disposal and Retrieval Operation

The winch for the disposal and retrievel operations, that is, for handling the grapple system and canisters, consists essentially of the following components:

- cable drum with brake discs,
- transmission gear with two motors for normal operation from the mine mains and at reduced speed from the rechargeable batteries and associated couplings,
- slip ring assembly,
- hoisting cable,
- monitoring devices.

Since the winch system had been designed for disposal in boreholes with a depth of 300 m, multistrand cable was employed; since the cable drum width was only 220 mm, a special guiding of the cable was not necessary.

The seven control conductors in the internal core of the hoisting cable are routed from the cable attachment point on the cable drum to the slip ring assembly flanged to the drum.

The transmission gear drive is attached to the winch drum axle. The direct current motor for operation in case of a mine mains power failure acts by way of an electromagnetic clutch on the B side of the main drive motor. The speed of the main motor is continuously controlled in the range 1:20 by frequency regulation (hoisting speed possible from 2.0 to 0.1 m/s; during test disposal, maximum hoisting speed: 1.0 m/s).

The structure of the hoisting cable is as follows:

A layer of stainless steel wire and an opposed layer of seven-strand stainless steel wire (material number of stainless steel: 1.4301) are stranded around the seven-conductor Peek-Kapton cable (nickel-plated stranded copper leads, 30 x 0.35 mm, sprayed with Peek, standed, bandaged with a Kapton layer, and sprayed with Peek, outside diameter: 7.8 mm).

Outside diameter of cable	15 mm
Service temperature	20 to 200 °C (300 °C for 8 hours)
Nominal load	11000 N (8000 N + cable weight)
Cable safety factor	7.5 at 200 °C

The same type of cable is also employed for canister handling above ground.

The manufacturer (Trefil Arbed, Köln) had determined low-torsion stranding in company-internal test.

The suitability of the cable and suspension clamp have been checked by the Cable Testing Office of the Westfälische Bergwerkskasse in Bochum (WBK).

The following monitoring devices are installed:

- Tachogenerators for rotational speed monitoring
- Centrifugal force switches for overspeeding of the drum
- Rotational pulse generators for measuring the lifting distance

The two flanged discs of the cable drum function as brake discs. Two rodless, electromagnetically lifting brake force generators act on each of the two brake discs. The brake force is generated by buffer washer spring group assemblies. The brake operates both as a service brake and as a safety brake; the particular function depends on the actuation. In the case of safety brake operation, two of the four brake force generators engage after a delay. Monitoring switches are installed on the brake elements for signalizing the brake status ("open" or "closed") and brake lining wear.

The cable deflection sheave is mounted on a load cell bolt at the jib end (in analogy with the crane facility above ground).

An evaluation device in combination with an indicating instrument permits continuous monitoring of the load suspended on the cable; the cable weight, which is no longer negligible with a cable 300 m in length, is always taken into account.

The deflection sheave and load cell bolt are installed in a frame which is supported on the jib by means of two pretensioned compression springs. If a preset force is exceeded (for instance, as a result of grapple obstruction), the springs are compressed, and two safety switches disable the winch drive system.

Winch for the Shielding Bell

As for the crane facility above ground, the shielding bell necessary underground is also suspended on two cables.

The winch for the shielding bell is fastened to the jib of the disposal machine; the two cable drums are located on the right and left of the jib. The low-torsion cables are coiled in a single layer. The cables are routed from the shielding bell over deflection sheaves to the cable drums. The winch is driven by a geared motor with a spring-loaded brake.

The working range of the winch is only about 1 m, but the shielding bell can be lowered to the gallery floor for servicing.

Electrical Installations on the Disposal Machine

Electric power is supplied by means of a cable (four-conductor with earthing conductor) from the 500 V mine mains. The power outlets are permanently installed on the walls of the gallery in the proximity of the area where the machine is employed.

The power system installed on the machine comprises the following:

- the power supply units for generating the auxiliary and supply voltages
  * control and supply voltage 42 V
  * actuation of grapple, DC 220 V
  * instrument terminal voltage 220 V

- the power unit for the winch drive systems
  * pulse converter with control range from 2.5 to 50 Hz for powering the alternating current asynchronous motor of the main winch
    special features:
    · constant torque in all rotational speed ranges
    · 1.5-fold torque for acceleration and deceleration
    · converter with external air cooling

- the power unit for driving the hydraulic system
  * 37 kW direct current series wound motor for driving the pumps; 160 volt operating voltage supplied from a working/charging rectifier; power supplied from rechargeable batteries during relocation or mains shut-down; continual recharging of the batteries from the charger

* in addition to pump motors, voltage supply from the rechargeable battery to both stored programme control systems, the monitors, as well as the E control valves in the event of a power failure

* battery capacity sufficient for travelling 450 to 600 m at a velocity of 0.5 m/s, or for supplying power to the remaining consumers for about 8 hours (without lighting)

- for the three-phase drive motors
  * jib slewing gear and height variation
  * winch for the shielding bell
  * drive systems on borehole slider

Control System

For controlling the disposal and retrieval operations, including actuation of the shielding bell and borehole slider, the disposal machine is equipped with a stored programme control system (SPC). A further SPC is provided for managing all deposited HAW-canisters.

The disposal and retrieval sequence can be monitored on a screen. The necessary operating data and possible fault signals are presented on an additional viewing screen.

Operating Modes

The machine can be controlled in three operating modes:
- automatic mode,
- manual mode,
- interlocked test mode.

In the automatic mode, the disposal operations proceed continuously in succession. If an operating cycle is interrupted, the process is continued at the point of interruption after reactivation.

In the manual mode, each of the individual motion sequences is initiated manually and terminated upon attainment of the final position.

The interlocked test mode is intended essentially for servicing and testing operations. This operating mode can be released only with a key switch. Certain individual steps are not feasible (interlocked), in analogy with the concept already realized with the transfer above ground.

All safety and operational signals and additional status messages are doubly recorded and processed. The safety circuit is a relay system; it is simulated by the stored programme control system and monitored for antivalence.

