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Deliverable 1 of Module 2
Work Package 1
Input Data and Functional Requirements

Waste Canister Transfer & Emplacement Technology)

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Summary

The integrated project ESDRED (Engineering Studies and Demonstration of Repository Designs) is a joint research project within the 6th Framework Programme of EURATOM. The overall aim within a 5 years programme is to demonstrate the technical feasibility at an industrial scale of a number of specific technologies related to the construction, operation and closure of a deep geological repository for spent fuel and long-lived radioactive waste.

The ESDRED programme consists of four technical Modules

- Module # 1: Buffer construction technology,
- Module # 2: Waste canister transfer and emplacement technology,
- Module # 3: Heavy load emplacement technology,
- Module # 4: Low ph cements for sealing plug construction and for rock reinforcement.

DBE TECHNOLOGY GmbH is responsible for the successful management of Module # 2: Waste canister transfer and emplacement technology. The contracting partners in Module # 2 are ANDRA (France), DBE TECHNOLOGY (Germany) and NRG (Netherlands).

The detailed objectives of this Module are:

- Identification of a clear set of shielding cask requirements based on European nuclear regulations and safety objectives of the implementers,

- Demonstration of the technical feasibility at an industrial scale of the transportation and emplacement of remote handled waste canisters in horizontal cells and vertical boreholes,

- Demonstration of the compliance of the development equipment with reversibility requirements.

This report summarises the input data and the functional requirements, which have been elaborated for Module # 2.

According to some of the national waste management programmes, the feasibility of a reliable and safe transportation/emplacement technology for remote handled waste canisters has to be developed and demonstrated prior to repository implementation. Module # 2 considers the emplacement of small canisters for vitrified waste and small canisters for spent fuel in specially prepared horizontal emplacement cells (French case) or into deep vertical boreholes (German case).

The report starts with a brief description of the German and French repository concepts for high level waste.

In Germany a salt dome close to the village of Gorleben, in the federal state of Lower-Saxony, is being evaluated as to its suitability to host all kinds of radioactive waste. A reference emplacement concept has been developed in the past, which consists of the emplacement of spent fuel elements in shielded POLLUX casks in horizontal drifts (cells). The appropriate transport and emplacement components have been developed and tested on surface in a 1:1 scale. The cask and a pilot conditioning plant have been realized. In comparison, the newly studied concept of canister (containing fuel rods from spent fuel assemblies) disposal in deep vertical boreholes is still lagging behind, development wise.

As an alternative to the disposal of POLLUX® casks in horizontal drifts, another concept has been examined on the basis of safety/technical and economic optimization for vertical disposal of canisters in salt, through the disposal in a common borehole of the following type of canisters:

- complete fuel rods from spent fuel assemblies,
- vitrified high level wastes from reprocessing, and
- compressed interim level wastes (cut cladding and structural parts arising from reprocessing),

These 3 types of waste packages considered have identical outer diameters and grapple heads, but different lengths, depending on the types of waste to be disposed of.

In France a repository concept for the emplacement of high level waste in argillites is subject of conceptual studies and underground research activities. The repository concept considers three main parts:

- The surface installations which cover an area between 500 and 1000 ha,
- The works connecting the surface with the underground which provide access to the underground facilities,
- The underground installations, located 485m below surface, which cover an area of between 1500 and 3000 ha.

The connection between the surface and the underground is provided by 4 large diameter shafts (8 to 12 m) and one ramp. The waste canisters will be disposed of in horizontal emplacement cells, which have been equipped in advance with a steel tube (also called inner sleeve), surrounded or not by prefabricated buffer rings. The disposal package (canister) is transferred underground, inside a metal radiation shielding cask via a waste shaft and horizontal drifts to the disposal zone.

The waste packages are specific to the national emplacement concepts.

In Germany the development of a new, relatively thin walled cask (Fuel Rod Canister BSK 3) – suitable for the interim storage and final disposal of spent fuel assemblies in vertical boreholes – was carried out by GNB. This canister has been designed for receiving fuel rods from a maximum of 3 PWR or 9 BWR fuel assemblies. The interim storage of the BSK 3 takes place in transport and storage casks. Details of the canister layout criteria and design specifications are provided.

In France the primary waste packages consist of a metal or concrete container that holds the radioactive waste. There are many different containers depending on the nature of the waste held within. These primary waste packages are transported by road and/or rail from the production centers to the repository. Road casks are used for this transport.

Upon arrival at the repository the waste packages are removed from the transport casks and "overpacked" into disposal canisters. A disposal package (a canister) essentially consists of a concrete or metal envelope that holds one or more primary packages of the same type. Two types of waste packages (CU for Spent Fuel and C for vitrified waste) are considered and described in detail in the present report. Details of the canister layout criteria and design specifications are also provided.

The report continues by describing the state of the art in drilling technology / tunnel boring technology and provides an appreciation of the room needed for vertical borehole / horizontal cell waste canister emplacement. In addition, the state of the art in disposing of waste canisters in horizontal cells and vertical boreholes has been analysed and the results are presented. Finally the emplacement concepts which have been selected for further investigations are briefly described.

The report ends with a section on the methodology for deriving functional requirements. The methodological approach to developing a set of functional requirements is described. This approach has been applied for the two emplacement concepts which are the subject of demonstration tests. Consequently the applicable norms and technical rules were derived and the safety requirements for the entire system were compiled. Finally the boundary conditions as well as the external requirements and constraints / interfaces between external and internal equipment were defined.

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1 Introduction

The integrated project ESDRED (Engineering Studies and Demonstration of Repository Designs) is a joint research project within the 6th Framework Programme of EURATOM. The 13 Partners from nine countries represent the major European waste management agencies (or subsidiaries of agencies) and appropriate research organisations.

The overall aim within a 5 years programme is to demonstrate the technical feasibility at an industrial scale of a number of specific technologies related to the construction, operation and closure of a deep geological repository for spent fuel and long-lived radioactive waste. The technologies to be developed have to be in compliance with requirements on operational safety, retrievability, long-term safety and monitoring.

The national waste management concepts considering different host rock formations and various types of waste packages are the fundamentals for the development of a common European view on the main issues related to the disposal of radioactive waste. Thus, the ESDRED project provides the opportunity to share the different approaches and to cooperate effectively to generate common technological solutions.

The ESDRED programme consists of four technical Modules:

- Module # 1: Buffer construction technology,
- Module # 2: Waste canister transfer and emplacement technology,
- Module # 3: Heavy load emplacement technology,
- Module # 4: Temporary sealing,

and also of three functional Modules:

- Module # 5: Training and communication activities,
- Module # 6: Integrating of project activities,
- Module # 7: Management of project.

DBE TECHNOLOGY GmbH is responsible for the successful management of Module # 2: Waste canister transfer and emplacement technology. The contracting partners in Module # 2 are:

- ANDRA (France),
- DBE TECHNOLOGY GmbH (Germany),
- NRG (The Netherlands).

The present report describes the input data and the functional requirements for Module # 2.

2 Objective and scope

According to some of the national waste management programmes, the feasibility of a reliable and safe transportation and emplacement system for remote handled waste canisters has to be developed and demonstrated. Whilst the implementation technology for heavy waste canisters into horizontal drifts (Contact handled German POL-LUX®-Cask concept) and short vertical boreholes (Swedish KBS3-V concept) has been successfully demonstrated at an industrial scale, so far the emplacement technology for remote handled small canisters (for spent fuel and vitrified waste) is still pending. The ESDRED project considers the emplacement of small canisters in specially prepared horizontal disposal cells or into deep vertical disposal boreholes.

The common interest of the participating organisations is to develop, manufacture and demonstrate appropriate shielding transportation casks and emplacement technologies matching the European nuclear regulations as well as the specific nuclear safety objectives of the implementers. The development of this technology will also address the retrievability issues. The waste canisters of concern will have diameters from 40 to 60 cm, lengths from 1.3 to 4.9 meters and weights up to 8.3 t.

Module # 2 addresses the handling cycle of two types of waste canisters:

- vitrified waste canister,
- spent fuel canister.

The detailed objectives are:

- Identification of a clear set of shielding cask requirements based on European nuclear regulations and safety objectives of the implementers,

- Demonstration of the technical feasibility at an industrial scale of the transportation and emplacement of remote handled waste canisters in horizontal drift and vertical borehole,

- Demonstration of the compliance of the development equipment with reversibility requirements.

The engineering process of this technical Module is developed in a very classical plan for applied research, i.e.:

Collecting input data, defining functional requirements, elaborating basic and conceptual designs (and formulations), building and testing at full scale a prototype and evaluating the performance of the concept.

Accordingly Module # 2 is divided into seven work packages:

WP1: Input data and functional requirements
WP2: Conceptual design
WP3: Basic design
WP4: Retrievability desk study
WP5: Detailed design
WP6: Full scale demonstration
WP7: Evaluation and final report

The following sections of the report summarize the results of WP1.

3 Brief description of the German repository concept for disposal of spent fuel

The salt dome near the village of Gorleben, in Lower Saxony, is being evaluated since 1979 as to its suitability to host a repository for all kinds of radioactive waste. The site exploration is aimed at furnishing the body of data and information needed on the one hand to prove the site suitability and on the other hand to support the later licensing procedure.

The geological setting, the gross structure of the dome, how it is embedded in the adjacent geology as well as the hydrogeological situation of the overburden were carefully evaluated during an extensive geological and hydrogeological surface exploration programme. The information obtained confirmed that the Gorleben dome spans from 260 m below the surface down to a depth of 3500 m, is about 15 km long and some 2 to 4 km wide at a depth of 800 to 1000 m (Figure 3-1).

The results of the surface survey supported the presumption of suitability of the dome to host a repository. Therefore, underground survey was started in 1983 to obtain additional data and information about the dome’s geological structure and to confirm the existence of homogenous rock salt volumes with sufficient extension for the waste disposal areas. At first two shafts were sunk in the central part of the dome and in 1996 these were connected by a drift at the exploration level of 870 m below ground. The drifts and chambers for the infrastructure of the exploration level are almost completely excavated.

In 1998, excavation of the survey areas at the northeast of the shafts was started. Concurrently, an extensive geo-scientific survey programme was being carried out, making wide use of cored drillings and non-destructive survey methods. The work included mapping of the geological strata of the exploration mine, analysis of the drilling cores, seismic profiling, and several methods to determine the rock permeability, the state of stresses, and the rock temperature. In autumn 2000 a moratorium on the exploration campaign at the Gorleben site was ordered by the Federal Government for a period of some three to ten years.

Figure 3-1: Gorleben Salt Dome (Prospective Geology as in the Working Model)

Disposal of POLLUX-Casks in horizontal drifts

The reference fuel is a UO2 PWR fuel assembly with a uranium enrichment of 4 % and 50 000 MWd /THM average burn - up. The waste package is a POLLUX-8-Cask, filled with the disassembled rods of 8 fuel elements. It was originally planned to fill the cask central bin with compacted fuel assembly structural parts. In a concept update, it was later decided to load the central bin with the fuel rods from two additional fuel elements, and to dispose of the compacted fuel element structural parts in so-called CSD C containers (“colis standard de déchets compactés” i.e. “standard package for compacted waste”).

Surface operations in a repository consist of the following steps in the case of POLLUX-Casks drift disposal. Waste packages arrive by railway or truck. After passing inspection the waste packages are loaded on the facility-internal rail-bound transport carts by a bridge crane. Thereafter, the transport cart is positioned for hoisting in front of the hoisting cage safety gate. When the hoisting cage is in place, the safety gate opens up and the transport cart is loaded into the cage by means of an under-floor caging device. The cage is then lowered down to the emplacement level.

A battery-driven mine locomotive pulls the loaded transport cart from the underground shaft landing station through the access drift into the disposal zone, until reaching the planned position in the disposal drift. The waste container is lifted from the transport cart by the waste emplacement machine; the cart is then towed away to clear the cask for emplacement, and the empty cart is transported on the same pathway in reverse direction back to the surface.

Thereafter, the waste package is lowered down onto the drift floor and the emplacement machine towed away into the neighbouring drift. With the emplacement drift now clear from heavy equipment, it is then possible to backfill the void volume around the emplaced waste container. The steel rails on which the heavy equipment is hauled into and out of the emplacement drift are not removed after the end of the disposal cycle. Figure 3-2 shows the sequence of disposal operations, and Figure 3-3 the equipment prototypes.

All these pieces of equipment have been manufactured in compliance with the full set of specifications of the real disposal equipment, successfully tested under simulated repository conditions, and fully certified by the competent certification bodies as ready for licensing.

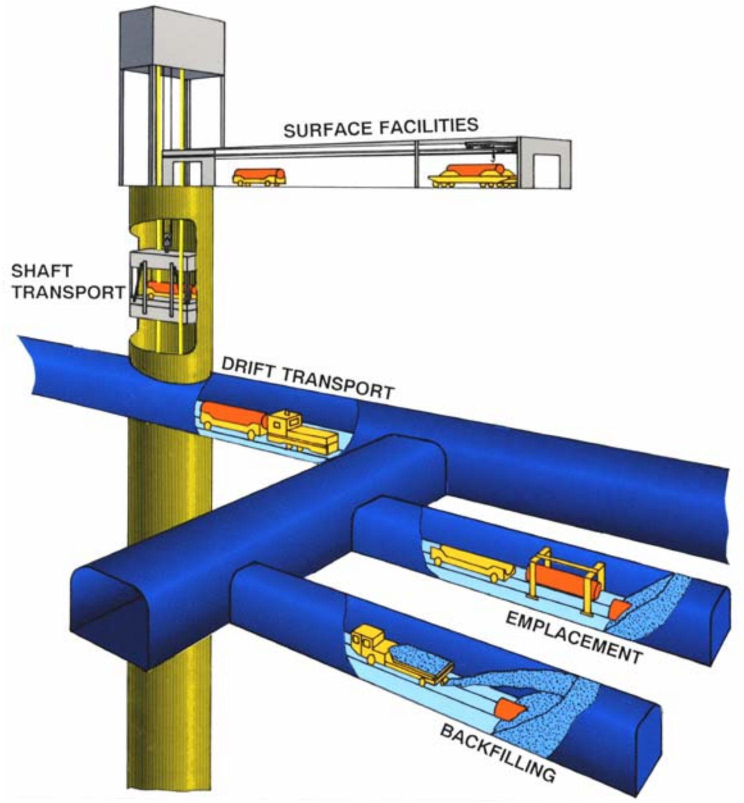


Figure 3-2: Drift Disposal Sequence of Operations

Figure 3-3: Emplacement Equipment

Disposal of BSK 3-Canisters in vertical boreholes

The drift disposal of POLLUX® disposal casks with fuel rods from spent fuel assemblies is developed almost to the point of being mature for use. The cask and a Pilot Conditioning plant have been constructed and the corresponding disposal technology has been developed and tested on surface. The practical below-surface demonstration of the disposal technology is still pending.

In comparison, the newly studied concept of BSK 3 canisters (containing fuel rods from spent fuel assemblies) disposal in deep vertical boreholes is still lagging behind development wise.

As an alternative to the disposal of POLLUX® casks in horizontal drifts, another concept has been examined on the basis of safety-technical and economic optimization for vertical disposal of canisters in salt, through the joint disposal in the same borehole of the following type of canisters with:

- complete fuel rods from spent fuel assemblies,
- vitrified high level wastes from reprocessing, and
- compressed interim level wastes (cut cladding and structural parts arising from reprocessing).

These 3 types of canisters have identical outer diameters and grapple heads, but different lengths, depending on the types of waste to be disposed of in boreholes.

With this disposal concept for fuel rod canisters emplacement in vertical boreholes, the following objectives shall be achieved:

- Savings on cask costs through transition to condensed canister disposal also for fuel rods from spent fuel assemblies (POLLUX® disposal casks are no longer required),
- Savings on development and operational costs through largely identical disposal technology for all types and shapes of waste,
- Improved control over the heat input into the host rock due to the possibility of vertically alternating disposal of highly heat generating wastes (canisters with fuel rods from spent fuel assemblies, high level vitrified waste canisters) and wastes with negligible heat generation (canisters with compressed cladding and structural parts) in the same borehole.
- Reduction of the repository area that needs to be explored and excavated.

The practical implementation of this concept foresees the direct emplacement of fuel rods as per the following steps:

- Interim storage of the spent fuel assemblies in CASTOR® casks,
- Disassembly of the fuel assemblies. Loading the separate fuel rods into stainless steel canisters, packing them denser in the process. Interim storage of the stainless steel canisters back into the same CASTOR® casks in which the complete fuel assemblies were previously stored, after change of baskets inside the CASTOR®,
- Transport of the CASTOR® cask to the reloading facility at the repository and the transfer of the stainless steel canisters from the CASTOR® cask into a transfer cask,
- Moving of the transfer cask down the shaft and into the disposal area,
- Lowering of the canisters out of the transfer cask and into the boreholes.

The analysis comprises the identification and derivation of all relevant boundary requirements regarding final disposal for the concepts.

In the realm of direct disposal of fuel rod canisters in boreholes, the emphasis is put on:

- Identification of the state of the art for the following components of the concept

    - fuel rod canister,
    - reloading facility at the repository,
    - transfer cask,
    - disposal technique and logistics,
    - drilling technique,
    - spatial distribution of the waste in the host rock (borehole length, gradient, spacing),

- Definition and evaluation of the development requirements necessary for realization of the concept.

During this process, consideration is given to the experience gained from the test preparations for disposal of HLW canisters and from the construction of disposal boreholes in the underground research laboratory of Asse, as well as from the results of the R&D plans regarding direct disposal of POLLUX® casks and the findings obtained within the framework of the "Update of the Gorleben Repository Concept".

The main task is the design of the canister emplacement device. Besides this, in order to record all criteria affecting the system, all processes in the whole repository must be observed for various components involved in the emplacement sequence. Here it is assumed that in the worst case, the reloading of the canister from the transport to the transfer cask takes place in the surface part of the repository. The following steps are to be considered in the determination of the design criteria:

- Reloading of the BSK-canister on surface

By rail or by road, 10 canisters packed in the Type B approved "CASTOR®"transport cask reach the reloading station at the repository. The cask, which arrives in the horizontal position, is raised with a hoisting device and brought into the docking position. After docking to the hot-cell, the transport cask is opened. One by one the canisters are pulled out from the transport cask by a hoisting device and installed into the hot-cell to be placed into or pulled into a transfer cask, which is docked to the hot cell as well.

After the closing of the cask and its disengagement from the hot cell, a hoisting device places the transfer cask onto the transfer cart intended for the transportation under ground.

In all handling operations, the activities of the radiation protection crew regarding control of the mechanical and radiological integrity of all components to be handled are to be integrated.

- Transport of the BSK-canister to the underground disposal location

The loaded transfer cart is transported to the hoisting shaft area with a stationary built-in hoisting device. The shaft hoisting system assumes the transfer cart transportation from surface down to the repository level and, after the shaft transport, pre-positions the cart within the underground shaft station.

A battery driven mining locomotive brings the transfer cart from the filling station to the disposal drift in the position required for transfer to the emplacement device.

- Emplacement process

Two variations of the emplacement device are considered (Figure 3-4, Figure 3-5), although the selection of one alternative follows within the framework of the conceptual planning.

Option 1: Emplacement with the transfer cask

Manufactured as a rail track bound, semi-mobile engine, the emplacement device awaits the transfer cart loaded with the transfer cask at the transfer station in the area of the emplacement borehole. The load reception spot of the emplacement device is positioned to the trunnion of the transfer cask and attached. The hoisting gear of the emplacement device (load portal) raises the transfer cask off the support of the transfer cart and moves it over the borehole.

With the tilting gear integrated into the load receptor, the transfer cask is raised and guided into the borehole mouth by lowering of the load portal.

The shielding hood installed in the load portal above the raised transfer cask is lowered onto the transfer cask and the transfer cask is opened at the head end. The opening process takes place with the actuator in the shielding hood, which is automatically connected to the locking slider of the transfer cask during the lowering process of the shielding hood.

The canister grapple in the shielding bell operates in the interior of the transfer cask and interlocks with the canister. The canister is then raised just enough so that the foot end slider of the transfer cask is not loaded. Then the opening of both the transfer cask and borehole follows. The locking slider of the transfer cask is opened by an actuator, which is either part of the borehole sluice or is automatically mechanically connected to the locking slider of the transfer cask during the docking process.

The canister is lowered into the borehole and discharged.

After release of the canister, the canister grapple is again pulled back into the shielding bell, the transfer cask and the borehole are closed and the shielding bell is raised. After removal of the transfer cask from above the borehole by the portal hoisting gear, a reverse step sequence follows.

The transfer cask is then ready to be transported back above surface.

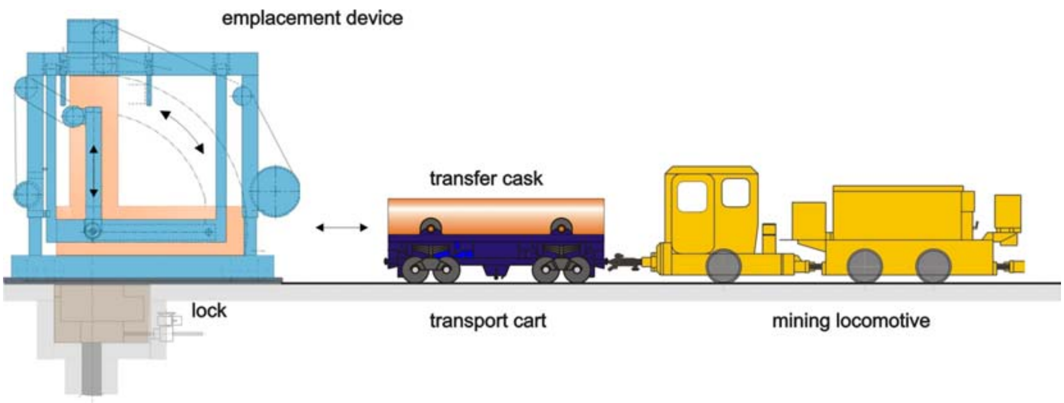


Figure 3-4: Option 1 for emplacement into disposal borehole

Option 2: Emplacement with integrated transfer bushing

Manufactured as a rail track bound, semi-mobile engine, the emplacement device awaits the transfer cart loaded with the transfer cask at the transfer station in the area of the emplacement borehole. For the unloading of the canister, the emplacement device with the transfer bushing is docked onto the transfer cask lying horizontally on the transfer cart. In addition, the emplacement device with its transfer bushing – which at the foot end is manufactured as a lock chamber– docks frontally onto the transfer cask.

After the docking, the interior of the transfer cask and the transfer bushing are opened. The opening of the transfer cask takes place over the actuator located in the lock chamber, which is automatically connected to the locking slider of the transfer cask during the docking operation or over the slider of the transfer bushing which is automatically mechanically connected to the locking slider of the transfer cask during the docking process.

An extension cylinder pushes the canister grapple from the interior of the transfer bushing into that of the transfer cask and the canister grapple interlocks onto the canister.

After the withdrawal of the extension cylinder, the canister hoisting gear pulls the canister inside the transfer bushing.

The transfer cask as well as the transfer bushing are closed and disconnected.

The transfer cask is then ready to be transported back to surface.

The emplacement device tilts the transfer bushing into the vertical position, moves to the borehole and with a lowering movement positions the lock chamber on the borehole, whereas the actuator in the lock chamber is automatically connected to the borehole slider or over the slider of the transfer bushing which during the docking process automatically is mechanically connected to the borehole slider.