Visualization

The data stored in the programmable control systems on the operational status of the disposal machine, the disposal and retrieval processes, fault messages, as well as information on the operation of the machine are presented on two colour monitors in the operator's cab of the disposal machine.

Screen 1

- Disposal vehicle, static picture for overall presentation of the disposal machine, the essential equipment and conditions
  * borehole number
  * connections (mine mains, borehole slider, shielding bell, on-site panel for levelling)
  * operating status (jib up or down, shielding bell up, position of slewing gear centre or degree indication, machine levelled)
  * menus for further information (winch system, borehole slider area, upper and lower end range for grapple travel, instructions for operation, and indication of fault messages)

- Winch system, static picture for presentation of all signals and status messages necessary for the winch operation (main winch)
  * unlocked manual mode
  * interlocked manual mode
  * automatic mode
  * disposal or retrieval
  * winch driven by winch motor
  * temperature monitoring of brake elements
  * converter operation
  * winch drive direction

- Borehole slider area, dynamic picture for presentation of variable situations and operating conditions in the area of the borehole slider and shielding bell
  * load status (overload, normal load, slack cable)
  * coupling grapple alone or with canister grapple
  * operating mode (unlocked or interlocked manual mode, automatic mode)
  * disposal or retrieval

* indication of grapple depth and weight from load detection
* position of grapple locking device
* indication of operating status of borehole slider
* Asse TB1 set in position or not
* shielding bell set in position or not
* direction of drive

- Upper end section of borehole (for grapple motion), dynamic picture of the variable situations in the borehole area
  * operating mode (as in preceding)
  * disposal or retrieval (as in preceding)
  * direction of drive (as in preceding)
  * load status (as in preceding)
  * depth indication
  * actual weight on grapple
  * velocity

- Lower end section of borehole (for grapple motion), as for upper end section, and in addition
  * indication of distance to final depth
  * indication of final depth

Screen 2

- Data management for the boreholes

  Borehole data management performed essentially by the second stored programme control system; continuous indication and storage of the following data during the disposal operation (and of course during retrieval, too, for HAW-project) (bubble memory for safe data recording):
  * borehole number
  * borehole assignment
  * canister number
  * canister position (level and location)
  * date and time

  Printer available for hard copy and recording of data (for instance, during malfunctions).

Disposal and Retrieval of Canisters

The components employed underground for disposal and retrieval are shown in Fig. 29.

The prerequisites which must be satisfied for executing the disposal or retrieval operation are as follows:

1. The disposal machine is located at the chosen borehole, the machine is supported and aligned horizontally. The upper carriage and the jib are positioned in such a way that the point of canister descent is exactly coaxial with the borehole (or STC).

2. The machine is electrically connected with the mine power mains and the borehole slider.

3. The operating mode selector is set to the automatic mode.

4. The propulsion of the vehicle, steering system, the upper carriage slide adjustment, and the jib height positioning "up" are locked.

5. The STC is positioned on the borehole slider (switches have responded).

6. The borehole slider is closed and locked.

7. The shielding bell is in the upper end position, and the coupling grapple is in the shielding bell; both elements are situated exactly over the STC, that is, not displaced laterally.

8. All controls indicate "ok".

<u>Disposal Operation</u>

1. The borehole number, canister number, disposal date and time are entered.

2. The coupling grapple is lowered to the canister grapple in the creeping mode; the claws of the canister grapple are thereby opened.
   In the event of "slack cable", the winch motor switches off.

3. The claws of the coupling grapple close, and the canister grapple is coupled.

Fig. 29: Underground Disposal and Retrieval of the Canisters; Components Shown; Gallery Transport Vehicle, Borehole Slider, Single Transport Cask, Asse TB1, Disposal Machine with Shielding Bell; STC Still Handled with the Load Hooking Device

4. The winch moves slowly in the lifting direction until "overload" is indicated. In combination with the position indication in the coupling grapple (plunger for claw actuation at midposition), "overload" signalizes that the grapple is in fact coupled. (The completed coupling process can be observed by the operating personnel present nearby, too.)

5. Moreover, the depth indication and displacement data acquisition are synchronized during the "overload" indication.

6. The shielding bell is set down on the STC (signal from the three proximity initiators at the lower rim of the bell).

7. The canister grapple is disengaged from the lid of the STC.

8. The grapple combination is lowered onto the canister (the claws of the canister grapple are thereby opened) until "slack cable" is indicated.
   This signal and the depth are transmitted for closing the grapple claws (signal for midposition on the grapple plunger).

9. The grapple combination is slowly raised; the weight is thereby determined and controlled as if the canister has in fact been grasped. The winch again travels to "overload". Data synchronization then follows.

10. The tools of the borehole slider are extended and rotated; the locking bolts of the STC are thus engaged and subsequently pulled; the sliding drawer of the STC is thus unlocked.

11. The slide over the borehole is opened, and the sliding drawer of the STC is thus also opened.

12. The canister is lowered into the borehole, first at low speed, and again at low speed (0.05 m/s) shortly before attaining its final position; the normal speed of descent is 2 m/s at greater depth or hoisting height. For the test disposal, the maximum velocity was decreased to 1 m/s. The disposal or final position is always redetermined by the electronic system of the machine in accordance with the filling level, indicated on the monitor, and processed for controlling the final velocity.

13. After indication of "slack cable" (and comparison with the borehole management, that is, checking whether the canister is indeed at the specified position), the claws of the

canister grapple are opened, and the mushroom grip of the canister is released. The winch starts slowly and then accelerates to the maximum speed. The load detection device indicates whether the canister has indeed been released.

14. The borehole position and data on the deposited canister are recorded in the stored programme control system and printed.

15. As soon as the grapple combination has approximately attained the level just below the borehole slider, the hoisting speed is decreased. The grapples slowly move into the STC until "overload" is indicated, and the winch drive system switches off. If the grapple has attained the correct depth, switch-over is initiated.

16. The borehole slider and the drawer of the STC close jointly.

17. The sliding drawer of the STC is locked, and the tools are retracted.

18. The canister grapple is locked with the lid of the STC.

19. The shielding bell is raised.

20. The coupling and canister grapples are separated (winch downward until "slack cable", open grapple claws, winch upward, grapple claws at rest position).

21. The coupling grapple moves into the shielding bell.

22. For allowing the STC to be raised, the jib of the disposal machine (and thus the shielding bell) must be swung to one side.

Retrieval Operation

The retrieval operation proceeds in analogy with the disposal operation. Steps 1 to 7 are identical, and are followed by the sequences of steps 10 and 11. The grapple combination is then lowered into the borehole onto the canister with the appropriate speed control, the canister is grasped, and raised into the STC. All checks are performed analogously. The borehole slider (and thus the sliding drawer of the STC) are then closed, and the drawer is locked.

The canister is now lowered onto the sliding drawer and disengaged there; the grapple then returns to the upper position.

All steps then proceed as described for steps 18, etc.

Experience and Recommendations

The majority of the problems encountered with the disposal machine have been solved in the course of commissioning, and were not of a conceptional nature. Nevertheless, a few items to be observed in future developments deserve mention:

1. The vehicle is easily manoeuvrable. The wheel load of about 7.5 t was also supported by the gallery pavement (steering and propulsion). A rail system is viewed as a serious hindrance to traffic with other vehicles (fork lift, gallery transport vehicle).

2. Because of the high ambient temperature at the disposal level, cooling of heat generators and electronic components is necessary. For this purpose, a central cooling system should be installed in the future for cooling the components in question. Attention must be paid to the possibility of condensation from the mine air. This condensate should be reevaporated immediately. (Water on the gallery floor dissolves the salt granulate under the gallery pavement and can thus damage the pavement). The elevated temperature can also result in failure of insulation. (Hence, cooling must be provided, or appropriate routing of cables must be ensured, in addition to the selection of thermally stable materials.)

3. Batteries for underground operation require extra care.

4. The stored programme control system should be provided with power from separate rechargeable batteries. "High power consumers" such as the propulsion and lighting systems draw heavy current, and the supply to the programmable controllers can fail as a result. (This case actually occurred!)

5. Brief failure of the mine power mains must be bridged with the use of rechargeable batteries.

6. Hydraulic fluid must be filtered, even in a closed circuit. (A high pressure filter with status indication is necessary.)

7. The possibility of load measurement is absolutely necessary for ensuring a specified safety standard and must therefore be included in the planning. (The STC must provide sufficient vertical clearance for suspending the canister with the grapple before or without indicating "overload".)

8. Synchronization must be provided.

9. A means of direct observation by the operating personnel is desirable.

10. "Slack cable" presents problems with a Lebus drum on winches without an automatic winding device.

3.14 Gallery Transport Vehicle

The transport vehicle of type Sirius (Fig. 30) performs two functions by means of onboard hoisting devices:

1. accepting the STC from the hoisting cage and placing it on the borehole slider (and vice versa), and

2. transporting the STC from the shaft to the disposal area and back.

This vehicle is capable of self-loading and -unloading. During the transport, the load is secured against falling. For approval of the vehicle, proofs of stability had to be provided for all possible operating states.

The transport vehicle was ordered from the Herbst Förder- und Hebetechnik GmbH (HFH) in June 1986, and application was filed for design approval in compliance with the requirements of the Supervising Mining Inspectorate in Clausthal. In December 1987, the vehicle was delivered, and approval was granted.

The transport vehicle has been designed with centre pivot steering:

1. The front carriage is equipped with the transport platform for the STC, the clamps for securing the STC during transport, the telescoping crane jib, the operating controls, as well as the driver's cab.

Fig. 30: Gallery Transport Vehicle, Sirius, with Single Transport Cask, Asse TB1

2. The rear carriage is equipped with the complete drive system, with air-cooled diesel motor, hydraulic system, and distribution gear, tanks, batteries, and fire extinguishing system.

Both axles are driven; the rear axle is of a swing axle type. All four wheels are equipped with drum brakes; a hydraulically lifted disc brake serves as parking brake. The vehicle has pneumatic tyres.

The two-stage telesopic crane jib is accommodated on the front carriage. A hydraulically actuated rotating device is suspended on gimbals at the jib head. Winch-type hoisting devices are not employed.

The clamping arms are hydraulically actuated and locked. The travel drive system is released only if the clamping arms are locked.

The fire extinguishing system consists of four cylinders with a capacity of 5.4 l each. Fires in the motor compartment, in the areas of the tanks, hydraulic drive system, and front tyres can thus be fought.

In the following, a brief key-word survey of the hydraulic and electrical systems is presented:

1. Hydrostatic propulsion
   Swash plate regulating pump
   Axial piston motor
   Forward and reverse drive by reversing of oil flow

2. Hydrostatic steering
   Power steering with power assist and emergency steering capabilities
   Oil supply with separate axial piston pump

3. Hydrostatic crane drive system
   Supply by means of axial piston pump, also for steering system, priority of steering at the expense of crane drive
   Tilting cylinder for vertical slewing
   Two cylinders for telescoping
   Rotating motor at end of crane jib
   Clamp actuation and locking

4. Gear pump for horizontal slewing and brake actuation
   Horizontal slewing of the crane jib by sensitive adjustment of the centre pivot steering system
   Dual-circuit service brake, single circuit parking brake with diaphragm accumulator
   Braking force of parking brake from spring actuator, hydraulic lifting
   (Hand pump in case of brake system failure, for instance, for towing of the vehicle)

5. Gear pump for separate cooling circuit

6. Electrical system
   Voltage: 24 V
   Function of crane system and vehicle propulsion system mutually interlocked (bridging with key operated switch)
   Cable remote control with all possibilities of manipulating the crane jib and the transport security system

7. Vertical hoisting control and operating principle

   During raising and lowering of the telescopic jib, the end of the jib describes a circular path. If the telescoping device fails to follow accordingly, the horizontal position of the load is altered.

   The vertical hoisting control system ensures that this horizontal motion is compensated by telescoping action (normal control). The vertical hoisting control system can be deactivated.