The transfer bushing as well as the borehole is opened and the canister lowered into the borehole and released. After release of the canister, the canister grapple is again pulled back into the transfer bushing and the transfer bushing and the borehole are closed.

After raising the transfer bushing out of the borehole and tilting it to the horizontal position, the emplacement device again resumes the starting pose: transfer position between transfer cart and transfer cask.

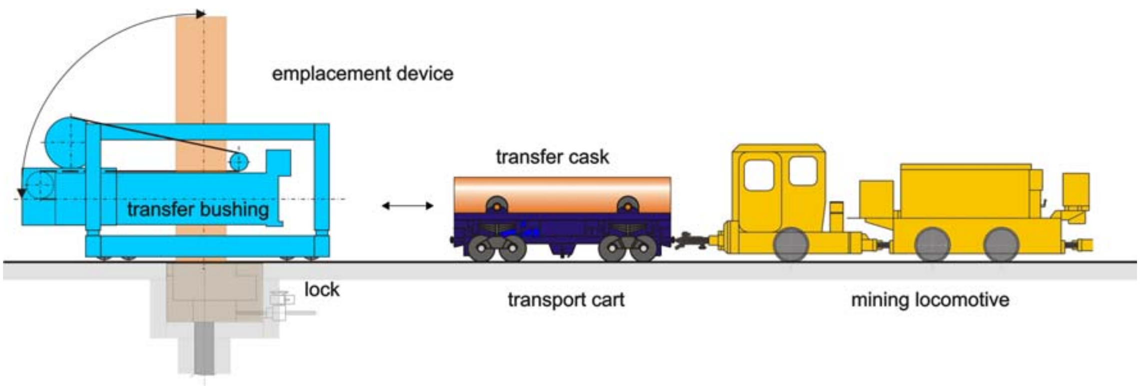


Figure 3-5: Option 2 for emplacement into disposal borehole

- Return transport of the unloaded transfer cask

The procedure for the return transport of the unloaded transfer cask to surface follows the same steps as the transport underground but in the reverse order.

- Backfilling

After the emplacement of a canister, the space between the canister and the borehole wall is backfilled with salt gravel.

For this, a rail track bound transport vehicle (e. g.) with an integrated backfill tank travels over the borehole from the direction in which the transfer cart left.

The hopper outlet of the backfill tank is placed over the borehole; the borehole and afterwards the backfill tank are opened.

After the backfilling, the backfill tank and the borehole are both closed and the backfill transport vehicle is transported back to the shaft station.

4 Brief Description of the French repository concept

General description of the facilities

The repository (Figure4-1) consists of three parts:

- The surface installations which cover an area between 500 and 1000 ha,
- The works connecting the surface with the underground which provide access to the underground facilities,
- The underground installations, located 485m below surface, which cover an area of between 1500 and 3000 ha.

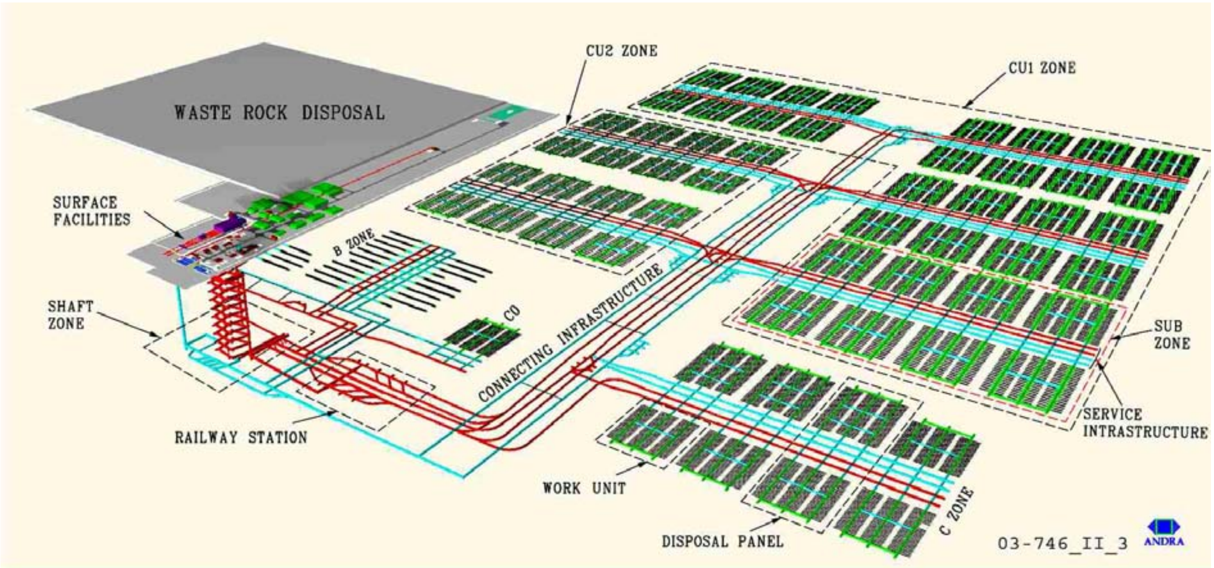


Figure 4-1: French repository concept

4.1.1 Surface installations

Surface installations comprise 4 zones:

- the nuclear zone,
- the industrial or non-nuclear zone,
- the general services area,
- the storage area for excavated material (dump).

All activities directly related to the radioactive waste packages take place in the nuclear zone include:

- reception and temporary storage of transport packages containing primary waste
- packaging the primary waste into disposal packages,
- temporary storage of the disposal packages and transport to the waste handling shaft,

This zone is physically separate from the other surface facilities. It is made up of two main buildings: one for repackaging types B and C waste and another for repackaging the spent fuels.

- The industrial zone includes all the facilities needed to support the underground construction and/or backfill operations. It consists of work shops, material storage areas and offices.

- The general services area is dedicated to utilities (electrical power, water, compressed air) and to administrative services.
  It consists of technical services buildings and offices.

- The waste rock disposal area covers between 100 and 500 ha. It receives all of the excavated material from the underground works. It represents the largest part of the surface installation foot print.

Some of the excavated rock will be used to backfill the underground drifts during closure.

4.1.2 Works that connect the surface with the underground

The connection between the surface and the underground is provided by 4 large diameter shafts (8 to 12 m) and one ramp. These openings are all grouped in one zone that is off-center in relation to the rest of the underground installations.

The four shafts provide for the transport of the disposal packages, personnel, the excavated material, backfill and concrete, as well as the air required to ventilate the repository.

The ramp (spiral tunnel with a 15% maximum grade) provides a transport service way and an emergency exit. A nearby 3 meter raise provides ventilation air during the driving and the operation of the ramp.

4.1.3 Underground installations

4.1.3.1 Common technical infrastructure

The common infrastructure is dedicated to:
- the transport equipment that moves disposal packages, consumables and personnel between the shafts or ramp and the underground facilities,
- the utilities (electrical power, compressed air , water),
- equipment maintenance shops.

This infrastructure consists of drifts developed on two levels over an area of about 50 ha.

4.1.3.2 Connecting infrastructure

The connecting infrastructure consists of a network of 4 drifts that connect the technical infrastructure to the disposal areas. The drifts are separated according to the type of circulation (nuclear or non-nuclear) that they support. These drifts are also used to carry the utilities network throughout the underground repository.

4.1.3.3 Disposal zones

There are 3 main types of disposal zones, each one dedicated to one of the 3 main categories of disposal package: zone B, zone C (vitrified waste), zone CU (Spent Fuel). Each zone is further subdivided into disposal panels which are accessible by the distribution network (drifts).
Each panel consists of disposal cells which are accessed via handling drifts.

4.1.3.4 Disposal cells

Type B Cells

A type B cell is a dead end tunnel with a 250 m long useable disposal area, holding thousands of parallelepiped waste packages. The diameter of the excavation can reach 12 m and the tunnel wall lining is made of concrete.

Note: *The disposal concept for this type of waste is not dealt with in the present document.*

C type cells (vitrified waste) (Figure 4-2)

C type cells consist of horizontal blind borings (drifts), 600 / 700 mm in diameter, 40 m long, lined with a metal sleeve holding 5 to 18 cylindrical waste packages.

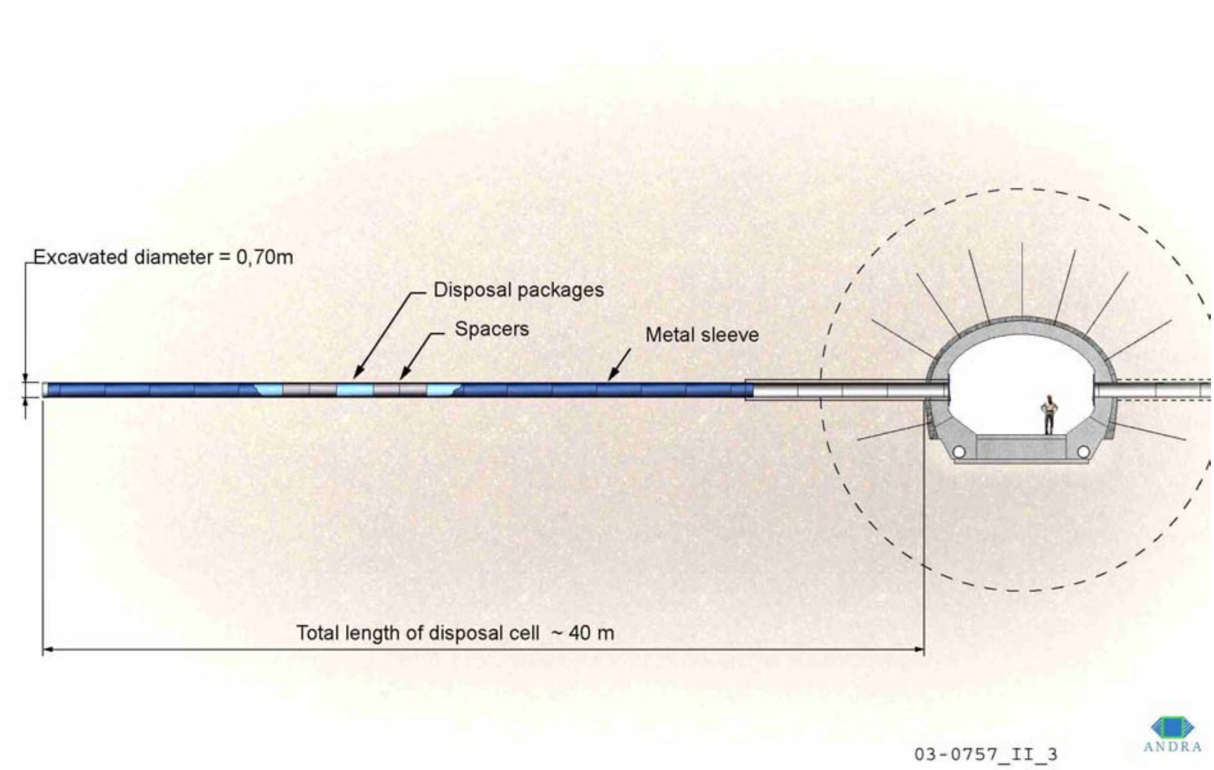


Figure 4-2: C type cells (vitrified waste)

CU type cells (Spent Fuel) (Figure 4-3)

CU type disposal cells (Spent Fuel) are small diameter (approx 3m) dead end tunnels, 40 m long, lined with a metal sleeve holding 3 or 4 cylindrical waste packages. The packages are surrounded by a layer of bentonite which constitutes a man made barrier, the “engineered buffer”.

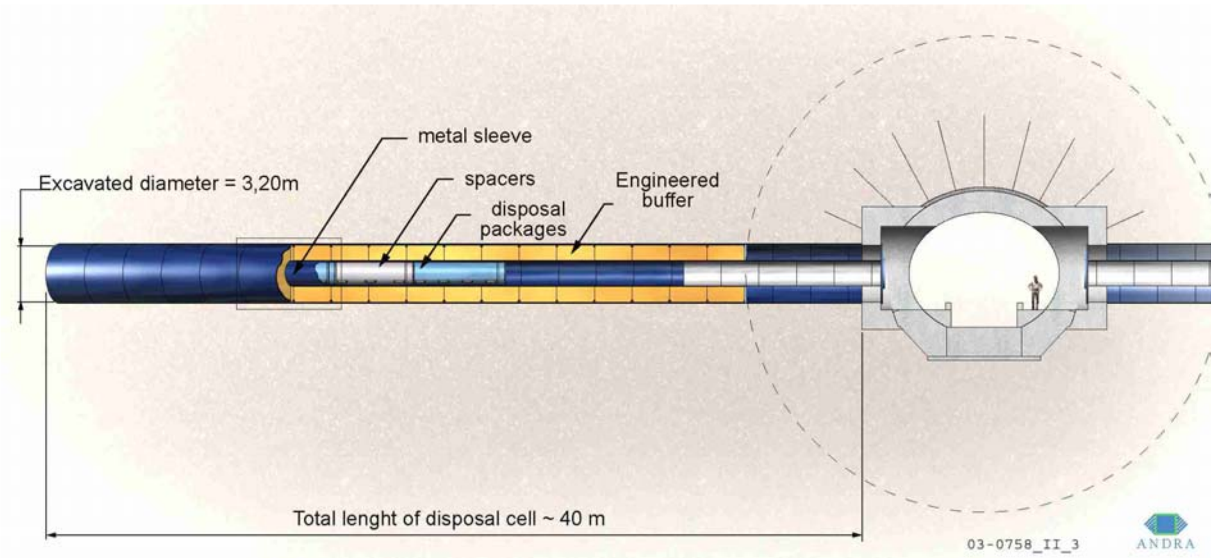


Figure 4-3: CU type cells (Spent Fuel)

General Description of the disposal procedures in ANDRA 's concept

The primary waste packages consist of a metal or concrete container that holds the radioactive waste. There are many different containers depending on the nature of the waste held within.

These primary waste packages are transported by road and/or rail from the production centers to the repository. Road casks are used for this transport.

Upon arrival at the repository the waste packages are removed from the transport casks and repacked into disposal packages (called canisters). A disposal package (a canister) essentially consists of a concrete or metal envelope that holds one or more primary packages of the same type.

The disposal package (canister) is transferred underground, inside a metal radiation shielding cask via a waste shaft and horizontal drifts to a disposal zone.

In the disposal zone the disposal package (canister) is removed from the shielding cask and is placed in the disposal cell.

Once the disposal cell is full it is closed and, following an observation period, the cell is sealed.

Eventually all the cells and drifts into a disposal zone are progressively backfilled and sealed by the following controlled and reversible procedures.

The schematic process envisaged for disposal of waste (from surface down to final emplacement in a cell) is shown here after. (Figure 4-4)

Schematic description of waste emplacement in a cell (example given for C type waste canister)

4.1.4 Description of the transfer cask for C type disposal packages

The transfer cask for C disposal (Figure 4-5) packages is made of steel/PPB/steel sandwich walls 40cm thick, and designed to include 23cm of steel + 15cm of PPB and 2cm of steel.
The maximum outside dimensions are: length 3.42 m, width 4.035 m, and height 1.8 m
The weight of a transfer cask is about 39 tonnes empty and about 41 tonnes when loaded with a 2 tonne disposal package.
The transfer cask is equipped with a self propelled pushing robot that loads and unloads the disposal packages. It includes the following main components :

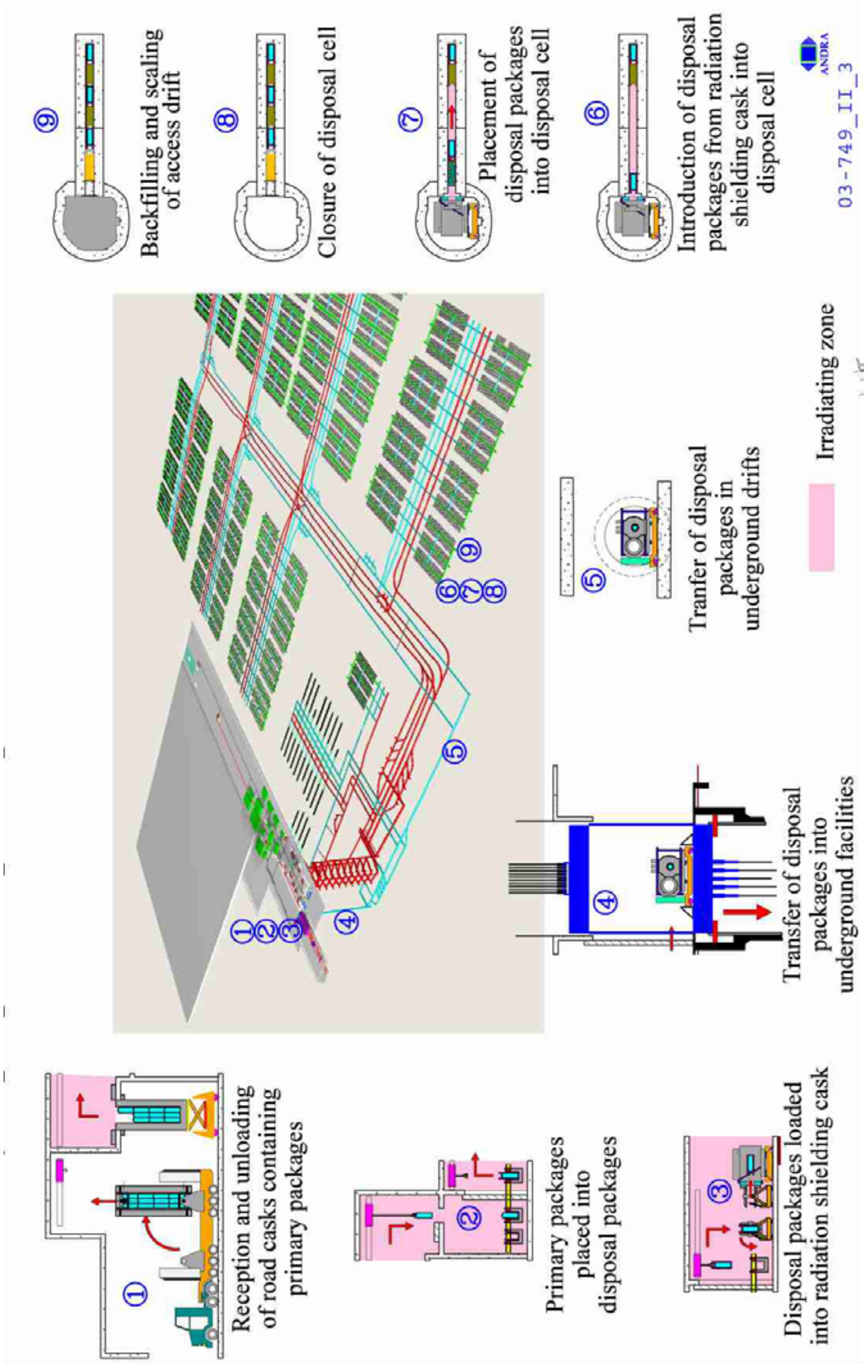


Figure 4-4: Simplified 3D schematic showing process for disposal of C type and CU type packages

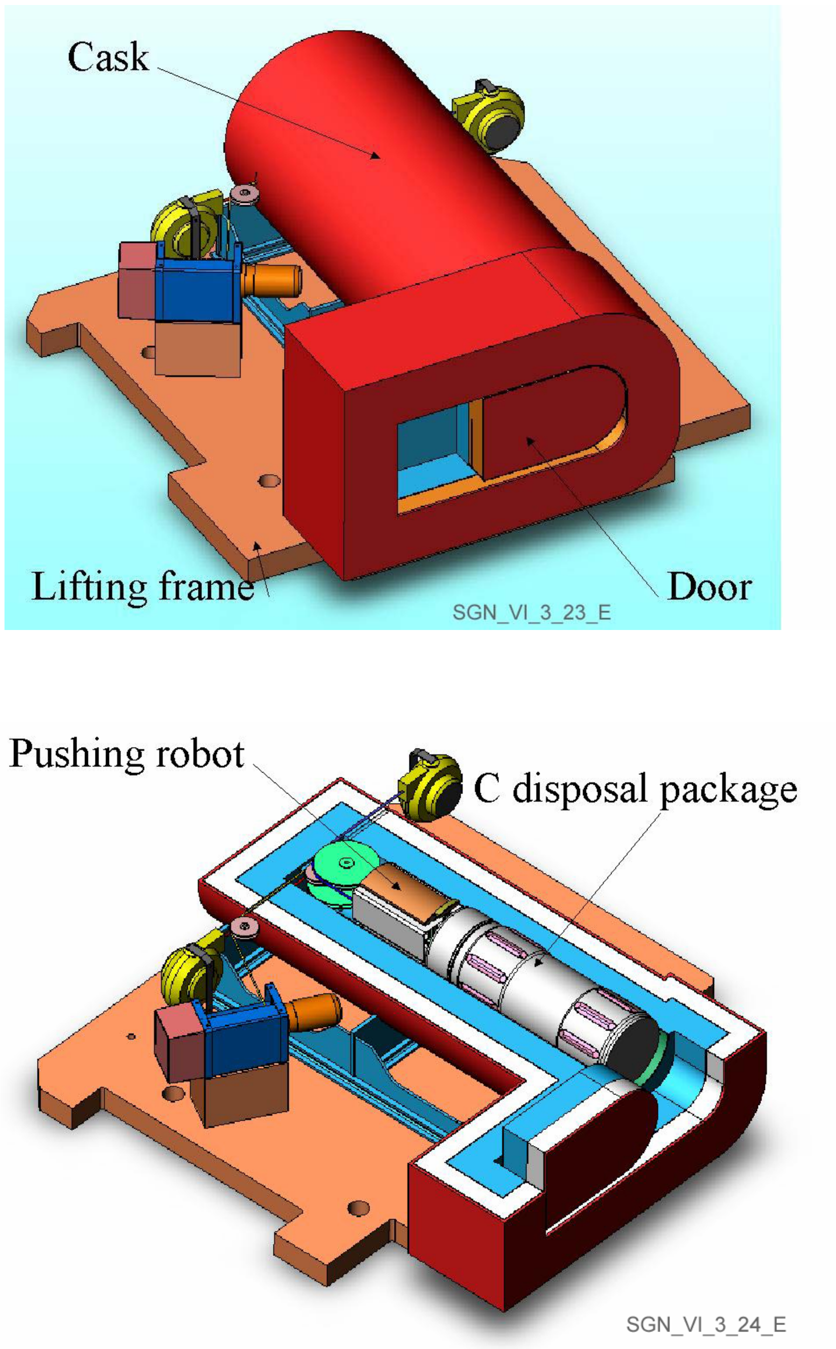


Figure 4-5: Radiation protection cask for C type disposal packages and cut-away view

<u>The lateral opening door</u>

The door is opened by an electric activator and is normally locked in the closed position by an intrinsic safety device that prevents the door from opening during transport. The door of the transfer cask is used as the motor to open the access port into the disposal cell.

<u>Internal equipment</u>

This equipment is a self propelled pushing robot with cylinders used for:

- loading the transfer cask while inside the surface installations
- placing the disposal package into a disposal cell
- retrieval of the disposal package from the disposal cell and placing it back into the transfer cask in case of a problem during the transfer or emplacement of the disposal package in the disposal cell
- retrieval of the disposal package in the event of a short term retrieval scenario

<u>External equipment</u>

This equipment is attached to the lifting frame of the transfer cask and includes:

- an electric cable reel which provides power and control to the robot
- a winch with its wire rope attached to the pushing robot. It is used as a last resort to retrieve the robot alone or when attached to a disposal package.