   In correspondence with the inclination of the telescopic jib with respect to the vertical, a set value is calculated for the telescoping action in conjunction with the instantaneous value of the telescopic extension upon further raising or lowering of the telescopic jib, and the extension is varied until the set value has been attained.

   Since the inclination with respect to the vertical is measured, the control system also operates when the vehicle is in a tilted position (permissible slope of the road: $\pm$ 5 degrees).

The technical data are presented in Table 9.

Operation

Travel: Travel is possible only if the telescopic jib is in the transport position, the cask clamps are closed and locked, and the manual control console is inserted in the holder (with the exception of bridging with key operated switch). Two speeds can be selected.

Braking: In the creep mode, the travel speed can be decreased to "0", independently of the engine speed. Braking is normally initiated by pressing a pedal (service brake), or pushing a lever (parking brake), or both.

Accepting or depositing a load:

Prerequisites:

The vehicle is brought to a favourable position;

the parking brake is actuated (the load clamps and the crane jib are thus released).

Table 9: Technical Data on the Sirius Transport Vehicle

Dimensions	
Length	8050 mm
Width	2750 mm
Height (Transport)	2575 mm
Height (Crane Jib, Maximum)	~5200 mm
Speeds	
Travel Speed I	0 to 6.2 km/h
Speed II	~ 15.0 km/h
Load Rotation	0.5 min^{-1} (formerly 1 min^{-1})
Raising, Lowering	1.5 m/min
Telescoping	4.0 m/min
Weights	
Dead Weight	31 190 kg
Permissible Overall Weight	41 190 kg

Axial Loads [kg]

	Travel		Crane Operation
	Empty	Loaded	
Front Axle	12 390	24 890	40 000
Rear Axle	18 800	16 300	1 190

Motor Power	132 kW
Maximum Permissible Slope	20 %
Turning Radius, Inside/Outside	4.5 m/7.6 m

Load handling:

The vertical hoisting control system is normally employed for load handling.

From the transport position (telescopic jib completely retracted and lowered), the telescopic jib is first raised and then moved until positioned over the load, and the load is then hooked.

After accepting the load from the hoisting cage or borehole slider and placing of the load on the platform, the cask clamps are closed and locked.

The vehicle can travel only if the telescopic jib has been completely retracted and lowered.

The load can be accepted and deposited with the use of the portable control console. Because of better observability, the control console is normally employed.

Experience and Recommendations

1. The rotary motion for the load hooking devices is initiated hydraulically. No element was provided for preventing slipping of the load in the event of excessively high acceleration or deceleration; furthermore, no elastic element was present. Consequently, the load hooking device originally installed was subjected to such high inertial forces during rotation of the load (at 1 min^{-1}) that

   a) the load hooking device failed, and
   b) further use of the device was not permissible.

   The three-strand chain suspension employed instead reacts less sensitively to stress of this kind. Nevertheless, the speed of the rotary motion (and thus the acceleration) was decreased.

   For new developments, positive transmission ("overload release clutch") or an elastic element (a long cable such as that on the crane of the transfer facility above ground) should always be provided, or components with a corresponding effect should be included in the hydraulic system.

2. Horizontal supporting surfaces must be demanded for the STC on the gallery floor or borehole slider as well as on the loading platform of the vehicle. Otherwise, the load suspended vertically on the hoisting device tilts when being set down, or must first be aligned upright. This results in nonuniform stress on the load hooking points, and must be appropriately taken into account both in designing and during operation. The elasticity of the tyres must also be taken into consideration.

In view of the considerations just mentioned, any attempt to load or unload the vehicle when it is in an inclined position in also illusory. At least the situations just indicated can be expected.

3. The hoisting height has already been discussed in conjunction with the shaft hoisting facility (section 3.7).

4. The cable connection between the vehicle and manual control device may present problems (tripping hazard, danger that the vehicle itself runs over the cable and thus severs it).

5. The service life and maintenance of the starter battery are important.

6. Improved silencing of the motor and/or a quieter motor are desirable.

3.15 Use of Fork Lifts Underground

Two existing fork lifts are employed within the scope of the HAW test disposal underground:

- a 15 t fork lift with crane jib (load bearing capacity: 10 t) for transfer of the borehole slider and the supplementary shielding of the borehole slider (fork lift II);

- a 2 t electric fork lift for smaller loads (fork lift III).

Experience

No problems were encountered during operation. Only the following is worthy of mention:

1. The effect of tyre elasticity and the associated horizontal displacement of the hook occurred during load acceptance (and, of course, deposition) with the 15 t fork lift, too. This undesirable effect was kept within tolerable limits by careful actuation of the fork lift (slight inclination of the mast).

2. The gallery floor must be level; the space requirement for manoeuvring is quite high.

3. Because of the visual hindrance by the mast, a second person is necessary for providing instruction and for hooking.

3.16 Load Hooking Devices

Special load hooking devices are employed at diverse locations:

- crane crosshead for handling the MTC (see section 3.11),
- three-strand chain suspension for handling the STC (after failure of the load hooking device, see section 3.2)
  - for the 10 t winch of the crane facility above ground
  - for the fork lift above ground
  - for the gallery transport vehicle,
- three-strand chain suspension on the 15 to fork lift underground for transferring the borehole slider and the supplementary shielding,
- belts and cables for handling the so-called dummy canisters and the STC insert basket.

In fact, problems resulted only from the failure to consider load hooking devices during the designing phase in most cases, and the long delay in procurement.

Experience and Recommendations

1. The experts do not like chains.
2. Especially with long chains, there is a hazard of twisting and thus being damaged when subjected to load.
3. Chains must be inspected for damage at least at three-year intervals (checking for surface cracks)

4 Experience During Cold Testing

In section 3 the experience gained with the components has already been discussed.

In this section the experience gained during disposal and - since this is important specifically for the approval at the Asse mine - especially retrieval, commissioning (performed from June to August 1990), approval by the mining authorities and TÜV/Hannover, and the later training runs (as of December 1991) is discussed.