4.1.5 Description of the procedures for transporting a C type transfer cask in the disposal drifts (cells)

A cycle for transporting a transfer cask in the disposal drifts (cells) consists of various operations broken down as follows:

<u>1st operation:</u> Transport (on transfer truck, then on docking shuttle) of the transfer cask from the waste transport shaft cage to a position in front of the disposal cell (Figure 4-6)

- picking up the transfer cask from inside the cage of the waste transport shaft disposal level station,
- transporting the transfer cask in the drift and delivery to the cross cut of the transport drift with the access drift,
- separating the transfer cask from the transport vehicle and loading it onto the docking shuttle thanks to its transfer wagon,
- having the docking shuttle deliver the transfer cask to the head of the disposal cell.

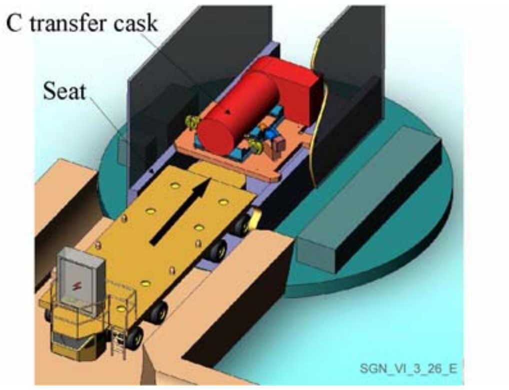
<u>2nd operation:</u> Docking the transfer cask to the head of the disposal cell (Figure 4-7)

- positioning the docking shuttle, with all the docking mechanisms, underneath the transfer cask,
- docking the transfer cask with the disposal cell head works

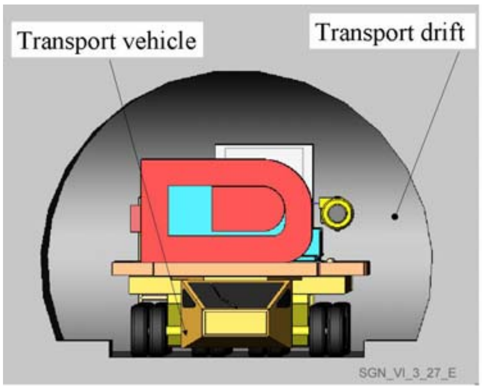
<u>3rd operation:</u> Emplacing the disposal package into the disposal cell (Figure 4-8)

- the gamma gates of the disposal cell and the shielding cask are opened,
- the pushing robot moves the canister inside the inner sleeve until it reaches its final position,
- the pushing robot is then removed back into the shielding cask,
- the gamma gates of the disposal cell and the shielding cask are closed.

a) Picking up the C type transfer cask in the cage



b) Travelling in the drifts



c) Going around a 90° turn (transport drift and handling drift)

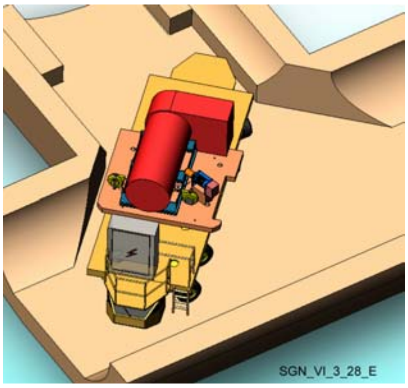


Figure 4-6: Kinematics of picking up a C type transfer cask and transporting it in the drifts

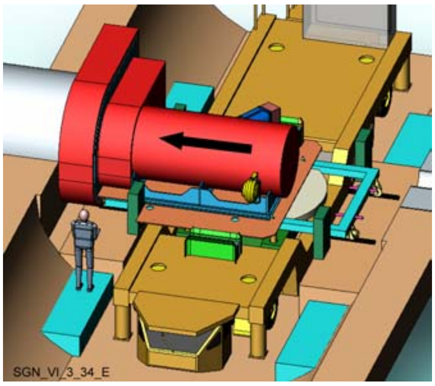


Figure 4-7: Setting the transfer wagon onto the guide rails and docking the C type transfer cask to the access port

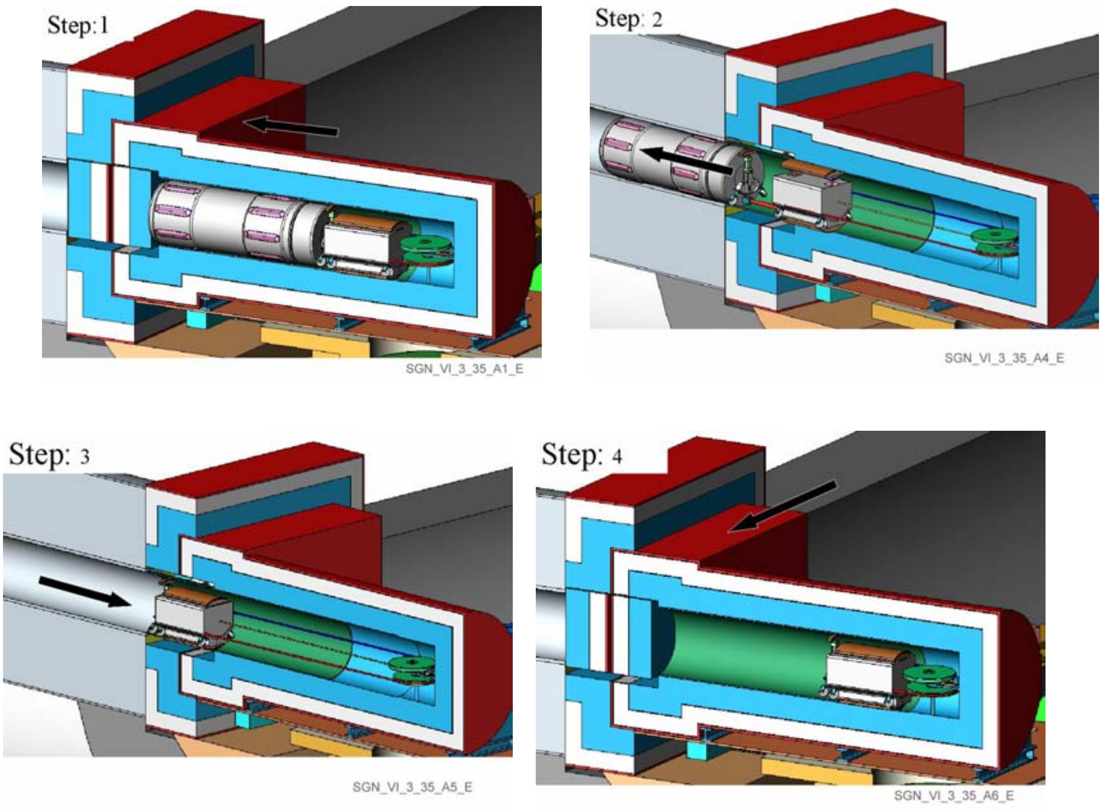


Figure 4-8: Synoptic of emplacing a C type disposal package

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Reversibility and staged operations in the French Concept

ANDRA started out investigating the motivations that would support having a reversible repository before embarking on the task of translating this concept into technical terms. In practical terms, reversibility can be defined as designing for *flexible management* of the disposal process, so that the next generations can have their own *freedom of decision,* regarding how they want to manage this process.

ANDRA elected to adopt a staged design as the basis for the flexibility of the process; these stages are identified. The duration of each stage is not imposed by the designer; it is left to the initiative of the upcoming generations, within the limits of the technical feasibility of the facilities while maintaining acceptable conditions for short term and long term safety. For the same reasons, a flexible and modular layout avoids permanently freezing, at the start of operations, the disposal panel design of the future.

At any moment during the process, the possible choices are essentially, to observe and maintain the facilities in the then current state, to advance to the next stage, to take steps backwards (including the possible retrieval of the disposal packages from the repository), to accept new waste packages or an evolution of the design of the facilities.

To preserve these choices, reversibility implies having at all times a full and thorough scientific and technical understanding regarding the evolution of the repository and having the means to act, as the situation may require. Several technical functions are clearly within this logic of reversibility. They cover the management of the packages and of the facilities and they include the ability to take steps backwards. The means for taking action are integrated into the design of the repository and are identified.

4.1.6 Expectations and possible motivations as to the reversibility of the repository

Expecting reversibility is closely linked to the principle of precaution. This principle demands taking action as soon as an activity is suspected of causing serious and irreversible damage, and this even in the absence of a scientific certainty relative to the real risk. Thus, safeguarding the reversibility option and putting in place the necessary means to do so refers to a "prudent" approach while manoeuvring in an uncertain environment.

As with the principle of precaution, a gradation in the approach to reversibility can be introduced, by considering "levels" of reversibility. Indeed, it is generally understood that the application of the principle of precaution is itself subordinated to applying the principle of proportionality between the possible risk (such as it is perceived at a given time), and means in place to prevent such risk.

Within the general framework of the principle of precaution, some reasons for adopting a reversible approach to the disposal of high level, long life radioactive waste can be outlined and put forward as follows:

- first of all, the disposal studies consider very long time periods. This inevitably involves uncertainties. Under these conditions, it is essential to be modest when taking into account the risks and the limits of present scientific knowledge;
- by corollary, it takes time to acquire any convictions. This is undoubtedly consolidated by observations over long periods and by a deepening of the comprehension of the phenomena;
- future generations may then want to diversify management options or, in the absolute, implement new ways that appear to be more relevant;
- the options retained in the field of radioactive waste management must be evolutionary, be subject to negotiation and, in short, form part of a flexible and negotiable process…

4.1.7 Stages of the disposal process

Levels of reversibility and stages

ANDRA elected not to fix, a priori, the duration of the reversibility option, but rather to reason in terms of levels of reversibility, which would decrease gradually, on the scale of one to a few centuries.

The disposal process is designed to function in stages as identified below. The passage from one stage to another is not final, and the ability to go backwards is always left open. Nevertheless, going to the next stage can entail a reduction in the level of reversibility: the more the repository process is advanced, the more a significant number of technical choices will have to be made and therefore the means required for going backwards will be more demanding. On the other hand, any decision to move forward to a stage with a lower level of reversibility will demand first having an appropriately high level of conviction.

It should be noted that, for a given stage of the disposal process, the evolution with time of the materials (corrosion of steel, physicochemical deterioration of concrete) and of the facilities can also lead to a reduction in the level of reversibility. In order to preserve options, the design of the disposal packages and the layout of the repository, presented below, aim to reduce the constraints attached to running the disposal process, while taking into account the technical and economic factors.

Identification of the stages (Figure 4-9)

The construction of a disposal panel constitutes the initial stage in the waste disposal process. Five subsequent stages have been identified, for managing the waste packages placed in the disposal panel and for managing the disposal panel itself.

<u>Stage 1</u>**:** This stage corresponds to the emplacement of the disposal packages in a disposal cell (a disposal cell is the most basic underground disposal facility).In this stage, the cell is sealed by head works which can be opened to allow the introduction of a disposal package, and then temporarily closed

again, in order to isolate the cell from the handling drift servicing it (this device is later on called an "obturator" or "operating plug "). The handling drift is accessible to operators because the “obturator” protects them from direct exposure to the radiation emanating from the disposed packages.

It is possible to compare this stage in the management of the disposal packages to a warehousing situation. The objective at this point in time is to be able to retrieve the packages in the same condition as when they were installed; the retrieval is carried out with the same means as were used for the emplacement, by simply reversing the process. The durability of the disposal packages placed in the disposal cells, of the cells themselves, of their equipment (in particular in supporting the argillite), of their operating plug, and finally also the durability of the handling drifts, defines the degree of flexibility that is possible during this stage. The determining parameters are, in particular, the temperature, the physicochemical atmosphere in the disposal cell, the mechanical deformations of the works and the saturation rate in the argillite and the works.

A monitoring system is considered as likely to be installed to keep a permanent record of the mentioned parameters, while the presence of the permanent inner sleeve (at least before the corrosion effects prevail) enables a physical re-entry of a pushing robot.

Stage 2: This stage corresponds to the sealing of a disposal cell which is thereafter in its final configuration. The construction of the definitive plug limits the physicochemical exchanges between the cell and the handling drift, ensures the long term safety, and also reduces the access to the packages which are disposed there. However, at this stage, the drift providing access to the disposal cell (or a group of disposal cells) remains open.

A decision to step backwards at this point implies dismantling, in whole or part, the definitive plug installed at the head of the disposal cell. Once this is done, the design of the packages and the repository layout presented hereafter is such that operating conditions, close to those of stage 1, will be found. The absence of any physical blocking of the disposal packages in the disposal cells facilitates the mechanics of their withdrawal. The durability of the disposal packages limits the risk of dissemination of radioactive elements, inside the disposal cell, for a long time, at least for hundreds of years. Particular attention will be paid to the control of potentially dangerous gases, which could have formed and accumulated in the closed disposal cell. It should be noted that the same open disposal panel can, at a given time, include disposal packages and disposal cells at stage 1 and other disposal packages and disposal cells at stage 2.

Stage 3: This stage corresponds to the closure of a disposal panel: thus at this stage the entire disposal panel is in its final configuration. The connection drifts serving this panel are accessible. The disposal panel closure includes back-filling the handling and service drifts dedicated to the closed disposal panel. For the disposal packages with a higher level of activity (in particular spent fuels), the closure of a disposal panel can induce an appreciable increase in temperature in the backfilled drifts. A return to the physical configuration corresponding to the preceding stage implies removal of the backfill material and, as needed, implementing additional safety measures and re-equing the drifts. It should be noted that a repository can, at a given point in time, include packages and disposal cells at stage 1 or stage 2 in still open disposal panels, and closed disposal panels at stage 3, at the same time.

Stage 4: This stage corresponds to the closure of the drifts that give access to one or more disposal panels. Only those drifts providing access to the disposal zone in question are still open (it should be remembered that the various categories of waste, B, C and spent fuel are considered to be placed in distinct disposal zones, for which the construction and management can be independent).The passage to stage 4 has little phenomenological impact on the evolution of the disposal panels. In order to go backwards in the process, the accessibility to the disposal panels and disposal packages is rendered more complex but the conditions are comparable to those of stage 3.

Stage 5: This stage corresponds to the closure of the connection facilities between the surface and the underground installations. All the disposal panels and disposal zones serviced by these facilities are then in a “post-closure” situation. The repository no longer needs any maintenance or complementary works; also reversibility is no longer considered in terms of stages. However going backwards is still a possibility: the reopening of the closed shafts (or the construction of new shafts) may again provide access to the underground works.

4.1.8 Technical means associated with reversibility

It is conceivable that as data are gathered or certainty is reinforced, moving forward to a stage with less reversibility can be considered. This can be done provided that the elements which justify this passage, that the means which make it possible, and that the implications, if necessary, of returning backwards to the former stage, are all well-known and understood. Within the framework of managing the disposal process by stages, reversibility is ensured by design and process provisions and by the ability to observe and record what is happening. These provide the basis for deciding to move forward towards complete closure of the repository, for waiting or for going backwards, whatever the reason.

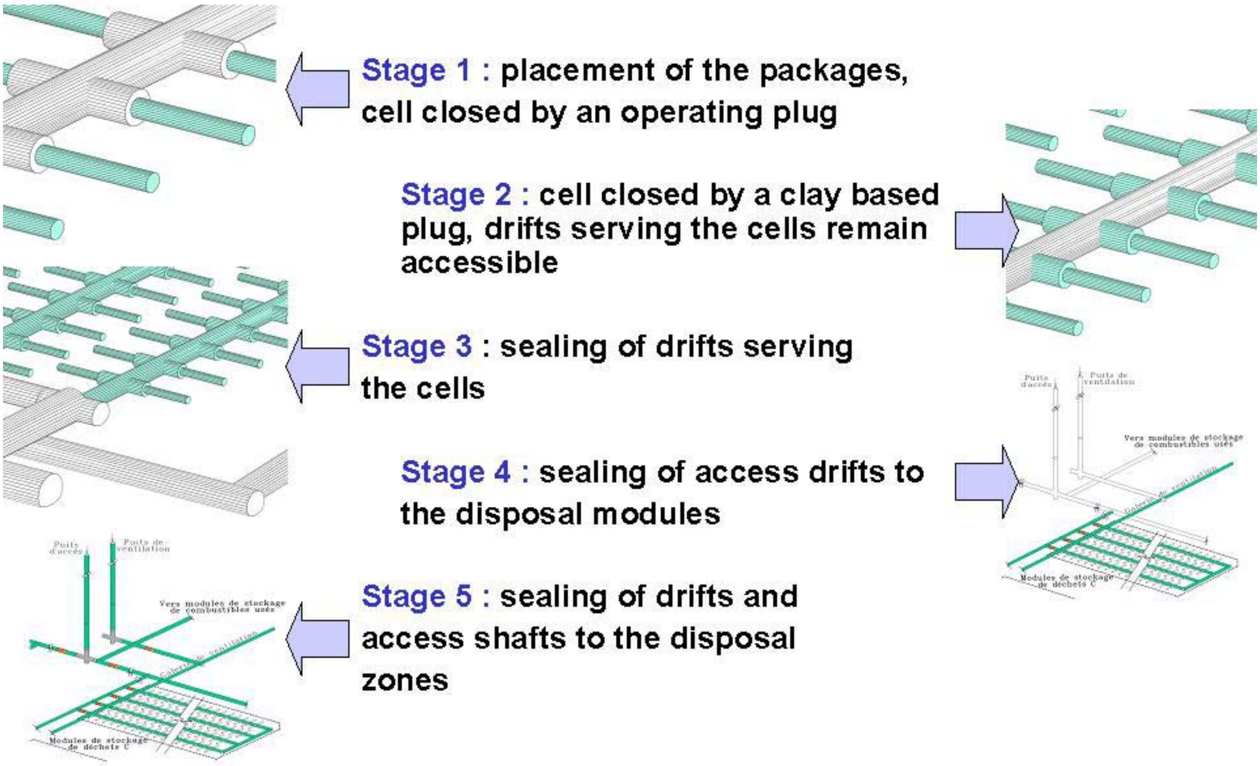

Figure 4-9: Principal stages of the disposal process after the completion of a disposal panel (illustration corresponding to C type waste or spent fuel packages)

<u>Monitoring programme and means</u>

The ongoing and long term process of disposal benefits from extended periods of observation, at each stage, which will reinforce convictions regarding the behaviour of the repository. The monitoring programme that has been integrated into the design of the repository makes it possible to collect and consolidate new and complementary data which will be used to track the actual evolution of the repository and to compare this to the forecasted evolution or model. Throughout this entire process particular care is taken to ensure and confirm that the robustness of the containment of the radioactive elements is never compromised.

<u>Design provisions</u>

The modularity of the layout and the ongoing flexibility of its construction (as previously mentioned), constitute essential provisions with respect to reversibility. In addition certain technical arrangements , integrated into the design of the disposal packages and of the underground facilities help ensure that there are options with regard to the management of the disposal packages and of the repository.

5 Description of waste packages

German waste package concept

In the following is described the German waste package concept.

5.1.1 Waste package fuel rod container BSK 3

Within the framework of the development of a disposal concept that includes interim storage and final disposal, the development of a new, relatively thin walled canister – suitable for the interim storage and final disposal of spent fuel assemblies – was carried out by GNB. The canister received the name Fuel Rod Canister BSK 3. This canister has been designed for receiving a maximum of 3 PWR or 9 BWR fuel rod assemblies. The interim storage of the BSK 3 takes place in transport and storage casks.

To begin with, the nuclear design was only performed for uranium fuel. Design criteria are 6 kW maximum transferable heat capacity and 0.8 E+17 Bq maximum total activity. The minimum decay time of the fuel assemblies to be disposed of is to be determined so that, for a given enrichment and burn up, the maximum allowable gamma and neutron dose rates on the surface of the interim storage cask as well as the permissible structural and fuel rod cladding temperatures are not exceeded.

5.1.1.1 Design criteria

GNB has various necessary licensing procedures for the fulfilment of the requirements for manufacturing, transport, interim storage and mining law that need to be addressed.

(1) For the transport on public transport routes, a transport license, type B (U) F, which covers the transport of the fuel rod canister BSK 3 in a transport and storage cask.

(2) Permit based on atomic law for the storage of the fuel rod canister BSK 3 in an interim storage cask in a facility for spent fuel assemblies.

(3) License based on mining laws for the final disposal of the fuel rod canister BSK 3.

The various design criteria arising due to the different requirements are compiled in Table 5-1.

Design criteria	Explanation	
Inventory of heavy metals	Loading with fuel rods from disassembled fuel assemblies from pressurized- and boiling water reactors	Up to 1,63 tHM
Heat	Max. heat output capacity of the canister contents	6 kW
	Max. cladding strain for the storage time by limitation of the cladding temperature	< 1 %
	Max. tangential tension	< 100 MPa
Criticality	Neutron multiplication factor during transport and inspection conditions	$K_{eff} + 2\sigma < 0{,}95$
Tightness	Allowable He-Standard-Leakage rate Sealing of the primary lid	1 E-3 hPA *l/s
	Allowable He-Standard-Leakage rate after welding of the secondary lid	<< 1 E-7 hPa*l/s
Strength	Design for maximum isostatic rock pressure in the repository.	30 MPa

Table 5-1: Design Criteria BSK 3

The following design characteristics characterize a packaging fit for disposal:

- The outer diameter of the fuel rod canister matches the HLW canister for vitrified high level wastes from reprocessing. Thus, the common handling and disposal of the 2 types of canister in boreholes is possible.

- The capacity of the interior is designed to hold 3 PWR fuel rods (corresponding to 9 BWR fuel assemblies for shortened baskets).

- The wall thickness of the fuel rod canister and the supporting effect of the fuel rods are sufficient to resist the forces applied by the rock pressure in the repository according to current knowledge. The packaging is sub-critical due to the high loading density in the fuel rod canister.

- The gas tight confinement of the radioactive materials during transport, interim storage and final disposal of the fuel rod canister after loading is ensured by the welding technical techniques which result in an airtight enclosure.

- The corrosion protection covering which is applied later, if deemed necessary, offers protection against a corrosion attack in the repository.

5.1.1.2 Structural set up of the BSK 3

The description given by GNB represents the construction basics of the BSK 3. In the following, these are briefly summarized.

Outer shell: Hollow cylindrical jacket with bottom of ferrite materials and with a wall thickness of 40 mm.

Lid: Primary lid is screw lid and includes a sealing while the secondary lid is a welded lid c/w grapple head.

Loading: Two internal baskets

5.1.1.3 Basic Material of the BSK 3

For the jacket, bottom, primary and secondary lid, a fine-grained construction steel 15 MnNi 6 3 will be used. A corrosion resistant coating can be applied at a later stage.

5.1.1.4 Thermal Characteristics of the BSK 3

According by GNB the fuel rod canister will be designed for a maximum decay heat output of 6 kW can be. This value relates to PWR fuel assemblies (of type 18x18-24) with an active fuel rod length of 3.9 m. Per meter of active length this results in a deferred decay heat of 6 kW/ 3.9 m = 1.5 kW/m. Design limiting are the permissible cladding temperatures of the fuel rods for prevention of systematic cladding defects as well as the permissible surface temperature of the transport- and storage casks for the fuel rod canisters.

5.1.1.5 Design Criteria Criticality Safety

The criticality safety for the BSK 3 during the interim storage in (storage cask) 21 is proven by GNB. The most reactive configuration was proven to be the situation where the BSK 3 is flooded and the remaining space in the cask is dry, this gives the outcome $k_{eff} + 2s \sim 0.9 < k_{eff} + 2s < 0.95$. The calculated result lies clearly below the limiting value in this most unfavorable case; hence the criticality safety is given.

5.1.1.6 Design stability criteria

In a GNS report, the mechanical analysis for an isostatic rock pressure of 200 bar corresponding to 22 MPa was conducted within the framework of a technical feasibility study for the fuel rod canister BSK 3.

For the analysis, a finite element model was used, taking into account both the stress and the critical buckling load on the fuel rod canister BSK 3. The maximum equivalent stress according to Von Mises was determined to be around 200 N/mm². The maximum lid displacement was in the order of 1 mm. A maximum diameter reduction of

1/10 mm resulted from the stress. The safety against buckling is therefore a factor of more than 20.

The result of the mechanical analysis was, that under the boundary conditions and assumptions of this report, in particular the load exercised by the hosting rock pressure, the integrity of the BSK 3 fuel rod canister is guaranteed.

5.1.2 Quantity structure

Basis for the work is the quantity structure described in Table 5-2.

HLW Canister	CSD-C Canister	Direct Disposal
4.778	8.764	8.947 tSM

Table 5-2: Quantity structure of waste packages

In Table 5-3 follows a representation of packaging according to common geometry, which allows for identical transport and disposal procedures, respectively according to packaging variations for the direct disposal.

<table>
<tr><th>Canister</th><th colspan="2">Direct disposal</th></tr>
<tr><td rowspan="1">13.542</td><td>POLLUX®-10
$\hat{=}$ 1.657</td><td>BSK 3
$\hat{=}$ 5.523</td></tr>
</table>

Table 5-3: Number of Packaging

5.1.3 Waste package geometry and weights

Due to the transport system of the repository developed in Reference /4-1/ and /4-2/, the following geometry and weight restrictions presently apply for the transfer cask including the waste package:

Length:	max. 6000 mm
Diameter:	max. 1583 mm
Weight, loaded:	max. 65 t

5.1.3.1 HLW Canister

The HLW canister (see Figure 5-1) contains high-level vitrified waste from the reprocessing of nuclear fuel.

Length:	1338 mm
Diameter:	430 mm
Weight, loaded:	492 kg
Volume HLW	150 l ~ 412 kg

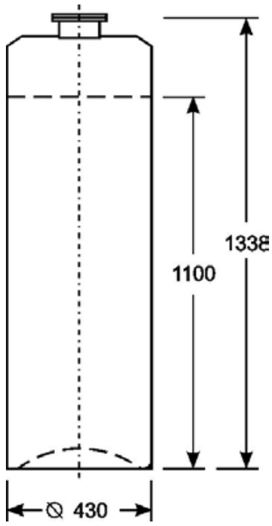

Figure 5-1: HLW Canister

5.1.3.2 CSD-C Canister

The CSD-C-canister (see Figure 5-2) contains claddings and structural parts as well as technological wastes from the reprocessing in compressed form.

Length:	≤ 1345 mm
Diameter:	≤ 440 mm
Weight, loaded:	≤ 850 kg

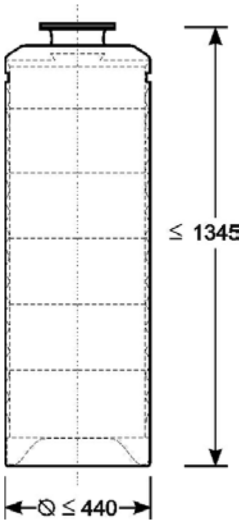

Figure 5-2: CSD-C Canister

5.1.3.3 Fuel Rod Canister 3 (BSK 3)

As reference loading the BSK 3 (see Figure 5-3) contains the fuel rods from 3 PWR fuel assemblies.

Length:	4980 mm
Diameter:	430/440 mm
Weight, loaded:	5.266 t
Heavy metal load:	2400 kg

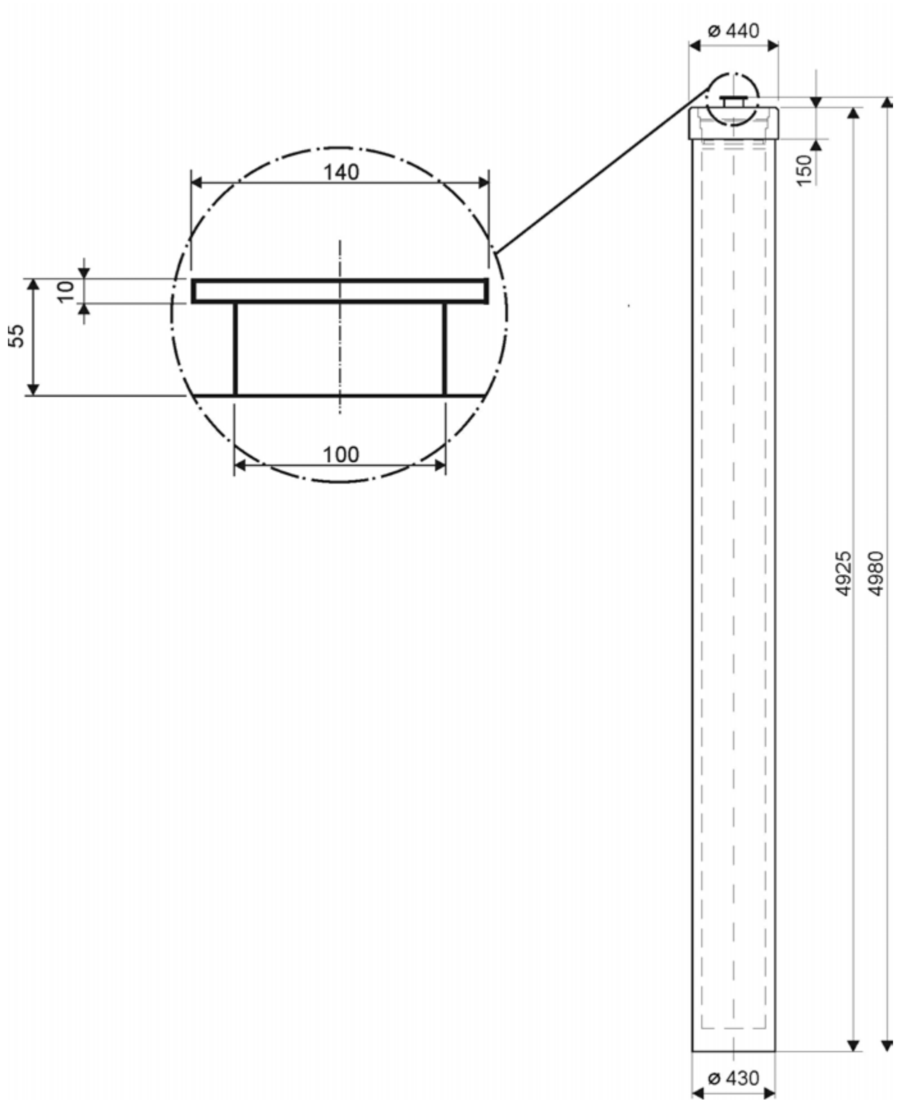

Figure 5-3: BSK 3

5.1.4 Final repository relevant characteristics and parameters

In /4-3/ the recommendations of the HLW-Products Working Group regarding characterization and assessment of repository relevant properties of high level waste products are documented. For the fuel rod canisters, repository relevant properties for conditioned LWR fuel assemblies in disposal packaging were described in paper no. 8. These are

- Total activity
- Activity of relevant nuclides
- Criticality safety
- Thermal properties
- Dose rate on the packaging
- Surface contamination
- Description of the waste product
- Hydrolytic resistance and radionuclide release
- Description and quality of the disposal cask
- Disposal packaging weight
- Mechanical properties
- Labelling of the disposal packaging

5.1.5 UO_2 spent fuel

The reference fuel is the formally mentioned UO_2 PWR fuel assembly with an Uranium enrichment of 4 % and 50 000 MWd/tHM average burn up. Figure 5-4 shows the heat capacity of a UO_2 PWR fuel assembly over the time.

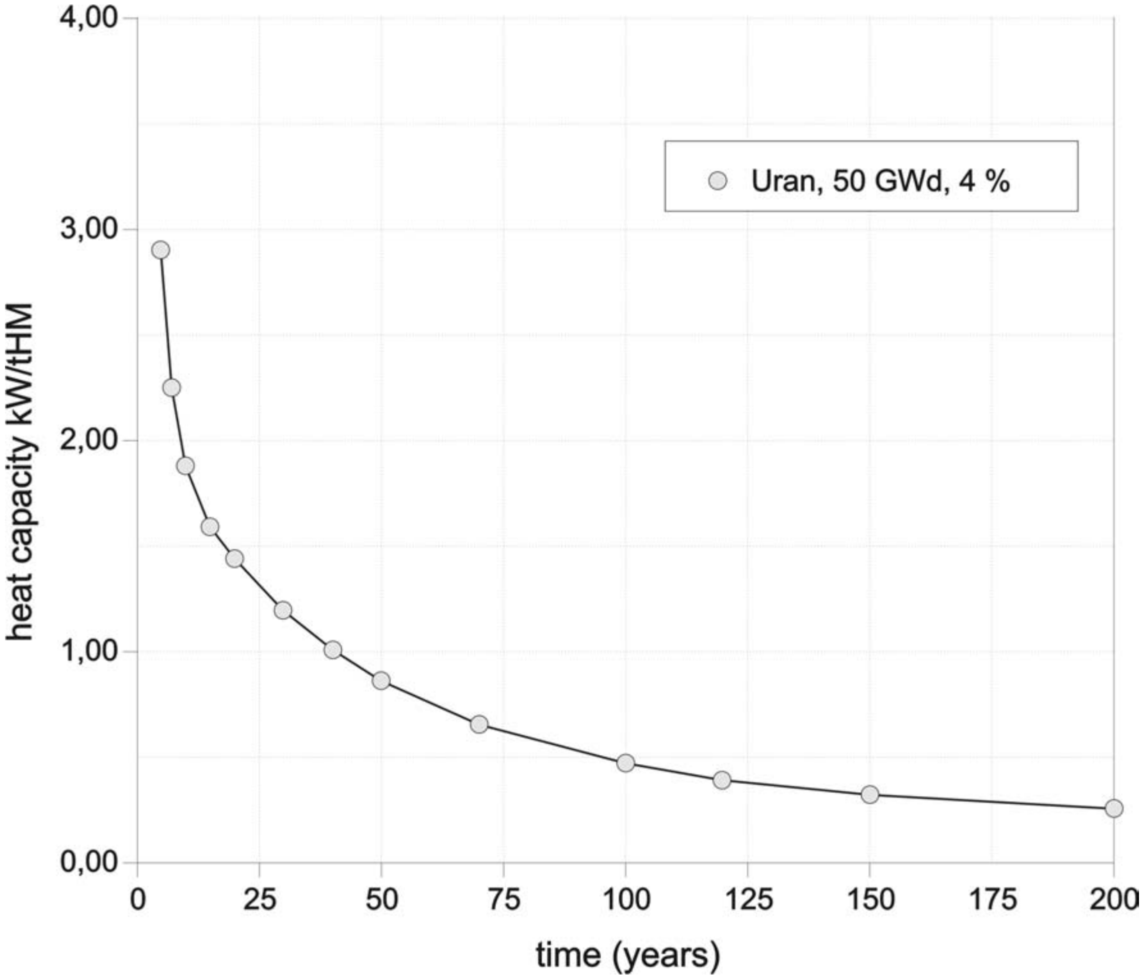

Figure 5-4: Heat capacity of a UO2 PWR fuel assembly

In Table 5-4 is listed the heat capacity of the BSK 3 filled with rods of the reference fuel over the time.

Time **[a]**	**BSK 3** **1,6 THM** **[kW]**
Entladung	**3.061,80**
1	21,22
2	11,84
5	4,70
6	3,65
10	3,03
15	2,58
20	2,32
30	1,93
40	1,62
50	1,39
70	1,05
100	0,76
120	0,64
150	0,52
200	0,42
500	0,23
1.000	0,13
10.000	0,03
100.000	0,00
1.000.000	0,00

Table 5-4: Heat capacity of BSK 3 for UO_2-PWR fuel rods with an Uranium enrichment of 4 % and 50.000 MWd/tHM average burn up.

French concept

5.1.6 French waste packages classification

The current studies which are investigating the feasibility of disposing of LLHL (Long Life High Level Waste) in a repository (located in a deep geological horizon area) include:

- In part, waste with medium levels of activity (LLML), also called B waste. These come from many different sources and are more diverse. They include primarily waste from operation of nuclear reactors, process waste (structural elements from fuel assemblies) and technological waste (effluent treatment sludge and technological waste) resulting from the treatment of fuels and from current operations and maintenance of fuel treatment centres. They also include waste from nuclear research centres, essentially technological waste.

  Note*: This category of waste and its packaging / emplacement is not dealt with in the present document,*

- In part, waste with high level of activity (LLHL), also known as **C type waste**, which is material contained in spent fuels that no longer has any value (mixture of fission products, actinides, and activation products), conditioned in a glass matrix (vitrified waste). This waste gives off significant heat;

- Spent Fuels, also known as **CU type waste**, that have been installed in a nuclear reactor are also considered, even though at this stage they are not considered to be waste because they still contain valuable material. They give off significant heat.

The distribution of the families of LLHL packages, by producer and type of waste is shown in table 5-5 below.

PRODUCERS	CATEGORY OF WASTE			TOTAL
	Spent Fuel	C Waste (vitrified)	B Waste	
ANDRA	0	0	3	3
CEA	1	1	19	21
EDF	4	0	3	7
COGEMA	0	10	21	31
Total	5	11	46	62

Table 5-5: Distribution of LLHL waste packages by producer and by category

5.1.7 Waste package characteristics in the French concept

5.1.7.1 C type waste (Package types C0 to C4)

Description of the packages

The vitrified waste packages C0 to C4 being considered, have the following definitions:

- **Package C type0**: old glass from fission products and actinides;
- **Package C type1**: glass from fission products and actinides produced by the treatment of UOX/URE fuels. This type of package is currently being produced;
- **Package C type2**: glass from fission products and actinides produced by the treatment of UOX/URE fuels. This type of package is forecast to be produced in the medium term, with an increase in the thermal power of the packages;
- **Package C type3**: glass from fission products and actinides produced by the treatment of UOX and MOX fuels. The MOX represents 15 % of this glass and it results in a higher actinide inventory than the C1/C2 type of packages ;
- **Package C type4**: glass from fission products and actinides with some Pu included.

Radiological and thermal characteristics – equivalent dose rates

The nominal activities of waste package types C0 to C4 are as follows:

C0.1: 2.0E+14 Bq

C0.2: 4.2E+14 Bq

C0.3: 1.6E+15 Bq

C1: 1.3E+16 Bq

C2 and C3: 1.4E+16 Bq

C4: 1.7E+16 Bq

The residual thermal energy of these packages is shown in figure 5-2 here after.

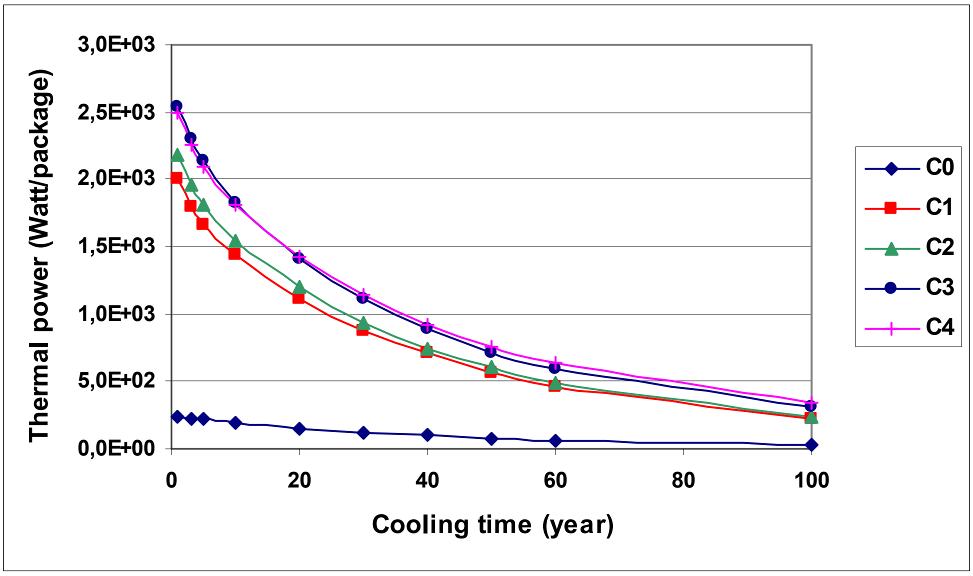

Figure 5-5: Illustration of the residual thermal energy for C0 to C4 packages

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The thermal activity of packages C0 to C4 is such that they require temporary storage before they can be placed in the repository.

- 20 years for C0 packages ;
- 60 years for C1 and C2 packages;
- 70 years for C3 and C4 packages.

The packages are irradiating. The equivalent gamma dose emission at the pseudo contact of the C1 and C2 packages is in the order of 250 Sv/h after 60 years of cooling. The equivalent gamma dose emission for the packages C0, C3 and C4 packages are being evaluated.

5.1.7.2 CU type or Spent fuels (CU1 and CU2 packages)

Description of the packages

The CU1 and CU2 type packages group together the full UOX, URE or MOX fuel assemblies, with the following characteristics:

- **UOX2** : initial enriched $U_{nat}O_2$ matrix of 3,70% U235, and average rate of burn up of 45 GWd/t ;
- **UOX3** : initial enriched $U_{nat}O_2$ matrix of 4,50% U235, and average rate of burn up of 55 GWd/t ;
- **URE** : initial enriched $U_{nat}O_2$ matrix of 4,10% U235, and average rate of burn up of 45 GWd/t ;
- **MOX:** mixed oxide matrix (U–Pu) O2 made from a depleted uranium base (0,225% U235) and plutonium dioxide (8,65% Pu), and average rate of burn up of 48 GWd/t.

2. Thermal properties

The nominal residual thermal energy of the CU1 packages during the 60 to 1000 year cooling period, after the fuel assemblies are removed from the reactors, is illustrated in figure 5-3 below.

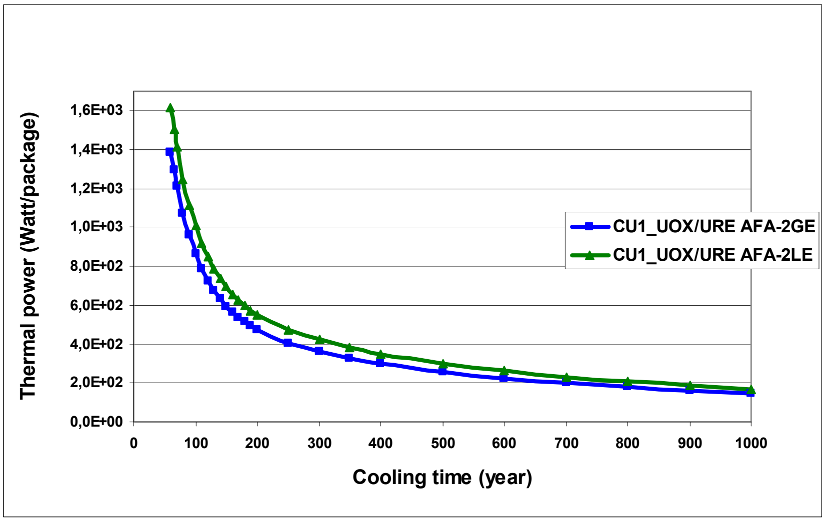

Figure 5-3: Illustration of the nominal residual thermal energy of the base case CU packages during the 60 to 1000 year cooling period, after removal from the reactors

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It is assumed that the repository will take the CU1 packages after a 60 year temporary storage period, following their removal from the PWR reactors.

The evolution of the nominal residual thermal power of the CU2 packages during the 60 to 1000 year cooling off period, after their removal from the reactors, is shown in Figure 5-4 below:

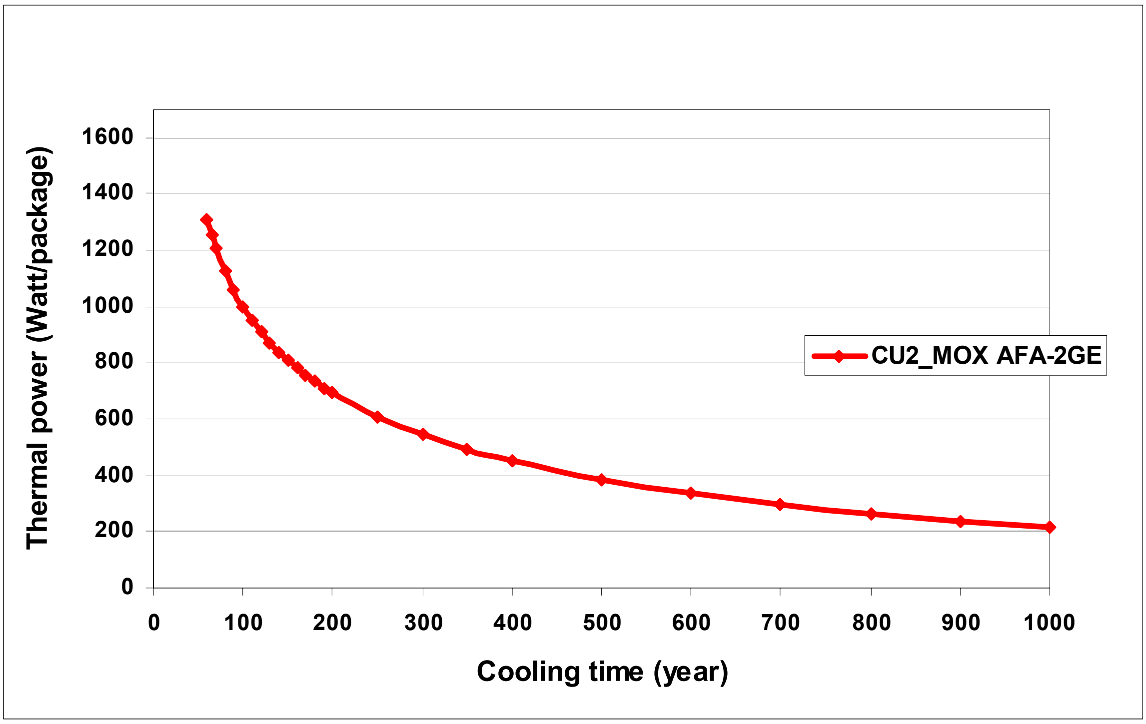

Figure 5-4: Evolution of the nominal residual thermal energy of the CU2 packages, during the 60 to 1000 year cooling off period, after their removal from the reactors

5.1.8 Final repository relevant characteristics of canisters

5.1.8.1 C type canisters

- The disposal canister of vitrified waste (C type) consists of a carbon steel cylinder, 55mm thick that holds a single primary package (Figure 5-5). This over-pack consists of two parts that are welded together: the cylindrical body with integral bottom and the lid.
- The cylindrical body of the over-pack is outfitted with sliding runners. These runners are pieces of steel with a ceramic coating. They are embedded in machined grooves in areas of the cylindrical body that have extra thickness for this purpose.