In addition the experience gained with the organization of the disposal and retrieval, as well as the implemented shielding measures is described.

4.1 Disposal and Retrieval

The applicability of the components in conformance with specifications, that is, the completion of all adjusting operations, for instance, was assumed as a condition for commissioning. However, this was not always the case. A few problems which occurred may be attributed to the installation, the adjustment, and the functional test, and are therefore described in section 3 if appropriate.

In section 2 it was pointed out that the approval authority demanded the guaranteed possibility of retrieving all thirty radiation sources within 72 hours. Plausible events affecting the retrieval within this period include, for instance,

- flooding of the mine, or
- failure of the borehole liner, or both.

Hence, the retrieval and removal of the canisters were planned and organized with special care. The entire sequence of "fast retrieval" ("emergency retrieval") was planned in great detail; the total and detailed time requirements were determined, and the sequence was examined (see Table 10).

As expert for the Mining Authority, TÜV/Hannover determined about 45 hours for the removal of all thirty radiation sources. This duration of 45 hours determined by TÜV corresponds with the status in May 1991 and is a conservative value determined with the use of highly simplified assumptions.

Table 10: Sequential Schedule for the Retrieval of all Thirty Canisters with Indication of Time Requirement

a) STC "A" and "B" in shuttle operation: crossing point of the two STC always above ground in front of the shaft
b) All MTC empty on the carriage in the shaft hall, beginning with MTC number 1
c) Numerical data: duration in minutes, time-determining path emphasized in boldface

Above Ground			Shaft Transport (S.T.) <---- a, b ---->	Underground		
				L 1	: Removal GMS, immediately subsequently time for removal of next GMS	**65**
				L 2.1	: Prepare borehole (set borehole slider in place)	**50**
				L 2.2	: Position disposal machine (duration can be shortened if parallel with L 1 and L 2.1)	**30**
-	: Set STC "A" on heavy-duty trailer	5		L 3	: Pull borehole plug	**45**
K	: Prepare empty MTC (no. 1) for transfer	40		L 4	: Retrieve dummy canister	**19**
O1 - O5	: Transport empty STC to shaft	2		N 1	: Retrieve first canister (in STC "B")	**14**
				N 2.1 - N 2.9	: Gallery transport of full STC and shaft transport to surface	**19**
			S.T. 1 a (<----)			
N 2.11 - N 2.14	: Full STC from cage	**11**		-	Wait!	**11**
O6 - O11	: Empty STC onto cage					
			S.T. 1 b (---->)			
N 2.15 - N 2.18	: Transport full STC	6		O10 - O13	: Shaft transport underground, and gallery transport	**17**
N 3	: Transfer first canister	35 (43)		N 1	: Retrieve second canister (in STC "A")	**14**
O1 - O5	: See above	2				
	Buffer: 7 min.			N 2.1 - N 2.9	: See above	**19**
			S.T. 2 a (<----)			

3 x 11	For third and fourth canister **2 x 50**
	Wait three times 3 x 11
	Σ 436 minutes

continued next page

Table 10 continued

							Subtotal : 436 minutes
			S.T. 4 b →				
				O10 - O13	: See above	17	
				N 1	: Retrieve fifth canister	14	
					Subsequently 47 min for transfer of disposal machine		
					Previously, there was sufficient time for preparation of next borehole (second borehole slider)		
				N 2.1 - N 2.9	: Gallery transport of full STC and shaft transport to surface	19	
			← S.T. 5 a				
N 2.11 - N 2.14	: See above	11		-	Wait!	11	47
O6 - O11	: See above						
			S.T. 5 b →				
				O10 - O13	: See above	17	
N 2.15 - N 2.18	: See above	6		L 3	: Pull second borehole plug	45	64
N 3	: Transfer fifth canister	35		L 4	: Retrieve second dummy canister (in STC "A")	19	
P	: Close full MTC (no. 1) and transport away	29		N 1	: Retrieve sixth canister	14	
	Simultaneously, there is sufficient time for transporting empty STC "B" to the shaft (after O1 to O5) Duration: 7 minutes			N 2.1 - N 2.9	: Gallery transport of last full STC and shaft transport to surface	19	
K	: Prepare empty MTC (no. 2) for transfer	40	← S.T. 6 a				
	Canisters no. 6 to no. 29 (Handling of STC in shaft hall)	24 x 11			4 x L3 and L4	4 x 64	
					Canisters no. 7 to no. 29	23 x 50	
					Wait 24 times	24 x 11	
			S.T. 29 b →				
				O10 - O13	: See above	17	
N 2.11 - N 2.14	: Full STC from cage	6		N 1	: Retrieve 30th canister	14	
N 3	: Transfer 29th canister The empty STC is no longer necessary; it is placed on the floor of the transfer hall (instead of step N 3.28). After step N 3.31, lashing is no longer necessary.	35		N 2.1 - N 2.9	: Gallery transport of last full STC and shaft transport to surface	19	
			← S.T. 30 a				Σ 2331 minutes
N 2.11 - N 2.14	: Last full STC from cage						
N 2.15 - N 2.18	: Transport full STC	11			*End of operations underground after about 39 hours!*		
N 3	: Transfer 30th canister	35			The personnel leaves the mine.		
P	: Close full MTC (no. 6) and transport away	29					
	Σ 2406 minutes						
	End of operations after about 40 hours!						

From Table 10 it is obvious that a duration of about 39 hours can be expected under favourable assumptions. Both values (39 and 45 hours) are far below the given value of 72 hours.

The organization of the disposal and retrieval sequences is described in an instruction. The individual operating steps are specified obligatorily. In two flow charts these steps are summarized to logical operational blocks and then assigned to the responsible personnel (GSF, 1992), (Figures 31 and 32).

The operating steps were rehearsed at three-month intervals (for the last time in September 1992) in training runs under conditions as realistic as possible. Training runs were conducted in December 1991, March, June, and September 1992.

The personnel is assigned as follows for disposal and retrieval.