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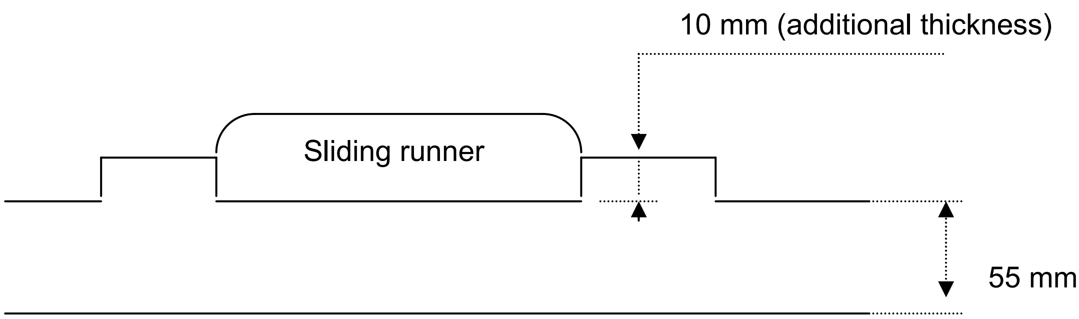

➢ On the inside the lid has a shape that fits the mushroom shaped grasping profile of the primary package and on the outside it is formed to facilitate handling. The latter consists of a groove machined into the rim of the lid.

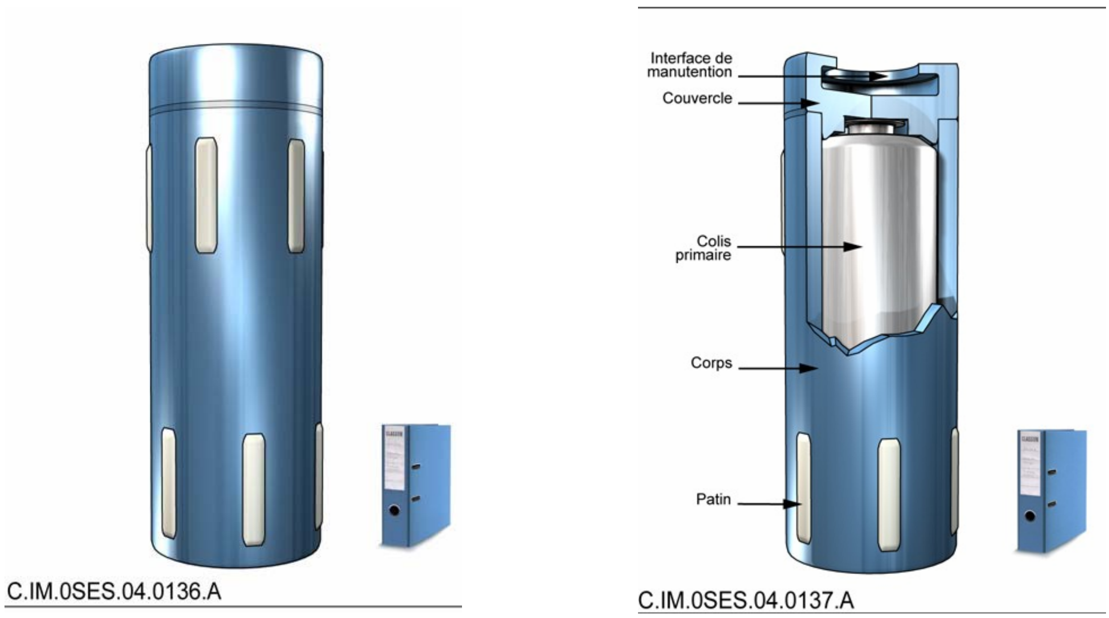

Figure 5-5: Overall view and cut away view of a C type canister

➢ There are 2 models of disposal canisters related to the geometry of the primary packages (the only difference between the 2 models is in their size and weight).

The C type waste canister considered in the present document for the future Demonstration of emplacement technology is illustrated below in Figure5-6 (for a maximum weight of 2 tonnes).

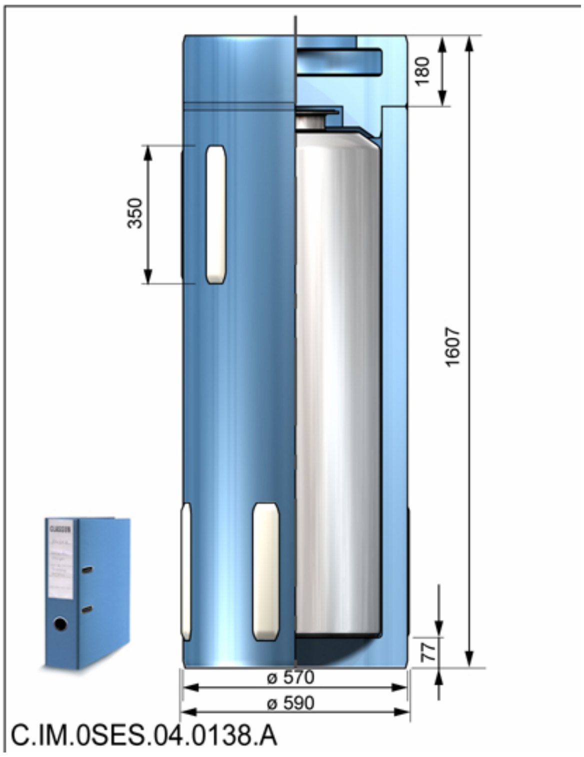

Figure 5-6: Geometrical characteristics of the C type canister to be emplaced in the demonstration phase of ESDRED Module 2.

5.1.8.2 CU type canisters

The canister consists of two parts that are welded together:

(i) A cylindrical body with or without an integral bottom,

(ii) A lid with handling recesses.

The canister is cylindrical to adapt to the design of the disposal cells and to minimize the voids therein. The base and the lids are flat; the lid has a groove machined into its thickness, for manipulation and in order to keep the voids in the disposal cell at a minimum.

The figure 5-7 below shows the main aspects of the CU 1 type canisters.

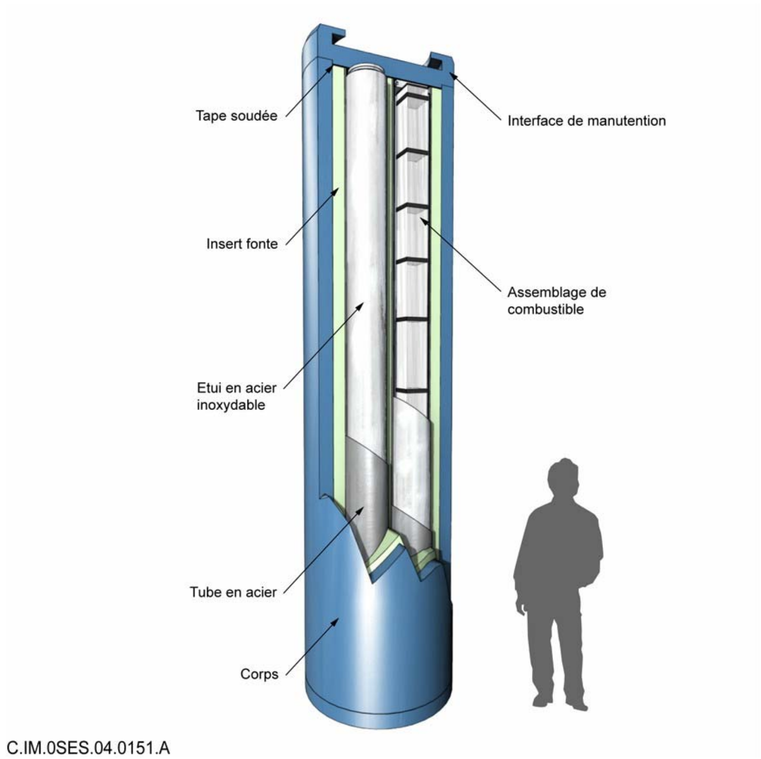

Figure 5-7: Cut away view of a CU1 canister

Note: *The emplacement technology for SF canisters of the CU1 type are dealt with in Module 3 (Heavy load emplacement), while Module 2 deals with a CU2 type of SF canisters.*

The CU2 type canister to be considered for the purpose of the demonstration in Module 2 is illustrated hereafter. The CU2 type canister differs from the CU1 type, mainly because it contains only one assembly of spent fuel (instead of four). Its weight and diameter are significantly different. Furthermore, it is equipped with sliding runners (similar to a C type canister), while the CU1 type canister is not (being emplaced by means of an air lift cradle and not by a pushing robot).

The figure 5-7 below shows the main characteristics of the CU2 type canister to be considered in the demonstration of Module 2.

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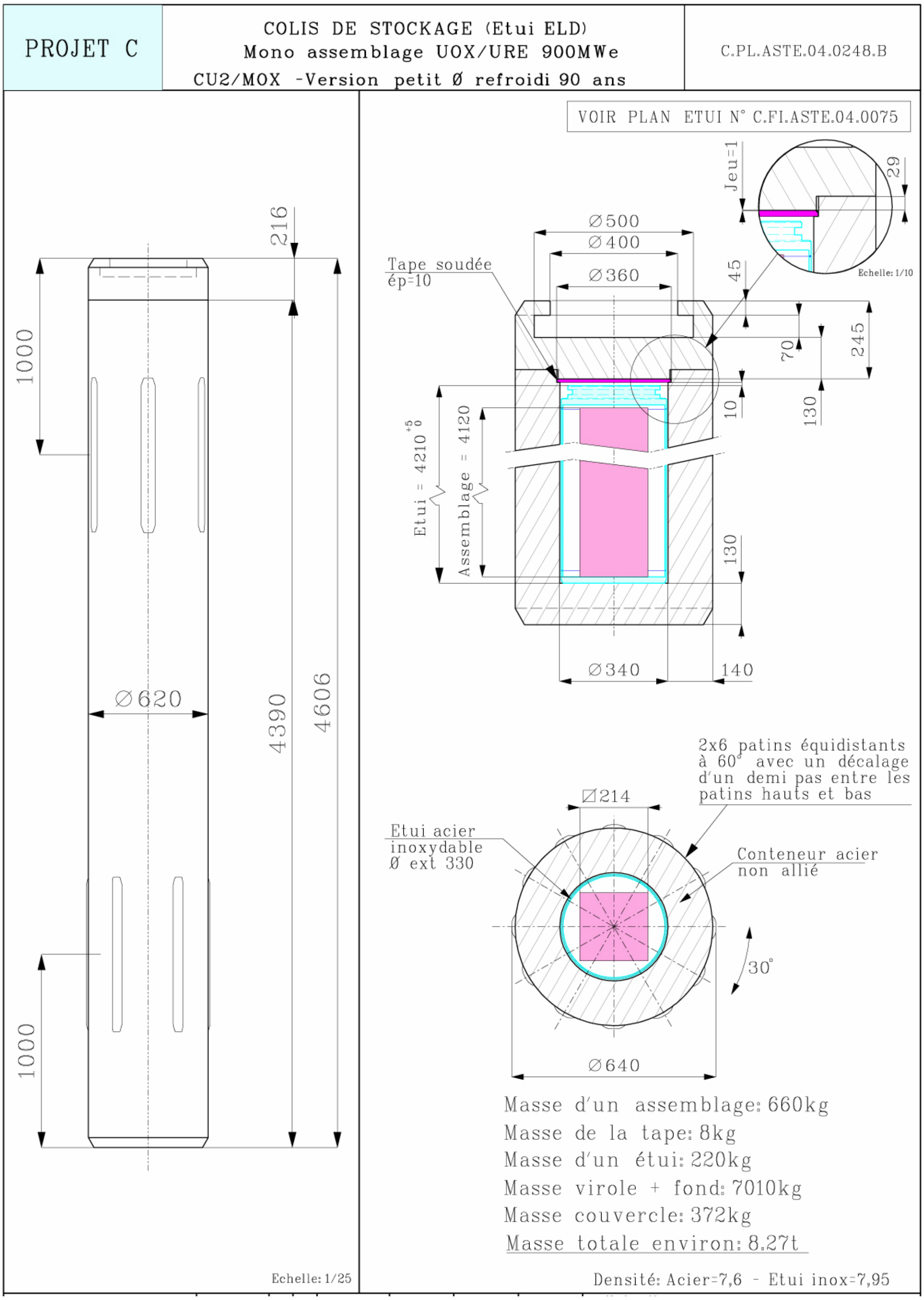

Figure 5-7: Main characteristics of a SF canister of the CU2 type.

6 State of the art drilling technology in the German concept

Generalities

For the preparation of the disposal boreholes, the state of the art in drilling technology is to be presented. It is furthermore to be shown, with which drilling technology method and equipment the task may be accomplished.

The input specifications for designing the drilling method are:

Drilling diameter:	600 – 700 mm
Borehole depth:	max. 500 m
Drilling cuttings removal (borehole circulation):	compressed air
Borehole deviation (from vertical):	max. 0.50 m

The conventional preparation of such boreholes is performed with brine circulation drilling technology. In this way however, the drill cuttings are carried out of the borehole by fluid circulation means. Besides the logistical problems created by the fabrication, use and disposal of the circulation brine below surface, the drawbacks of this procedure are the size of the drilling equipment incl. pumps as well as the low drilling power in salt by use of large diameter drilling bits.

Air is generally preferred as circulation means for evacuating the drilling cuttings up to the borehole head when drilling in salt. The various states of the art in drilling technology differ according to the mode of drilling, the circulation of cuttings, the direct circulation method or the lock drilling head system.

Direct Circulation Method

In contrast to the lock drilling head system, a standpipe with suction equipment at the borehole head is necessary for the direct circulation method. A precondition for this is, that the drilling cuttings pumped up are discharged into the annular space and that it is possible to install a blow out preventer (BOP) as a protection against gas and brine discharge (blow out).

The direct circulation drilling method still holds optimization potential in the rig components for the circulation of air (compressor technology, air cooling for heightening the dew point) and for the other drilling equipment.

In the KTB (continental deep drilling programme) project, a rotary vertical drilling system with a direct brine circulation method (also termed self-steering directional drilling system) was successfully employed.
The directional steering process takes place automatically in the borehole. The position of the drilling head is permanently recorded by sensors and transmitted to the steering

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Module above the drilling head. In case of deviations, a steering command is issued to the hydraulically adjustable designed runners. With this system, the drilling data are transferred to the surface via the drilling fluid. Other data transfer systems, like electromagnetic waves or cable, are either in the test stage or already in use, so that this directional drilling system also can be applied with air circulation.

In case there is a requirement to pre-drilling a core hole, it has to be checked if the vertical steerable drilling system is combinable with a core drilling system. Manufacturers of these systems are claiming this is possible. However, to date this has not been in application.

In Figure 6-1, a drilling rig of type Wirth HKB 2 for pre-drilling to a depth of 400 m is shown as it would be used for exploratory drilling in a salt deposit.

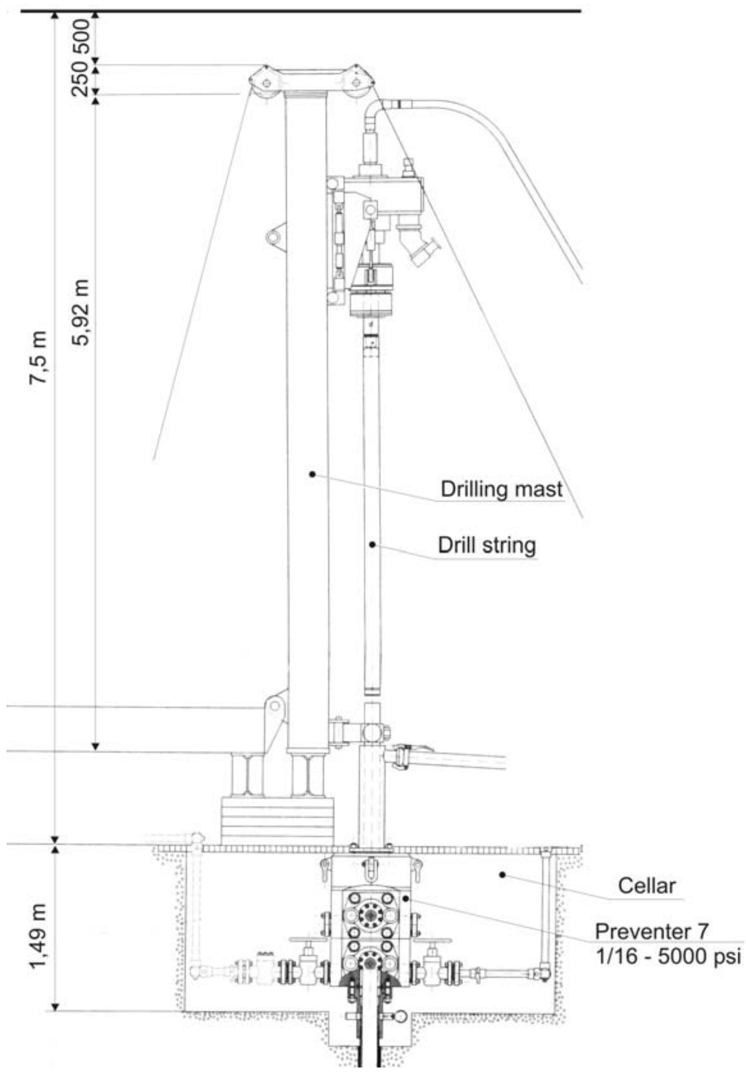

Figure 6-1: Drilling rig of type Wirth HKB 2 for pre-drilling to a depth of 400 m

Lock Drilling Head System

The results of an R&D project in the Asse URL showed the feasibility of using a lock drilling head system for repository purposes. There, one could forego pre-drilling a core hole due to detailed knowledge of the salt deposit and the thereby qualified certainty of the absence of gas pockets. The technology employed there is based on a drilling rig that consists of a planetary drilling head with a guide component.

The main part of the guide component is a booth wheel designed as a lock. This is driven by a cable with an arrangement of drill pipes over a reduction gear unit. It brings the drilling cuttings from the drill, which works under atmospheric pressure, to the feed stream of the air circulation, which stands under overpressure.

Over the planetary disks and screw the drilling cuttings arrive from the drilling head at the feed opening of the booth wheels, which feed it to the continuous conveying air flow.

In this planetary drilling head of type SBK600 by the company Turmag (no longer in operation), a control and steering system was incorporated in order to be able to perform blind hole drilling with minimum deviation even at great depths. For this purpose the stationary part of the drilling head contains two Inclinometers designed for this rough operational environment. They show the borehole deviation during drilling on a display at the borehole head.

After evaluation of the inclination data, a computer calculates the absolute deviation and the azimuth. With this data, the device operator has the option of correcting the drilling head by means of hydraulically driven servo units. These are steered by cable and servo valves.

With this system, blind hole drilling of 600 mm diameter and a depth of 330 m with a deviation of 120 mm has been performed in the URL Asse.

Technical maturity for using this equipment was not achieved within this project. For that, a number of developments/improvements are still necessary. The construction of a cellar is not necessary. According to a concept study, minimal drift heights of 4.200 mm are feasible with this method. It still needs to be examined whether further development of this technique with regard to applicability in gas prone areas is possible.

Project Related Implementation of the State of the Drilling Technology

For drilling in salt and site-independent planning it must be conservatively assumed that gas occlusions are present. For this reason it has to date been necessary to perform a pre-drilling. This is because the controlled discharge of gases under high pressure when drilling small diameter boreholes is technically well controllable.

The basic concept is the employment of a drilling system with direct circulation method, with which the pre and main drilling operations are both performed with the same drilling equipment. According to statements by the renowned manufacturer of drilling rigs Wirth, in Erkelenz (Germany), similar rigs have already been realized in surface fields.

In order to be able to do without expensive special sizes and special adaptations (e. g. double wall drill pipes) by gas tight borehole closure (the so-called BOP), it is sensible to employ drill bits and drill pipes of standard sizes when performing the pre-drilling. With the given drift height, the drill bit and drill pipe sections will be maximum 3 m long. This means a small but still acceptable drilling progress due to the frequent breaking of the drill pipes.

After completion of the pre-drilling, drilling according to the reference diameter is performed. Here the pre-drilling can serve as a guiding hole.

7 State of the art of Tunnel Boring Method applied to horizontal cells in the French concept

Note: *The descriptions provided hereafter apply to the concept and construction of C type waste disposal cells (a similar method can be used for excavating CU type disposal cells, but with a larger diameter to allow for engineered barrier emplacement).*

Description of a typical disposal cell

A standard C type disposal cell is a small 700mm diameter dead end tunnel about 40m long and lined with a metal sleeve and **without an engineered barrier**.
The disposal cell is made up of the active section (body) and the head:

- The 30m long active section (or body) receives the disposal packages. It is located outside the damaged zone that surrounds the handling drift. It is outfitted with a permanent metal sleeve which holds from 5 to 22 disposal packages (depending on their thermal power), separated by spacers.
- The head, 8m long, evolves with the transition from the operations to the sealing phase:
  - during the operations phase it consists of an assembly of interlocking metal tubes,
  - during the sealing phase the metal tubes are removed and replaced by a double plug of clay and concrete.

Note: *The figure 7-1 shows the main components of a C type waste disposal cell.*

The components of the active section and their functions

- The **permanent metal sleeve** holds the disposal packages and enables these to be retrieved in the framework of reversibility. It is intended to be functional for a century. The sleeve also contributes to improve heat transfer even if that is not its primary function.
- The **spacers** separate the disposal packages from each other and therefore reduce the average heat flow to the surface of the sleeve. This makes it possible to have fewer disposal cells as compared to the number that would be required if the disposal packages were “touching”. Therefore the presence of spacers helps to reduce the m3 of excavation per disposal package, which has a big impact on the cost of the repository and also contributes to the optimisation of the layout of the repository

The components of the head of the disposal cell and their functions during operations

- The **temporary sleeve (casing)** is a metal tube used to cap the head of the disposal cell. It is attached to the permanent sleeve; this allows the disposal packages to be inserted from the head of the disposal cell. It is hammered tight into the rock before the excavation starts. Its function is to keep the damage zone in the critical area, where the clay plug is to be installed, to a strict minimum. During closure of the disposal cell the temporary casing is withdrawn at the end of the process and is replaced by a plug of swelling clays, without leaving any annular voids

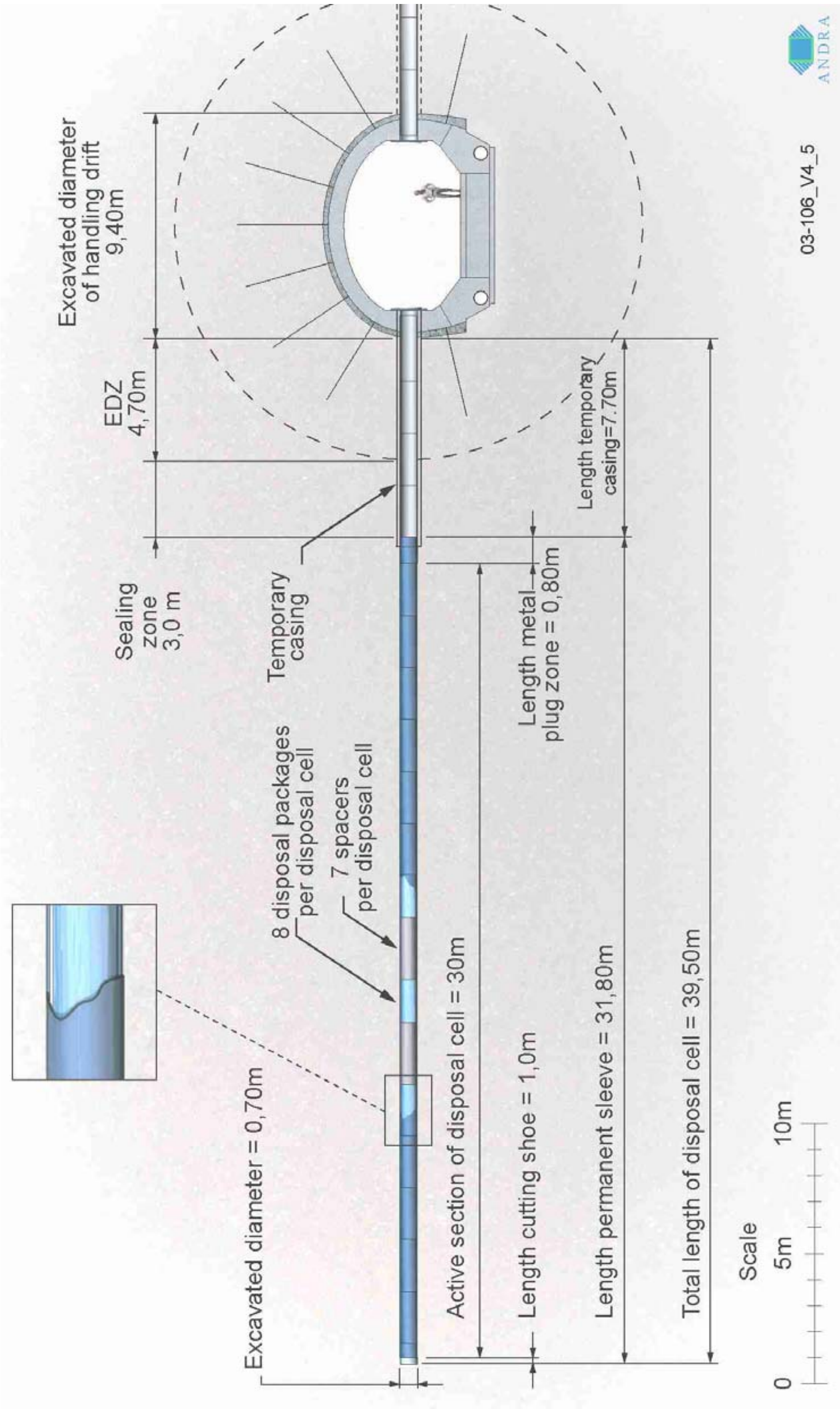

Figure 7-1: Main components of a C type waste disposal cell

- The **docking equipment (shield and access port)** enables the transfer cask to dock with the head of the disposal cell and provide radiation shielding when operating the disposal cell; they are removed when the disposal cell is closed.

<u>The components of the head of the disposal cell and their functions during sealing</u>

The following components play a role during closure:

- The **metal plug** ensures radiation protection during closure. It is installed immediately after the last disposal package is inserted and is permanently left in place behind the last disposal package and the swelling clay plug.
- The **swelling clay (bentonite) plug** is at least 3m long; is made of a mixture of swelling clays and sand; it must be located outside the damage zone created by the handling drift, i.e. at least 0,5 times the handling drift radius away from the handling drift
- The **retaining (concrete) plug** behind the swelling clays plug is made of concrete. Its length is at least 0.5 times the handling drift radius. In order to withstand the swelling pressures this retaining plug has been provisionally sized at 1,0 times the radius of the handling drift i.e. 4,7m.

<u>Note:</u> *The cross section of the cell and the mechanical clearances with the waste package to be emplaced are illustrated below in Figure 7-2.*

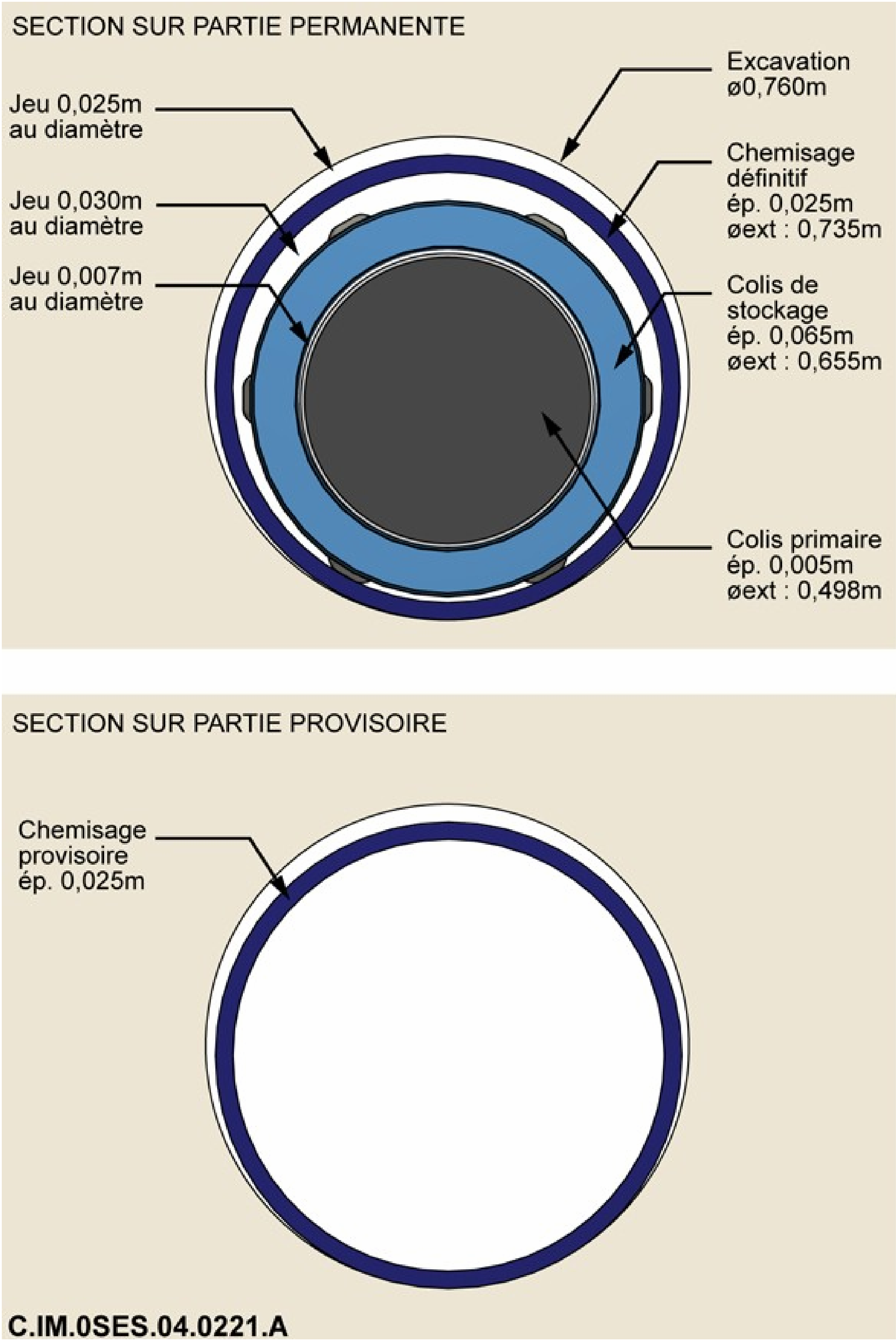

Figure 7-2: Cross section view of the main mechanical clearances in a disposal cell for C type canisters

Description of the implementation method

In order to best reduce the damage to the argillite in the sealing zone, a tube (temporary casing) is first introduced into the ground. This installation method guarantees a perfect contact between the casing and the ground, thus no subsequent convergence[1]. Installation by hammering is possible because:

- the casing is relatively short (approx 8m),
- the diameter of the casing (approx 700mm), guarantees sufficient inertia,
- the ease of penetration into the argillite,

The hammering of the temporary casing is followed by drilling, first inside the temporary casing and then on the extension of the 38 to 40 m of the disposal cell. This excavation is done by a cutting tool that is rotated and pushed by a string of rods attached to the drill. The cutting head is followed in the hole by a tube that secures the ground and which is left in place to become the permanent sleeve. Sections of the sleeve are inserted, screwed together and pushed into the drill hole by a “tube pusher” mounted on the drill; the drill – push tube assembly is mounted on the “pusher frame” that is mounted in the handling drift. The sleeve is pushed but is never turned in the ground.

At the end of the drilling the cutting tool is removed from inside the sleeve. This presumes a retraction of the gauge cutters which in the drilling mode cut a diameter equal to the external diameter of the sleeve. Retraction of the gauge cutters enables the cutting head to pass through the interior of the sleeve to be fully recovered and reused for another disposal cell.

The end of the sleeve is then closed off by welding a plate on the end.

The different phases and the associated materials/equipment are described below and illustrated in figure 7-3.

<u>The pusher frame, the drill and the tube pusher</u>

The pusher frame is anchored into the invert lining of the handling drift.
The drill provides the rotation and the pushing force on the cutting tool.
The tube pusher slides the sleeve into the ground (and can trim the hole, see below)
Two clamps mounted on the drill slide enable two sections of sleeve to be screwed together. The forward clamp holds the part of the sleeve already inserted into the drill hole while the back clamp rotates the new section of sleeve.
The length of the drilling equipment inside the handling drift is 5m, and would be longer if sleeve sections longer than 2m were to be used.

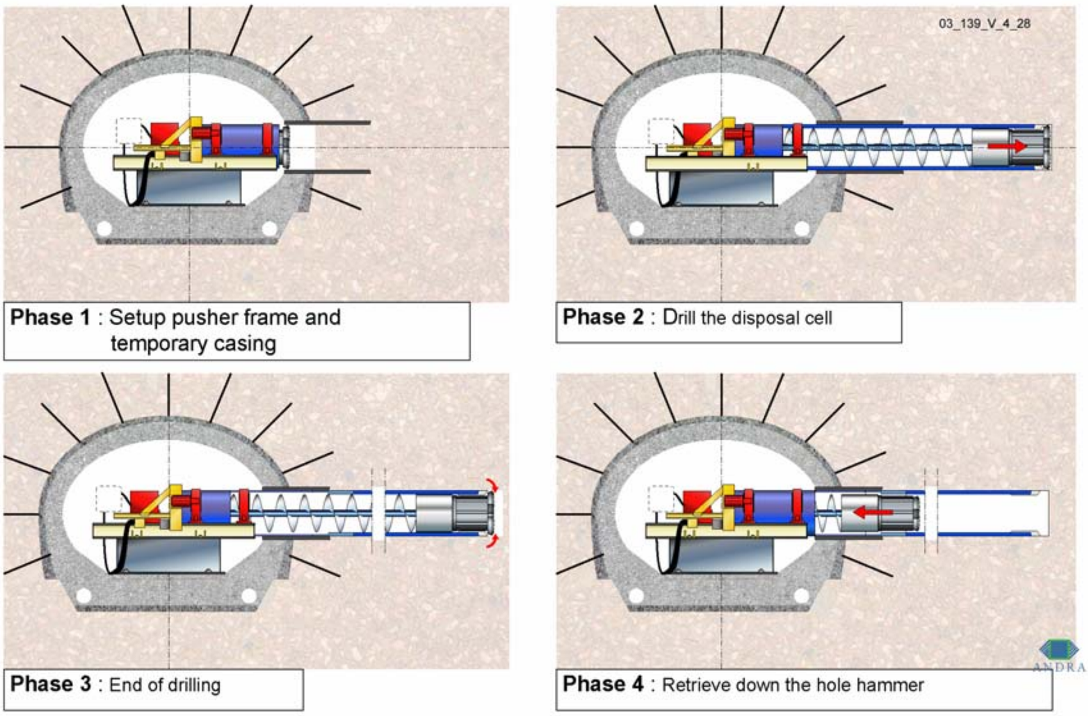

Figure 7-3: Main Steps of an excavation sequence for a C type canister disposal cell

8 State of the art of borehole disposal

General description of the borehole disposal concept

For the final disposal of heat generating, unshielded HLW canister and BSK 3 types, the emplacement in vertical boreholes is conceptually feasible. The depth of the vertical boreholes is approximately 325 m. After allowing 10 m for the plug and 25 m for non-removable cuttings at the bottom the useable length of deep boreholes is approximately 290 m. The actual usable borehole length in the final disposal concept can not be determined as it depends on a number of factors like, e.g., heat quantity, waste quantity, emplacement technique, and drill technique. It is furthermore possible also to emplace CSD-C-canisters with identical technique, as long as their outer geometry is adapted to the HLW-canisters. The diameter of the borehole depends on the convergence rate of the surrounding salt and time lapsed before filling the borehole with waste canisters.

For borehole disposal, the designated emplacement drifts are furnished with boreholes at regular intervals. The drilling begins at the front end of an emplacement drift and ends at the branch off to the cross cut following the order of later waste disposal and backfilling. Every borehole is furnished with a concrete borehole head, which will be locked by a borehole cover. The borehole cover enables the prepared empty boreholes to be crossed during emplacement operations. After removal of the borehole cover, the borehole head accommodates the borehole lock, which takes care of the shielding of the borehole during the emplacement phase. The ventilation of the boreholes is accommodated through an annular gap over a socket, onto which a suction pipe is attached.

The HLW-, CSD-C- and fuel rod canisters are delivered to the shaft station handling facility in transfer casks, reloaded onto transport carts and transported to the final disposal location underground. Each transport cart can carry one transfer cask.

8.1.1 Emplacement Technique for Borehole Disposal of HLW- and CSD-C- Canisters

The transport cart with the transfer casks for separate HLW canisters is pulled by a mining locomotive from the shaft loading station along the access path to the predetermined emplacement location. In the emplacement location the loaded transport cart is pulled under the emplacement device which has been positioned above the foreseen borehole (Figure 8-1). With gantry crane 1 the transfer cask is raised and positioned on the borehole lock. A turning device on gantry crane 1 makes the simultaneous substitution of a loaded and an emptied transfer cask in a single swap operation possible. For the emplacement, gantry crane 1 is moved to the side and gantry crane 2 positioned over the transfer cask which stands on the borehole lock. Gantry crane 2 is equipped with a shielding cap and an emplacement winch. The shielding cap serves as shield of the package while opening the upper transfer cask lid. An actuator for the opening and closure of the upper transfer cask lid and the package gripper is integrated into the shielding cap. After the positioning of gantry crane 2 above the transfer cask the shielding cap is lowered and bolted onto the transfer cask. Afterwards, the upper lock plate of the transfer cask is removed and the package gripper lowered onto the package and locked onto it. After a slight rise of the package, the lower lock plate of the transport cask and the borehole lock are opened and the package lowered into the borehole. After the lowering of the package, the gripper is decoupled from the package and the hoisting wire is retracted. The transfer cask lock plates as well as the borehole lock are closed. Subsequently, the shielding cap is unlocked, raised and moved to the side using gantry crane 2.With gantry crane 1, the unloaded transfer cask is removed from the borehole lock and loaded onto the transport cart for transportation. Afterwards the reception of the next package can follow. All processes are carried out by remote control from the local control centre. On the basis of a safety analysis to be carried out, it shall be decided if load reduction elements are to be inserted into the borehole and at which intervals these are necessary in order to avoid eventual unacceptable loads on the package by the remaining package column mass above it.

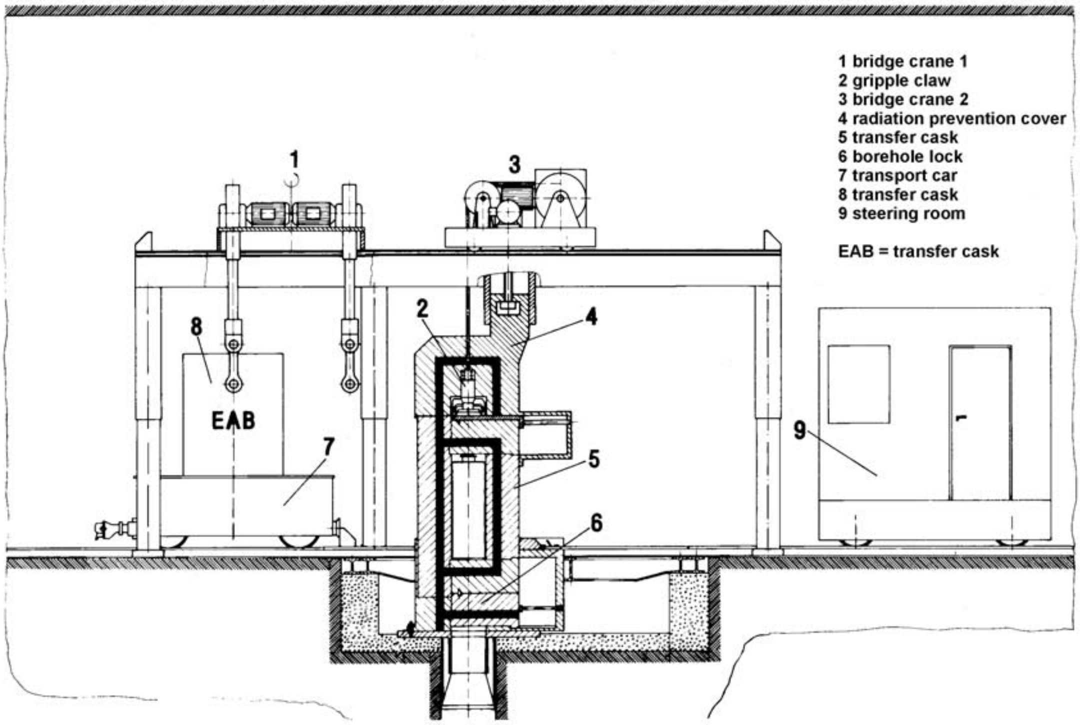

Figure 8-1: Emplacement Device for the Borehole Disposal of HLW Canisters

The boreholes are filled up within 10 m of the borehole head, backfilled and subsequently closed at the level of the drift floor. An outline of the required cross-section of the transportation drift is shown in Figure 8-2. The height of the transportation drift is determined by the height required by the drilling equipment.

After filling of a borehole, the emplacement device is moved to the next borehole by means of a transport cart. Here it is set up and equipped. After attachment of the supply and steering cables as well as a test run, the emplacement of the packages follows in the same way as described above. After the filling and closure of all boreholes in a disposal drift, this is closed.

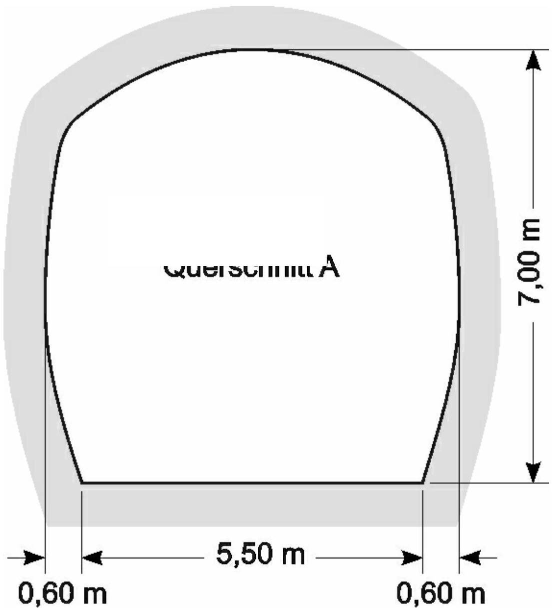

Figure 8-2: Outline of the Required Drift Cross-section for Deep Borehole Disposal of HLW and CSD-C Canisters

8.1.2 Emplacement Concept for Fuel Rod Canisters

As an alternative to the direct disposal of spent fuel assemblies in POLLUX® casks in horizontal drifts, a concept for vertical borehole disposal of fuel rod canisters was developed.

In a similar way as described under 6.1 it seems to be possible, with the help of a larger emplacement device, to bring in larger packages, like the BSK 3, into a borehole as well. The height of the transportation drift is no longer determined by the height of the drilling equipment but by the height of the emplacement device. In addition it is necessary to raise the transfer cask into the upright position at the place of loading onto the transport cart, at the shaft landing station and at the place of emplacement. An outline of the necessary cross-sections is given in Figure 8-3.

In the study "Update of the Concept – Repository Gorleben" it was assumed that the transfer casks were loaded in the PKA (Pilot Conditioning Plant) and delivered ready for use in the emplacement process.

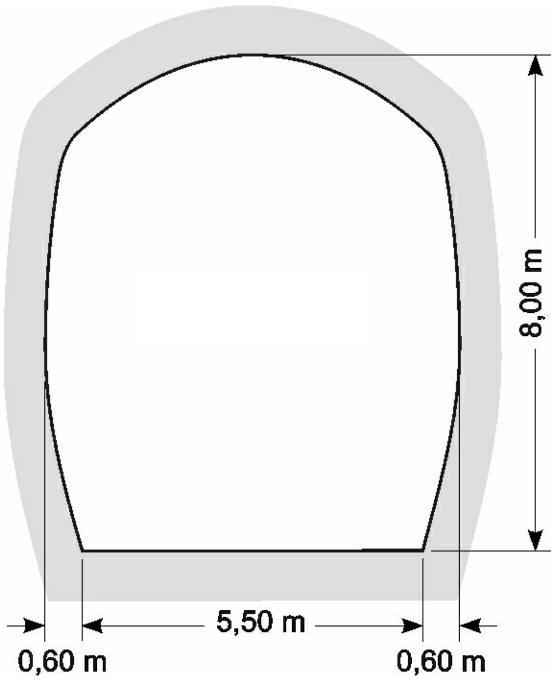

Figure 8-3: Outline of the Required Cross-section for the Deep Borehole Disposal of BSK 3

HLW-Experiment at the Underground Research Laboratory Asse

As only tested and proven methods may be employed in a repository Reference /7-1/, should, a technical system for the emplacement of highly radioactive waste canisters must be developed and tested within the framework of the HLW project. Within this system, an emplacement method for Cogema HLW canisters should be developed. The test with test sources was planned in the Asse mine. The test programme could be completed up to the realization of the emplacement with active sources.

8.1.3 Emplacement Concept

The technical system of the HLW borehole disposal test comprises all handling operations from the arrival of the loaded transport casks at the mine to the emplacement of the canisters. To this end an above surface reloading facility was constructed, in which the canisters were reloaded from multiple transport casks into transfer casks.

The components of the system had to be adapted to the conditions of the Asse mine. I.e. the transport weight of the loaded transfer cask could be 10 t maximum, corresponding to the lifting capacity of the mine hoisting system. The width of the shaft cage limited the outside diameter to 1.15 m. Because the borehole was lined for retrieval reasons, the diameter of the canisters had to be chosen smaller in order to simulate the proper outside diameter when coupled together with the tubing. For the same reason, a higher radiation dose rate had to be realized in order to compensate for the shielding effect of the tubing, but preserving the same heat rate.