P1 One person is responsible for the transport of the STC with the Unimog and heavy-duty trailer, as well as providing assistance (for instance, marshalling).

P2 One person is responsible for the transport of the MTC, transfer of the STC with fork lift I to or from the hoisting cage, and for providing assistance (for instance, marshalling).

P3 One person operates the mobile crane during transfer of the MTC from the railway cars to the carriages and back again. This person is assigned by an external company.

P4 One person moves the carriages with the railway gang vehicle, and the railway cars with the locomotive.

P5 One person controls the transfer of the canisters in the transfer hall.

P6 One person operates fork lifts II and III and provides assistance.

P7 One person is responsible for transporting the STC on the 800 m level with the gallery transport vehicle and provides assistance.

P8 One person operates the disposal machine with the borehole slider.

P9 Two persons install and remove the gap measuring system (GMS), operate fork lift III, and provide assistance in positioning the disposal machine.

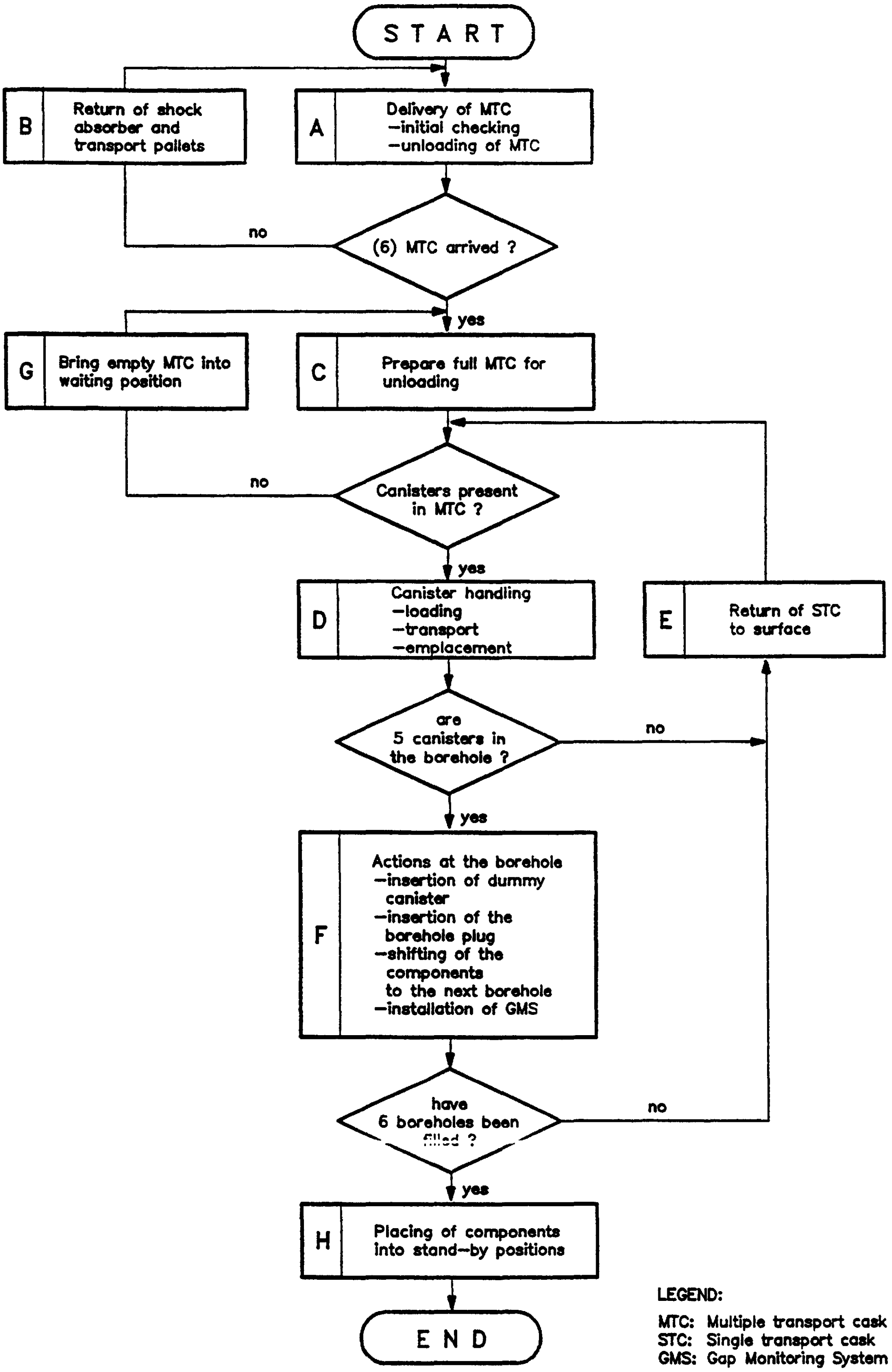


Fig. 31: Flow Chart for Disposal Sequence (GSF, 1992)