8.1.4 Component Description

The Asse HLW emplacement system (Figure 8-4) consists of;

- **Above surface reloading hall with reloading station**
- **Transfer cask (single shielding cask) with canister gripper**
- **HLW test canister**
- **Borehole lock**
- **Drift transport vehicle**
- **Emplacement device, and**
- **Shielding cap with coupling gripper**

- **Above surface reloading hall with reloading station**

Multiple use transport casks are delivered, which are discharged directly into the transfer casks through a docking station.

- **Transfer cask (single shielding cask) with canister gripper**

The transfer cask consists, besides the cask body, mainly of a canister gripper integrated in the lid and a lock at the cask bottom. With the use of the canister gripper, on which the coupling gripper couples to the shielding cap, the canister is lowered into the borehole. The canister gripper is activated by magnets in the coupling gripper and grabs – together with the coupling gripper – the canister. The relatively large opening arising from the lowering of the canister gripper is shielded by the shielding cap.

The lock at the cask bottom is opened by and with the borehole lock over the borehole.

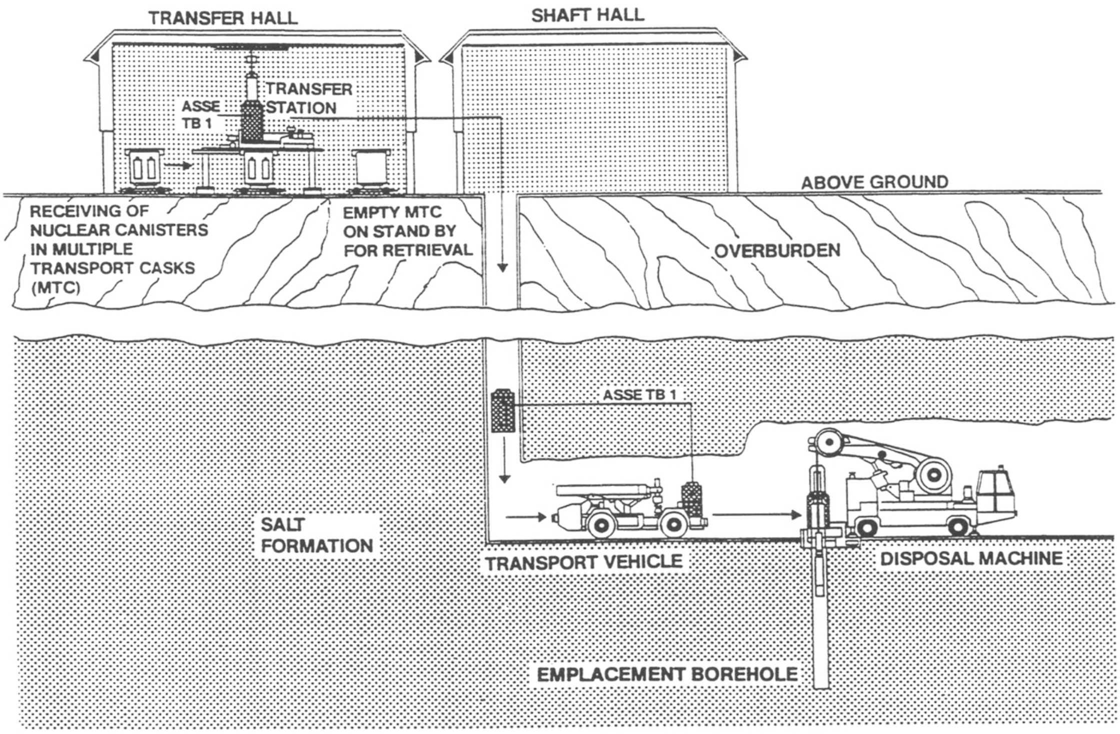

Figure 8-2: Overview of the “Asse” HLW Emplacement System

Main data of the transfer cask (without shock absorbers)

- Outside diameter: 1100 mm
- Utilizable inside diameter: 440 mm
- Height: 2000 mm
- Utilizable inside height: 1214 mm
- Cask weight (loaded): 10 t

– **HLW test canister**

- Weight 250 kg
- Height: 1200 mm
- Diameter: 300 mm

– **Borehole lock**

The borehole lock consists of a casing with the lock, the lock drive, the drives for the interlock of the drawer, the chamber for the reception of the locks and the drawer of the transfer cask. The drivers are controlled by the emplacement device (ELV). The weight is approximately 1 t.

– **Drift transport vehicle**

The drift transport vehicle is an underground licensed, diesel powered kink loader. It serves to transport the transfer casks from the shaft loading station to the emplacement borehole. The handling of the transfer casks including transport and positioning onto the borehole lock, is carried out by the drift transport vehicle by means of its retractable crane arm. The head of the crane arm is fitted with a gimballed hydraulic driven turning device.

– **Emplacement device**

The canister within the transfer cask positioned on the borehole is handled by the drift transport vehicle through the emplacement device (see Figure 8-5), i.e. lowered into the borehole. The ELV can move around on pneumatic wheels.

The ELV accomplishes the following tasks:

- Largely automatic emplacement of the HLW canisters (including handling of the shielding cap) as well as control of the borehole lock,
- Independent repositioning to the next borehole.

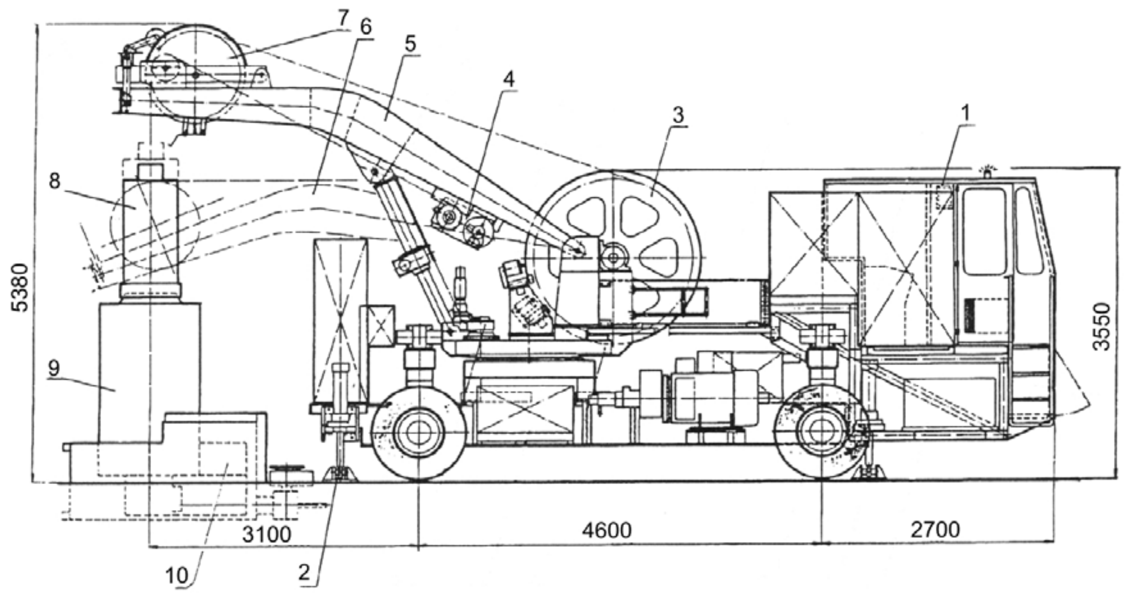

Figure 8-5: Asse Emplacement Device

The drive of the ELV, respectively of the single components takes place electrically or electro-hydraulic through a 500V connection or by means of batteries. On the vehicle frame there is a sled onto which a hoisting arm slewing unit is attached, which holds the hoisting arm, the main winch, and the winch for the shielding cap. The frame also holds a cabin, which serves as steering and operator cabin, the hydraulic system, the steering canister, the batteries and the telescopic support for the level control system of the vehicle. Besides the other positioning capabilities of the ELV, the sled also serves the fine adjustment positioning above the transfer cask through movements in the vehicle lengthwise direction. The hoisting arm slewing unit is operated by means of a spindle lift device between the transport position and the work position; with the hoisting arm fine adjustment of the position is possible as well. For this purpose the rope which, besides the task of holding the canister and the shielding cap, also serves the electromagnetic activation of the gripper, via seven interior copper laced wires. The control of the emplacement process (i.e. the winch for the canister and the shielding cap, the canister, the coupling grippers as well as the borehole lock) including the mounting of the supporting elements and the salt gravel for the filling of the annulus takes place by means of memory programmable controller (SPS).

Essential technical data:

Dimensions

• Length		9800 mm
• Width		2800 mm
• Height with hoist arm	in driving position	3800 mm
	in emplacement position	5300 mm
Total weight (evenly distributed over 4 wheels)		29,7 t

Emplacement winch (main winch)

• Load capacity	1,4 t
• Depth	300 m
• Rope diameter	15 mm
• Hoisting drum diameter	1700 mm
• Diameter of the deflection roller	1000 mm

Energy supply

• For the stationary winch operation from the mining network	3 x 500 V, 50 Hz
• For the traction operation (batteries, rectifier, charger)	160 V ≈

- **Shielding cap with coupling gripper**

The shielding cap consists of the shielding body including neutron shielding as well as the therein integrated coupling gripper. The coupling gripper is firmly connected to the rope of the respective hoisting gear. It contains a magnet with 3 coils for coupling, activation (grab the canister) and release of the canister gripper. Through 3 metal sticks the gripper latches are operated, which grip from inside the head of the canister gripper.

Essential technical data

- Total height: 1553 mm
- Total weight: 1650 kg

Emplacement Device in Underground Research Laboratory Äspö, Sweden (SKB)

In 1996, the Swedish final disposal organization SKB commissioned the present Babcock Noell Nuclear GmbH for the development of a borehole emplacement device for the demonstration of the disposal of casks with spent fuel assemblies. Basis for the work was SKB's KBS-3 final disposal concept from 1983 Reference /7-2/, which foresaw the vertical disposal of casks in shallow boreholes.

The proposed disposal cask for spent BWR or PWR fuel assemblies is characterized by the following main characteristics:

Diameter	1050 mm
Height	4833 mm
Total weight (according to Noell)	29 t
Side dose rate	300 mSv/h
Top and bottom dose rate	100 mSv/h
Cask material	Copper

The disposal procedure takes place as follows:

- Delivery of the transport cask below surface
- Reloading of the disposal canister from the transport cask into a transfer cask at a reloading station below surface
- Transportation through the drift transport of the transfer cask
- Handing over of the transfer cask onto a transfer platform
- Engaging of the transfer cask by the transfer platform in the track connected emplacement device
- Drift transport by means of the emplacement device to the emplacement position
- Opening of the cask by division into two parts within the emplacement device

- Unloading of the half with the disposal cask in a tilting movement with simultaneous horizontal movement in a borehole already furnished with bentonite rings for long term sealing
- Placing of the disposal canister in the borehole
- Closing of the borehole with prefabricated bentonite parts

The borehole (Figure 8-3) with raw dimensions ø 1750 mm, l = 7833 mm is filled in with a canister. After positioning of the bentonite bottom slab and 5 bentonite rings covering the height of the disposal canister the borehole still has a depth of 7333 mm and an inside diameter in the bentonite stretch of 1070 mm.

The emplacement device (see Figure 8-4) has the following technical data:

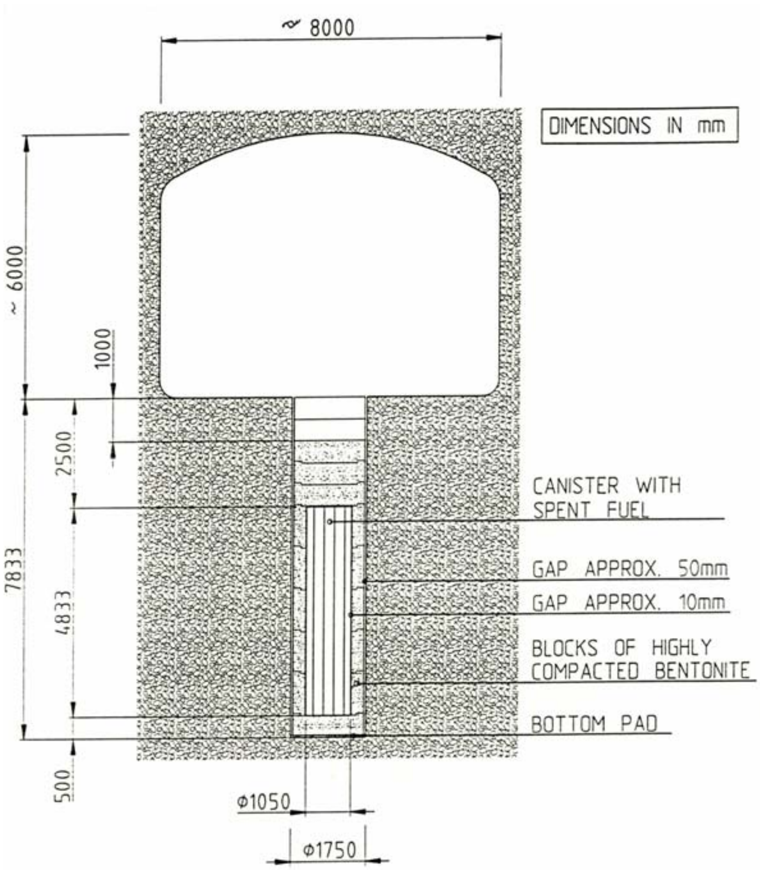

Figure 8-3: Borehole and traverse drift as of 1996.

Figure 8-4: Emplacement Device in Underground Research Laboratory Äspö

Length	11.8 m
Width	3.7 m
Height	4.6 m
Weight (loaded)	approx. 160 t

The height of the emplacement drift to accommodate the erection of the emplacement device is approx. 4.7 m. German mining regulations, like e. g. to observe a minimum distance of 500 mm between the roof and the horizontally movable emplacement device, were thereby not considered.

With the emplacement device the emplacement of a disposal cask was successfully demonstrated.

9 State of the art of emplacement in horizontal cell as per the French concept

No previous technical experiments have been implemented by ANDRA in underground (mine or URL) locations, so far. The state of knowledge is therefore limited to the experiments carried out by other Waste Management Organizations (see chapter 8) and to ANDRA 's preliminary studies (see chapter 4).

10 Methodology for deriving functional requirements

To derive functional requirements the following methodological steps have to be applied:

- Methodological advice on proposing the set of functional requirements
- Definition of applicable norms and technical rules
- Compilation of safety requirements, radiation protection and classical security for the entire system
- Compilation of operational requirements for the entire system
- Compilation of boundary conditions as well as external requirements and constraints
- Definition of interfaces between external and internal equipment

Methodological approach to develop a set of functional requirements

To derive the functional requirements, it is recommended to proceed step-by-step as described below.

a) Following the definition of the applicable norms and technical rules a list of safety and operational requirements that must be met during the design, manufacturing and experimental phase of the disposal operation have to be compiled. In addition the boundary conditions, external requirements and constraints have to be considered. On the basis of the appropriate results the functional requirements have to be fixed for the entire emplacement system.

b) The next step is a comparison of several technical solutions which all meet the requirements defined before. This will lead to the best conceptual design of an emplacement device. It is recommended to use, whenever possible well known and well advanced, highly reliable technical components for the details of the construction.

c) An optimized conceptual design will provide the basis for determining the developed functional requirements. Finally this will lead to the development of functional interlocking conditions (mechanical and electrical) controlled by a safety circuit.

Definition of applicable norms and technical rules

The functional requirements shall be developed on the basis of the guidelines and regulations issued by the competent regulatory bodies. Basic recommendations are included in the IAEA Safety Standard Series. In the document "IAEA Safety Standards: Safety Principles and Technical Criteria for the Underground Disposal of High Level Radioactive Wastes Safety Series No. 99" Reference /9-1/ , the following is explicitly stated

> "Criterion No. 5: Repository design and construction"
>
> A high level radioactive waste repository shall be designed, constructed, operated and closed in such a way that the post-sealing safety functions of the host rock and its relevant surroundings are preserved.
>
> In the early stage of site confirmation and later during the construction and closure of a repository, special attention should be given to the techniques used and to the execution of fieldwork so that the isolation capabilities of the site will be diminished as little as possible. The consequences of disturbances caused during these operations should be assessed with regard to their safety implications.
>
> The impact of the wastes and any engineered structure emplaced in the repository on the characteristics of the hydrogeological environment should not impair those properties of the host rock which are relevant to safety."

In "IAEA Safety Standards: Geological Disposal of Radioactive Waste, Draft Safety Requirements, DS 154, 2003-04-01" /9-2/ the following demands are listed for the operational phase:

- Elaboration on radiological protection policy for the disposal of radioactive waste is given in Reference /9-3/,

During the operational phase of a geological disposal the radiation doses to workers and members of the public exposed as a result of operations at the disposal facility shall be as low as reasonably achievable, social and economic factors being taken into account, and the exposures of individuals shall be kept within applicable dose limits and constraints, given in the Basic Safety Standards (BSS) References /9-4/ and /9-3/.

In addition to the routine exposure of workers and members of the public, consideration also needs to be given to potential exposures in non-routine or accident situations. These might include, for example, a fire involving waste packages or their damage during handling on the site. Requirements for the management of such hazards are given in Reference /9-4/.

In this document it is stated:

- National radiation protection requirements shall take due account of the BSS Reference /9-4/ and shall apply to the operational phase of the repository.

In particular, the radiation protection of persons who are exposed as a result of operations at the waste repository shall be optimised and the exposures of individuals kept below dose limits. The dose limits for occupational exposure for workers and for members of the public prescribed in national regulations shall apply during the operational phase of a repository. Internationally endorsed values for these limits are contained in Schedule II of the BSS Reference /9-4/

As shown in these guidelines the national radiation protection rules consider that the international standards are applicable to radiation protection purposes. The national rules for engineering and workers safety shall be applied. For the radiation protection, the engineering and workers safety rule and limit shall be compiled and exposed.

The regulations that have influence on the structural design and the operational safety (particularly safety technical rules and quality assurance) are quoted.

For some different systems within the repository project, no specific regulations are in existence. In those cases, a specification is written following the blueprint planning. The specifications are based on regulations that refer to similar types of technical facilities. For the canister emplacement device, for example, they are supported by the regulations for hoisting devices (KTA rules and norms).

10.1.1 International regulations

The following table gives a compilation of international regulations

Denomination	Title, German	Title, English	Edition
ICRP	Empfehlungen der internationalen Strahlenschutzkommission (ICRP Nr.60)	Recommendations of the International Commission on Radiological Protection, ICRP Publication 60, Annals of ICRP 21, Nr. 1-3	1990
ICRP	Empfehlungen der internationalen Strahlenschutzkommission	Conversion Coefficients for use in Radiological Protection Against External Radiation, ICRP Publication 74, Annals of ICRP 26, Nr. 3-4	1996
ICRP	Empfehlungen der internationalen Strahlenschutzkommission	General Principles for the Radiation Protection of Workers, ICRP Publication 75, Annals of ICRP 26, Nr. 3-4	1997
IAEA	Veröffentlichung der Internationalen Atomenergie-Organisation (IAEO)	Recommendations of the International Atomic Energy Agency, Safety Series N. 60	1983
IAEA	Veröffentlichung der Internationalen Atomenergie-Organisation (IAEO)	International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115	1996
IAEA	Regelungen für den sicheren Transport von radioaktiven Stoffen	Safety Standards Series No. TS-R-1 (ST-1, Revised); Regulations for the Safe Transport of Radioactive Material: Requirements	1996
IAEA	Veröffentlichung der Internationalen Atomenergie-Organisation (IAEO)	Safety Series No. 111- G-4.1, Sitting of Geological Disposal Facilities- A Safety Guide	1994

Denomination	Title, German	Title, English	Edition
IAEA	Veröffentlichung der Internationalen Atomenergie-Organisation (IAEO)	Safety Series No. 111-F, The Principles of Radioactive Waste Management	1995

10.1.2 European regulations

This section contains, among others, harmonized norms whose sources of information have been published in the gazette of the European Union and which triggers the conformance presumption. I.e. the manufacturer may assume that the safety requirements of the corresponding EU guidelines are fulfilled by the correct application of harmonized norms.