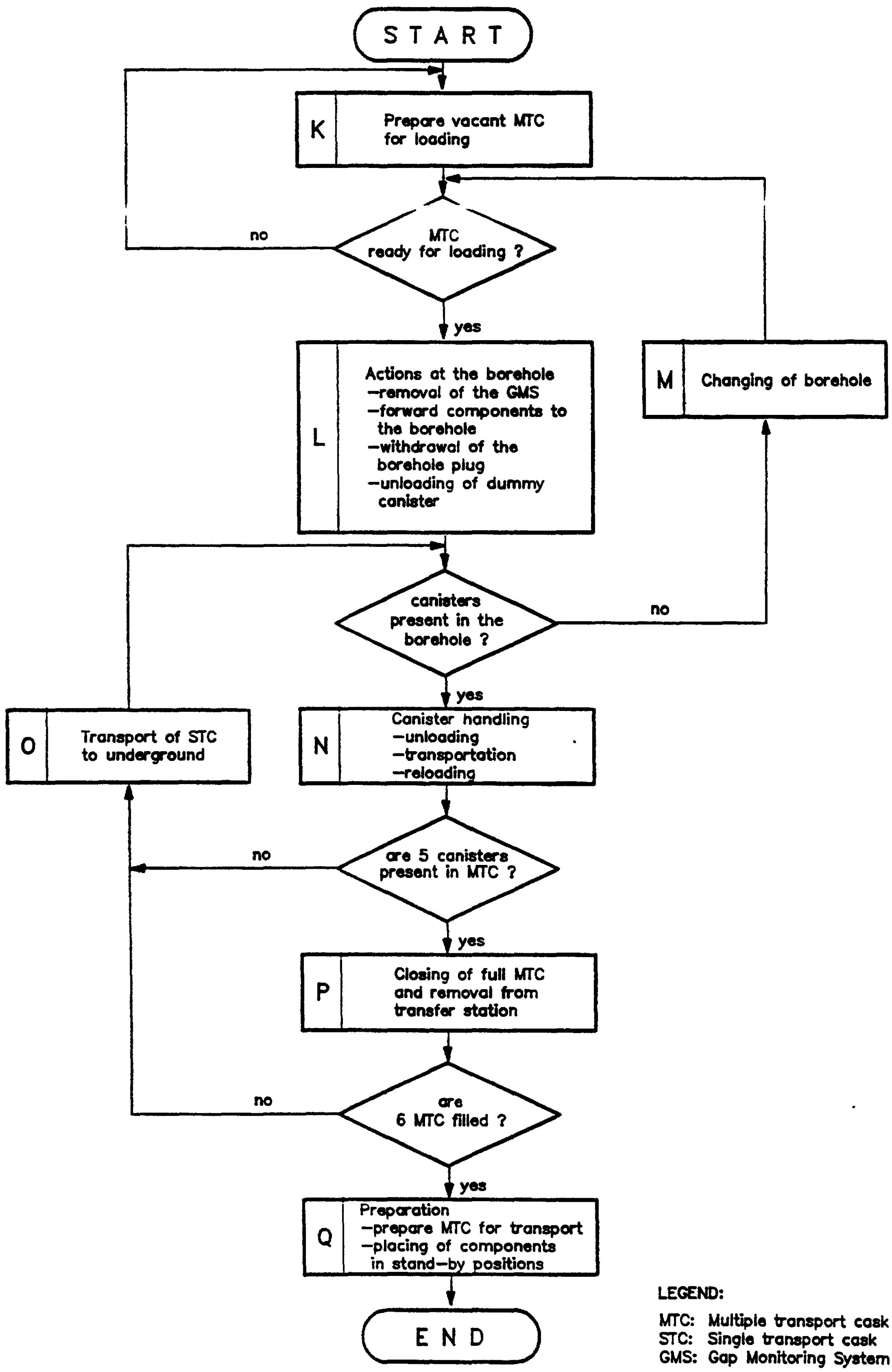


Fig. 32: Flow Chart for Retrieval Sequence (GSF, 1992)

TO Technical supervisor above ground: One person assumes the task of recording and checking the disposal or retrieval sequence as well as the ancillary activities above ground.

TU Technical supervisor underground: One person assumes the task of recording and checking the disposal or retrieval sequence as well as the ancillary activities underground.

Moreover, one banks man each, that is, a person responsible for the activities at the hoisting cage, is assigned above ground and underground; further personnel are the hoisting machinist, the operational radiation protection personnel (radiation protection officer and measuring personnel), as well as the project manager.

As already mentioned, so-called fast retrieval was of special interest to the approval authority. The sequence in which the boreholes are to be emptied should be specified in accordance with the respective situation. Fast retrieval differs from normal retrieval only by the assignment of two operating teams. The requirement on the duration of retrieval can thus be satisfied.

The starting prerequisites have been defined for clearly describing the disposal sequence. Of course, the activities for setting up the components in the condition described in conjunction with the starting prerequisites are time-consuming and must be well organized. An important requirement is that all components, equipment, and personnel be available and kept on stand-by. The assigned personnel are familiar with the activities for start preparation and work independently without supervision.

If an instruction for fast retrieval of all thirty radiation sources is issued, time must be allowed for the arrival of the personnel, changing of clothes, and transport to the components (important for the personnel assigned underground). For this purpose, 2 to 4 hours can be allowed. All starting prerequisites are fulfilled in a further hour.

The flow chart for the retrieval sequence (Fig. 32) indicates diagrammatically the sequence and loops which are executed in accordance with the answers to the yes/no questions. The survey (Table 10) indicates the time requirement for the individual steps, which partly proceed in parallel, the use of the two STC and the two borehole sliders, and begins with the removal of the gap measuring system (GMS) and the transfer of the components. The designations (such as 01 - 05) provide a reference to the instructions in (GSF, 1992). They are meaningless if the instructions are not known exactly. The use of the STC in shuttle operation has been specified; that is, for pulling the borehole plug, the STC intended for the purpose must be converted twice, among other items.

4.2 Radiological Check

Enclosed radioactive sources must be handled and stored in such a way that the limiting values of the dose rate to man shall not be exceeded, in conformance with § 49 StrlSchV for personnel occupationally exposed to radiation, § 51 StrlSchV for other persons in operational surveillance or control fields, and § 44 StrlSchV for external surveillance fields. Of course, the minimization requirement is applicable here, too.

On the one hand, this objective is achieved by the radiological design of the transport casks in the course of the approval procedure for type B(U) packages. With the awarding of the appropriate certificates and approvals, the requirement resulting from transport regulations can be viewed as satisfied.

Furthermore, since long-term storage of the radiation sources other than those in the boreholes is not regarded as necessary or desirable, corresponding proofs were not necessary. Associated considerations were not continued further. Instead, application was filed for temporary storage of the radiation sources in the Fuel Element Repository (BLG) at Gorleben after completion of the tests, and the appropriate proofs were submitted. With the decision not to begin the test at all, no further basis existed for such an application. It was formally cancelled in the summer of 1993. Chargeable test results did not yet exist at that time.

The components and parts thereof which perform a shielding function during handling of the sources have been designed for adequate attenuation of the radiation field. For this purpose, the local dose rates were calculated for points under consideration regarded as critical, and compared with the limit values.

The ultimately applicable, calculated values of the local dose rates were submitted to the responsible authority with the application for approval of the test in compliance with § 9 AtG, and subsequently examined by the expert from the approval authority. Adequate radiation protection for the test disposal of the thirty radiation sources is attested in the expertise, with due consideration of a few reservations.

Since it was evident on various occasions that

- significant points under consideration possibly had not been considered at all radiologically, and

- an analytical determination of the radiation field attenuation is not possible with a few complicated types of geometry,

the shielding was also checked by measurements.

The initial radiation penetration tests with a weak source indicated that stronger sources must be employed for obtaining results capable of interpretation.

Weaknesses were revealed by a preliminary experimental check on the shielding of the transfer station above ground with the use of a 100 Ci Co^{60} source. After elimination of the deficiencies by supplementary shielding, the transfer facilities above ground and underground were reexamined with a Co^{60} source. This examination was conducted in May 1993. The results have been compiled in a separate report (not to be published).

The conversion with supplementary shielding proved successful. By means of administrative measures (shorter residence time for persons in critical areas, for instance), the dose rates for the operating personnel can be kept so low that no objections exist from a radiation protection standpoint for execution in conformance with specifications.

5 Conclusions and Recommendations

The development and availability of the handling system for the HAW test canisters with the aim of performing the in situ test has been completed. The fact that this system was not applied in operation as intended is very unfortunate. Hence, the "acid test" still has not been performed. Nevertheless, valuable experience has been gained. This report is an attempt to document this experience.

The recommendations already formulated in various sections of this report are again summarized globally here:

1) Preparation of the general conditions

1.1) The compilation of a specific set of regulations is highly recommended for specifying the dimensioning, construction, quality assurance, and approval of components, to mention a few examples. A possible prototype is the already mentioned "Guideline for hoisting devices for handling radioactive packages at the Asse mine", for instance. When reference is made to known rules, they should be studied very carefully beforehand. Wording such as "in analogy with KTA-xyz" is not very useful. The problems are associated with the details.

1.2) For planning a final repository, the value of the permissible local dose rate at selected points is important. This matter is not as trivial as it sounds.

For a routine operation, the shielding specified by transport regulations is not sufficient. Moreover, the presence of several loaded casks in the proximity of the personnel concerned with the disposal of canisters in the repository must be taken into consideration. The extent to which reflected and scattered radiation effects can at present be estimated is not yet clear.

Above ground, the dose rate at the fence of the plant is important and also affects the component dimensioning and logistics.

1.3) A vital question is whether the canister mantle can be regarded as a tight enclosure. A repetition of the leak tight test is most probably impossible. This affects the barrier principle (two lids, metal or elastomer seals, monitoring of transport cask sealing, if sealing in compliance with the requirements for BLG is demanded, etc.). On the other hand, it must be determined whether a certificate for leak tightness is necessary for disposal of canisters and whether the tightness must be granted during the disposal procedure.

1.4) Because of the actinide content, application must be filed for approval of disposal in compliance with § 6 AtG. Moreover, law of mines (UVV, approval of operating schedule), transport regulations (type B(U) packages), possibly specifications applicable to an intermediate repository, and finally also IAEA regulations must be observed.

2) For company-internal transport casks, no application should be filed for type B(U) approval. For this purpose, too, the creation of internally applicable codes of practive is recommended. Individual specifications can and should then be derived from the GGVS, for instance, dropping tests, perhaps fire testing, but not the yield limits on materials at unrealistic temperatures as demanded by transport regulations. (A cask loaded with HAW will never be exposed to a temperature of -40 °C in Germany.) However, considerations concerning the corrosion properties are far more important; this also includes the maintenance of the casks during operation under alternating conditions both above ground and in a salt dust environment underground (above ground absorption of moisture by the adhering salt dust!).

3) In a final repository, an appropriately equipped hot cell facility must be available. A transfer station is suited only for accepting certain specific types of casks. A universally applicable transfer facility is feasible only in a hot cell. This has also been confirmed by the experience gained with the transfer station at the surface for HAW test disposal.

4) Disposal underground is essentially a transfer from one container to another. One container is the transport cask, and the other is a very long or high container (the borehole).

A possible solution may be developed from the ideas on which a GNS patent is based (Baatz et al., 1990) for a disposal facility applicable underground in the future.

The experience gained with the underground system (disposal machine, STC of type Asse TB1, and borehole slider) and the transfer facility above ground can be employed for this purpose.

The following would be of advantage:

a) Disposal could proceed directly from normal transport casks without a problematic bottom slider. Even direct disposal out of a MTC is imaginable.

b) Transfer casks with bottom sliders present problems with respect to shielding against n radiation during transfer of canisters.

c) It is possible that no transfer of canisters is not necessary at all above ground of the final repository site, especially if MTC are employed.

d) The "tight enclosure" could be ensured by the transport cask and its lid system all the way to the final disposal site.

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EUR 16554 — The HAW project: Test disposal of highly radioactive radiation sources in the Asse salt mine Documentation and appraisal of the disposal system

K. Müller, T. Rothfuchs

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The primary objective of the HAW project was to investigate the interaction of high-level radioactive waste canisters with the final repository medium, rock salt. A further major objective of the research project was the prototype development and trial of a technical system for the disposal of highly radioactive canisters in deep disposal boreholes.

The disposal system encompasses all components which are necessary for safe handling of canisters. Moreover, technical-organizational measures were developed for the execution of the emplacement and retrieval.

In the present report the components of the final disposal system are described; their position and function within the overall handling sequence are explained. Special emphasis is placed on questions of radiation protection and accident prevention, on functional and operational safety, on quality assurance and examination of documents, materials, preparation, and function, and on documentation.

As far as planning of the disposal technique for a final repository mine is concerned, the experience gained from the development and operation is recorded in this report, and recommendations are made for further developments. Problems which occured during work on the HAW project were due partially to test-specific causes and will not occur in this manner, or at all, in a final repository mine.

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