Denomination	Title, German	Title, English	Edition
DIN EN 418	Sicherheit von Maschinen; NOT-AUS- Einrichtung, funktionelle Aspekte; Gestaltungsleitsätze	Safety of machinery - Emergency stop equipment, functional aspects; Principles for design.	01/1993
DIN EN 457	Sicherheit von Maschinen; Akustische Gefahrensignale; Allgemeine Anforderungen, Gestaltung und Prüfung	Safety of machinery; auditory danger signals; general requirements, design and testing	04/1992
DIN EN 775	Industrieroboter; Sicherheit	Manipulation industrial robots; safety	08/1993
DIN EN 791	Bohrgeräte; Sicherheit	Drill rigs; safety	01/1996
DIN EN 842	Sicherheit von Maschinen; Optische Gefahrensignale; Allgemeine Anforderungen, Gestaltung und Prüfung	Safety of Machinery – Visual danger signals – General requirements, design and testing	08/1996
DIN EN 954-1	Sicherheit von Maschinen; Sicherheitsbezogene teile von Steuerungen; Teil 1: Allgemeine Gestaltungsleitsätze	Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design	03/1997
DIN EN 1050	Sicherheit von Maschinen – Leitsätze zur Risikobeurteilung	Safety of machinery – Principles for risk assessment	01/1997
DIN EN 1175-1 (VDE 0117 Teil1)	Sicherheit von Flurförderzeugen; Elektrische Anforderungen; Teil 1: Allgemeine Anforderungen für Flurförderzeuge mit batterieelektrischem Antrieb	Safety of industrial trucks – Electrical requirements- Part 1: General requirements for battery powered trucks	11/1998
DIN EN 1889-2	Maschinen für den Bergbau unter Tage; Anforderungen an bewegliche Maschinen für die Verwendung unter Tage; Sicherheit; Teil 2: Lokomotiven	Machines for underground mining; requirements applying to mobile equipments for use below surface; Safety; Part 2: Locomotives	11/2003

Denomination	Title, German	Title, English	Edition
DIN EN ISO 12100-1	Sicherheit von Maschinen; Grundbegriffe, allgemeine Gestaltungsleitsätze; Teil 1: Grundsätzliche Terminologie, Methodologie	Safety of machinery - Basic concepts, general principles for design - Part 1: Basic terminology, methodology	4/2004
DIN EN ISO 12100-2	Sicherheit von Maschinen; Grundbegriffe, allgemeine Gestaltungsleitsätze; Teil 2: Technische Leitsätze	Safety of machinery - Basic concepts, general principles for design - Part 2: Technical principles	4/2004
DIN EN 12385-1	Drahtseile aus Stahldraht; Sicherheit; Teil 1: Allgemeine Anforderungen	Steel wire ropes – Safety – Part 1: General requirements	03/2003
DIN EN 12385-2	Stahldrahtseile; Sicherheit; Teil 2: Begriffe, Bezeichnung und Klassifizierung	Steel wire ropes – Safety – Part 2: Definitions, designation and classification	04/2003
DIN EN 12385-4	Drahtseile aus Stahldraht; Sicherheit; Teil 4: Litzenseile für allgemeine Hebezwecke	Steel wire ropes – Safety – Part 4: Stranded ropes for general lifting applications	03/2003
DIN EN 13478	Sicherheit von Maschinen; Brandschutz	Safety of machinery – Fire prevention and protection	04/2002
DIN EN 60204-1 (VDE 0113 Teil 1)	Sicherheit von Maschinen; Elektrische Ausrüstung von Maschinen; Tei 1: Allgemeine Anforderungen	Safety of machinery - Electrical equipment of machines; Part 1: General requirements.	06/1993
DIN EN 60204-32 (VDE 0113 Teil 32)	Sicherheit von Maschinen; Elektrische Ausrüstung von Maschinen; Tei 32: Anforderungen für Hebezeuge	Safety of machinery - Electrical equipment of machines; Part 32: Requirements for hoisting machines.	06/1999
DIN EN 60947-5-5 (VDE 0660 Teil 210)	Niederspannungsschaltgeräte Teil 5-5: Steuergeräte und Schaltelemente; Elektrische NOT-AUS- Gerät mit mechanischer Verrastfunktion	Low-voltage switchgear and control gear - Part 5-5: Control circuit devices and switching elements - Electrical emergency stop device with mechanical latching function	09/1998

Denomination	Title, German	Title, English	Edition
EG	Europäische Gemeinschaft, Richtlinie 96/29/EURATOM des Rates vom 13. Mai 1996 zur Festlegung der grundlegenden Sicherheitsnormen für den Schutz der Gesundheit der Arbeitskräfte und der Bevölkerung gegen die Gefahren durch ionisierende Strahlungen, ABL. EG Nr. L 159	Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation	05/1996
EG	Richtlinie 2001/6/EG vom 29.Januar 2001 zur dritten Anpassung der Richtlinie 96/49/EG des Rates zur Angleichung der Rechtsvorschriften der Mitgliedstaaten für die Eisenbahnbeförderung gefährlicher Güter an den technischen Fortschritt, ABL. EG Nr. L 30	Commission Directive 2001/6/EC of 29.January 2001 adapting for the third time to technical progress Council Directive 96/49/EC on the approximation of the laws of the Member States with regard to the transport of dangerous goods by rail	01/2001
EG	Richtlinie 2001/7/EG der Kommission vom 29. Januar 2001 zur dritten Anpassung der Richtlinie 94/55/EG des Rates zur Angleichung der Rechtsvorschriften der Mitgliedstaaten für den Gefahrtransport auf der Straße an den technischen Fortschritt	Commission Directive 2001/7/EC of 29.January 2001 adapting for the third time to technical progress Council Directive 94/55/EC on the approximation of the laws of the Member States with regard to the transport of dangerous goods by road	01/2001

10.1.3 German National laws

The following list of regulations is valid both at the national and the federal state levels

Denomination	Title, German	Title, English	Edition
AtG	Gesetz über die friedliche Nutzung der Kernenergie und den Schutz gegen die Gefahren (Atomgesetz AtG) vom 15.07.1985 (BGBI. I, 5. 1565), zuletzt geändert d. Art.8 des Gesetzes vom 06.01.2004 (BGBI. I, S. 2)	Act on the peaceful use of nuclear energy and on the protection against its risks (Atomic Law)	15.07.1985, zuletzt geä. durch Art. 8 d. Gesetzes vom 06.01.2004
StrlSchV	Verordnung über den Schutz vor Schäden durch ionisierende Strahlen (Strahlenschutzverordnung - StrlSchV) vom 20.07.2001 (BGBI. I, 5. 1714) mit Berichtigung vom 22.04.2002 (BGBI. I, 5. 1459), zuletzt geändert d. Art. 2 der Verordnung vom 18. Juni2002 (BGBI. I, S. 1869, (1903))	Ordinance on the Protection against Damage and Injuries Caused by Ionizing Radiation (Radiation Protection Ordinance) of 20 July 2001	20.07.2001, zuletzt geä. durch Art. 2 d. Verordn. vom 18.06.2002
GGVSE	Verordnung über die innerstaatliche und grenzüberschreitende Beförderung gefährlicher Güter auf der Straße und mit der Eisenbahn (Gefahrgutverordnung Straße und Eisenbahn — GGVSE) in der Fassung vom 10.09.2003 (BGBI. I,S 1913), berichtigt am 13.10.2003 (BGBI, I, S2139); zuletzt geändert davon Art. 1 der Verordnung vom 24. 03.2004 (BGBI, I S. 485)	Commission Directive 2001/6/EC and 2001/7/EC of 29.January 2001 adapting for the third time to technical progress Council Directive 96/49/EC and 94/55/EC on the approximation of the laws of the Member States with regard to the transport of dangerous goods by road and by rail	10.09.2003, zuletzt geä. durch Art.1 d. Verordn. vom 24.03.2004
GefStoffV	Verordnung zum Schutz vor gefährlichen Stoffen (Gefahrstoffverordnung)	Regulation for protection against dangerous substances	15.11.1995, zuletzt geä. durch Art. 2 d. Verordn. vom 25.02.2004

Denomination	Title, German	Title, English	Edition
9 GSGV*	Maschinenverordnung	Machines Ordinance	01/2004
BBergG	Bundesberggesetz	Federal Mine Act	13.08.1980, zuletzt geä. durch Art 123 d. Verordn. v. 25.11.2003
ABBergV [1]	Allgemeine Bundesbergverordnung	Federal Mining Ordinance	23.10.1995, zuletzt geä. durch Art. 24 des Gesetzes v. 06.01.2004
GesBergV	Gesundheitsschutz-Bergverordnung	Mining Ordinance on Healthcare	31.07.1991, zuletzt geä. durch Art. 2 d. Verordn. vom 18.10.1999
ABVO	Allgemeine Bergverordnung über Untertagebetriebe, Tagebaue und Salinen	General Mining Ordinance for Underground Works, Open Pit Mines and Salt Mines	02.02.1966
KlimaBergV	Klima- Bergverordnung	Mining Ordinance for the Protection of Health against Climatic Effects	09/06/1983
EMVG	Gesetz über die elektromagnetische Verträglichkeit von Geräten	Law of the electromagnetic compatibility of appliances	18.09.1998, zuletzt geä. durch Art. 230 der Verordn. v. 25.11.2003
ELBVO	Elektro- Bergverordnung	Mining Ordinance on electricity	23.10.2000
LOBA A 2.8 (Land NRW)	Maschinen und maschinelle Anlagen	Machines and mechanical systems	12/1993
LOBA A 2.11 (Land NRW)	Förderung und Materialtransport in söhligen und geneigten Grubenbauen	Furtherance and material transport in horizontal and inclined mines	
BGV D 6	UVV Krane	Cranes	10/2000

Denomination	Title, German	Title, English	Edition
(bisher VBG 9)			
BGV D 6 DA (VBG 9 DA)	Durchführungsanweisungen zur UVV „Krane“	Implementing instructions for the regulations on the prevention of accidents: “Cranes”	10/2000
BGV D 8 (VBG 8)	UVV Winden, Hub- und Zuggeräte	Winches, lifting appliances and drawing machines	01/1997
BGV D 8 DA (VBG 8)	Durchführungsanweisungen zu-rUVV Winden, Hub- und Zuggeräte	Implementing instructions for the regulations on the prevention of accidents: ”Winches, lifting appliances and drawing machines”	04/1996
BMI	Bekanntmachung der Leitlinien zur Beurteilung der Auslegung von Kernkraftwerken mit Druckwasserreaktoren gegen Störfälle im Sinne des §28 Abs.3 der Strahlenschutzverordnung - Störfall-Leitlinien -Bundesanzeiger Nr. 245a vom 31. Dezember 1983	Guidelines for the evaluation of the lay-out of nuclear power plants with pressurized water reactors against operation disruptions according to § 28 clause 3 StrlSchV-Disruption of Operations Guidelines	10/1983
BMI	Sicherheitskriterien für die Endlagerung radioaktiver Abfälle in einem Bergwerk RdSchr. d. BMI v. 20.4.1983 -RS-AGK3 515790/2 -	Safety criteria for the final storage of radioactive wastes in mines	04/1983
BMU / (REI)	Richtlinie zur Emissions- und Immissionsüberwachung kerntechnischer Anlagen (REI) vom 30.06.1993, (GMBI. Nr. 29 5. 502), ergänzt um die Anhänge B und C vom 20.12.1995 (GMBI. 1996, Nr. 9/10, 5. 195)	Guidelines for the control of emission from nuclear plants	12/1995

The above list order applies to machines in the conventional area. Exempted are, among others, those that are developed and employed for the handling of radioactive materials and whose break down can lead to an emission of radioactivity.

10.1.4 German national regulations

Not harmonized norms are considered important and helpful by some EU member states for the proper implementation of the fundamental safety and health requirements. The German national set of regulations does not trigger any conformance presumptions.

Denomination	Title, German	Title, English	Edition
DIN VDE 0118-1 (VDE 0118 Teil 1)	Errichten elektrischer Anlagen im Bergbau unter Tage; Teil 1: Allgemeine Festlegungen	Erection of electrical installations in mines Part 1: General requirements	11/2001
DIN VDE 0118-2 (VDE 0118 Teil 2)	Errichten elektrischer Anlagen im Bergbau unter Tage; Teil 2: Zusatzfestlegungen für Starkstromanlagen	Erection of electrical installations in mines Part 2: Supplementary requirements for power installations	11/2001
DIN VDE 0118-3 (VDE 0118 Teil 3)	Errichten elektrischer Anlagen im Bergbau unter Tage; Teil 3: Zusatzfestlegungen für Fernmeldeanlagen	Erection of electrical installations in mines Part 3: Supplementary requirements for telecommunication installations	11/2001
DIN 4132	Kranbahnen; Stahltragwerke; Grundsätze für Berechnung, Bauliche Durchbildung und Ausführung	Crane ways; Steel structure; Principles for calculation, design and construction	02/1981
DIN 15018-1	Krane; Grundsätze für Stahltragwerke; Berechnung	Cranes; steel structures; verification and analyses	11/1984
DIN 15018-2	Krane; Stahltragwerke; Grundsätze für die bauliche Durchbildung und Ausführung	Cranes; steel structure; principles of design and construction	11/1984
DIN 15019-1	Krane; Standsicherheit für alle Krane außer gleislosen Fahrzeugkranen und außer Schwimmkranen	Cranes; Stability for All Cranes Except Non-rail Mounted Mobile Cranes and Except Floating Cranes	09/1979
DIN 25423-1	Probeentnahme bei der Radioaktivitäts-überwachung der Luft	Sampling procedures for the monitoring of radioactivity in air- Part 1: General	12/1999

Denomination	Title, German	Title, English	Edition
	Teil 1: Allgemeine Anforderungen	requirements	
DIN 25423-2	Probeentnahme bei der Radioaktivitätsüberwachung der Luft Teil 2: Spezielle Anforderungen an die Probeentnahme aus Kanälen und Kaminen; Prüfungen	Sampling procedures for the monitoring of radioactivity in air- Part2: Special requirements for sampling from air ducts and stacks	08/2000
DIN 25423-3	Probeentnahme bei der Radioaktivitätsüberwachung der Luft , Probenahmeverfahren	Sampling procedures for the monitoring of radioactivity in air; sampling methods	03/1987
DIN 25458	Ortsfestes System zur Überwachung von Ortsdosisleistungen innerhalb von Kernkraftwerken	Stationary System for Monitoring Area Dose Rates Within Nuclear Power Plants	10/1999
KTA 1501	Ortsfestes System zur Überwachung von Ortsdosisleistungen innerhalb von Kernkraftwerken	Stationary System for Monitoring Area Dose Rates Within Nuclear Power Plants	11/2003
KTA 1503.1	Überwachung der Ableitung gasförmiger und an Schwebstoffen gebundener radioaktiver Stoffe Teil 1: Überwachung der Ableitung radioaktiver Stoffe mit der Kaminfortluft bei bestimmungsgemäßem Betrieb	Monitoring and Assessing of the Discharge of Gaseous and Dispersed Particles Bound Radioactive Substances; Part 1: Monitoring and Assessing of the Stack Discharge of Radioactive Substances during Specified Normal Operation	06/2002
KTA 1503.2	Überwachung der Ableitung gasförmiger und an Schwebstoffen gebundener radioaktiver Stoffe Teil 2: Überwachung der Ableitung radioaktiver Stoffe mit der Kaminfortluft bei Störfällen	Monitoring and Assessing of the Discharge of Gaseous and Aerosol bound Radioactive Substances; Part 2: Monitoring and Assessing of the Stack Discharge of Radioactive Substances during Anticipated Operation Occurrences and Accident Conditions	06/1999

Denomination	Title, German	Title, English	Edition
KTA 1503.3	Überwachung der Ableitung gasförmiger und an Schwebstoffen gebundener radioaktiver Stoffe Teil 3: Überwachung der nicht mit der Kaminfortluft abgeleiteten radioaktiver Stoffe	Monitoring and Assessing of the Discharge of Gaseous and Aerosol bound Radioactive Substances; Part 3: Monitoring and Assessing of not Discharge via the Stack	06/1999
KTA 1504	Überwachung der Ableitung radioaktiver Stoffe mit Wasser	Monitoring and Assessing of the Discharge of Radioactive Substances in Liquid Effluents	06/1994

10.1.5 French national regulations

10.2.5.1 Regulations related to construction activities (underground) and to mining operations

Access to underground installations (shaft)	- Decree 10/07/13 - Decree 09/06/93 - Decree 17/10/77
Circulation	- Labour code / Article R233-2 - Decree n°65-48
Air pollution	- Decree of 08/06/90 - Decree n°65-48 Art 84 - Decree n°65-48 Art 85
Temperature	- RGIE Article 10
Noise	- Labour code / Article R232-8 & s
Lighting	- Labour code / Article R232-7-1
Signalling	- Decree n°65-48 Art 95
Means of alarm and safety	- Labour code / Article R232-12-17 & following ones

10.2.5.2 Regulations related to nuclear operations

The most important thematic regulations are listed below:

- Quality
  - Arrêté qualité et circulaire du 10/8/1984

- Radioprotection
  - Decree n° 2002-460 & n° 86-1103
  - Decree n° 95-306 & decree of 7/7/1977
  - Instruction Euratom 96/29 & CIPR 60

- Safety of nuclear installations and facilities
  - Decree n° 63-1228 & decree of 11/3/1996
  - Decree of 31/12/1999
  - RFS I.1.a/b/c

- RFS I.3.c
- RFS I.4.a, RFS II.a

- Protection of environment / Release of gas & liquids
  - Decree n° 95-540
  - Decree of 26/11/1999

- Protection of environment / ICPE – Waste and Nuisance
  - Law n° 76-663
  - Decrees of 2/2/1998, 23/1/1997, 31/12/1999

- Fire safety
  - Labour Code
  - Decree of 31/12/1999
  - RFS I.4.a, RFS II.a

- Health & safety at work
  - Labour Code
  - Decree n° 88-1056
  - Decrees 28/1/1993, 4/11/1993, 19/12/1988

- Transports
  - Decree of 1/6/2001

Compilation of safety requirements for the entire system

10.1.6 German Concept

10.1.6.1 Experiences Considered

To compile the safety requirements the following documents were taken into consideration:

- Konrad repository licensing documents.
  - Shaft landing station straddle carrier

- Gorleben repository conceptual design documents
  - Description of the shaft hoisting equipment
  - Waste emplacement device

- The HAW project: Test disposal of highly radioactive radiation sources in the Asse salt mine
  - Waste emplacement device
  - Borehole slider (lock)
  - Transfer cask

10.1.6.2 Preliminary safety requirements

On this basis, the following list of safety requirements should be taken into account:

- Delimitation of radiation protection areas (controlled area, limited access areas)
- Sufficient radiation exposure reduction measures for operating personnel including prevention of radiation leakage at the connecting zones between transfer cask, borehole lock and the shielding bell
- Fire prevention for supporting devices and components as well as electrical systems and components
- Avoidance of the waste packages crashing into the borehole during emplacement operations
- Avoidance of the battery locomotive and the cart crashing onto the borehole emplacement device
- Avoidance of the crashing of other heavy loads onto the waste packages
- Avoidance of hoisting winch over winding
- Avoidance of over speed while lowering loads or other movements
- Transfer of the system into safe condition in case of operational malfunction or power supply outage.

- Locking or stopping of the borehole emplacement device hoist in case of exceeding operational limits for the selected operating mode
- Availability approved design and operational-engineering documentations
- Disabling undue borehole emplacement device movement during BSK 3 emplacement

10.1.7 ANDRA 's safety requirements for radiological conditions

a) Regulation and ANDRA 's design criteria :

The French Regulation has set up a maximum dose limit of 20 mSv per year for the workers.

Within an ALARA type approach, ANDRA has set up, as design criteria, a maximum dose limit of 5 mSv (i.e. ¼ of the regulatory value) for the workers. These 5 mSv per year are broken down as follows:

- 4.5 mSv per year for external exposure (irradiation),
- 0.5 mSv per year for internal exposure (inhalation, ingestion).

b) Dimensioning of radiation shielding for Spent Fuel type and C type canisters:

For the dimensioning of radiation shielding concerning spent fuel, the application of the dose rate design criteria set up by ANDRA implies the following equivalent dose rate values:

- 3 µSv h^{-1} at a 30 cm distance from the cell shielding gate. In the absence of the shielding transfer cask (containing the Spent Fuel Canister), this value allows for the permanent presence (1500 h of effective labour) of workers, without exceeding ANDRA 's dose limit target,
- 25 µSv h^{-1} at a 1 m distance from the shielding transfer cask (containing the Spent Fuel Canister). In normal operational conditions, workers stay at more than 1 m from the cask.

Compilation of operational requirements for the entire system

10.1.8 German Concept

10.1.8.1 Experiences Considered

To compile the operational requirements the following documents were taken into consideration:

- Konrad repository licensing documents.
  - Shaft landing station straddle carrier

- Gorleben repository conceptual design documents
  - Description of the shaft hoisting equipment
  - Waste emplacement device

- The HAW project: Test disposal of highly radioactive radiation sources in the Asse salt mine
  - Waste emplacement device
  - Borehole slider (lock)
  - Transfer cask

10.1.8.2 Preliminary operational requirements

On this basis, the following list of operational design requirements should be taken into account:

- Capability of safely reaching the disposal position
- Capability of reaching the storage level depth
- Borehole emplacement device hoisting of cylindrical BSK 3 with a gross weight up to 5.3 t and with following dimensions:
  - Height 4980 mm
  - Diameter up to 440 mm
- Compliance with the necessary throughput capacity
- Reliable transfer of signals and power to the BSK 3 gripper control and the backfill bucket
- Safe power supply for the hoisting components
- Reliable control unit power supply
- Easy maintenance and servicing, including decontamination of systems coming in contact with waste packages, corrosion protection, mining conditions proof systems
- Equipment shall be made of materials compatible with the anticipated loads and climatic conditions

- The component, parts, and devices shall be certificated for work under mining conditions
- All equipment shall have a schedule for preventive maintenance and repair.

10.1.9 French concept

10.4.2.1 Experiences considered

No previous experience is available as a background for the coming studies and demonstrations.

10.1.9.2 Preliminary operational requirements

The following list of operational design requirements should be taken into account:

- Capability of safely reaching the disposal cell location,
- Capability of reaching the storage position inside the disposal cell,
- Emplacement devices compatible with the payloads (C type and CU2 type canisters),
- Compliance with the necessary throughput capacity,
- Reliable transfer of signals and power to the canister gripper control,
- Safe power supply for the moving components,
- Reliable control unit power supply,
- Easy maintenance and servicing, including decontamination of systems coming in contact with waste packages, corrosion protection, mining conditions proof systems (or as a minimum a life guaranty of 5 to 10 years),
- Equipment shall be made of materials compatible with the anticipated loads and climatic conditions,
- The component, parts, and devices shall be EC certificated,
- All equipment shall have a schedule for preventive maintenance and repair.

Compilation of boundary conditions as well as external requirements and constraints

10.1.10 German Concept

10.1.10.1 Prevailing climatic conditions at the site

The following boundary conditions shall be taken into account in the equipment design:

- Prevailing climatic conditions at the site
    - Temperature max. 52 °C
    - Humidity max. 70 %

10.1.10.2 Technical external requirements

- Prevailing technical conditions of the BSK 3 filling station
- Prevailing technical conditions of the shaft hoisting system

10.1.10.3 On site characteristics

- Dust
- Lighting
- Convergence of the salt
- Power supply

10.1.11 French concept

10.1.11.1 Prevailing climatic conditions at the site (Bure URL)

The following boundary conditions shall be taken into account in the equipment design:

- Temperature max. 28 °C
- Humidity max. 90 %

10.1.11.2 Technical external requirements

No data available (i.e. extracted from previous experience or construction)

10.1.11.3 On site characteristics

No data available (i.e. extracted from previous experience or construction)

Definition of interfaces between external and internal equipment

10.1.12 German Concept

The emplacement System has to fulfil several different tasks.

10.1.12.1 Tasks of the emplacement system

These are:

- to transport the transfer casks from the filling station to the shaft
- to transport the BSK 3 at the shaft to the shaft landing station
- to transport backfill to the borehole
- to handle the backfill at the borehole
- to allow personnel to inspect, repair and maintain the borehole emplacement device during the operational phase
- to transport and position the borehole lock

10.1.12.2 Interfaces between external and internal equipment

The main interfaces are:

- for the transfer cask, the trunions and the runs of the transport cart,
- for the transfer cask, the lock compatibility to the reloading station above ground, and the borehole lock,
- for the transport cart, the compatibility to the loading and unloading devices at the shaft and the shaft transport,
- for the transport cart, the compatibility to the underground rail system,
- for the transfer cask, the trunions and the runs of the borehole emplacement device,
- for the emplacement device winch, the gripper to the BSK 3,
- for the BSK 3 round head, the grippers of the borehole emplacement device,
- for the transfer cask, the cask lock to the borehole lock,
- for the transport of the backfill, the borehole lock,
- for the battery locomotive, the coupling to the transport cart,
- for the battery locomotive, the radio controlled steering of the borehole emplacement device.

10.1.13 French Concept

10.1.13.1 Tasks of the emplacement system

These are:

- to transport the transfer casks from the surface filling station to the shaft,
- to transport the canister, via the shaft cage, down to the shaft landing station,
- to transport the canister via the drifts to the docking gate of the disposal cell,
- to emplace the canister inside the disposal cell,
- to allow personnel to inspect, repair and maintain the emplacement device.

10.1.13.2 Interfaces between external and internal equipment

The main interfaces are:

- for the transfer casks : the transport shuttle and the disposal cell docking gate,
- for the transport shuttle: the compatibility of the loading and unloading devices with the ones of the transport truck between the shaft landing station and the cell chamber,
- for the emplacement device: the gripper to the canister lid.

11 List of References

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/9-3/ International Commission on Radiological Protection, Radiological Protection Policy for the Disposal of Radioactive Waste, Publication No. 77, Elsevier, Oxford (1997)

/9-4/ Food and Agriculture Organization of the United Nations, International Atomic Energy Agency, International Labour Organization, OECD Nuclear Energy Agency, Pan American Health Organization, World Health Organization, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

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ANDRA	Agence nationale pour la gestiondes déchets radioactifs
BSK 3	Brennstabkokille (Fuel rod canister) 3
BWR	Boiling water reactor
CSD-C	Colis Standard des Dèchets Compactès
DBE	Deutsche Gesellschaft zum Bau und Betrieb von Endlagern für Abfallstoffe mbH
ESDRED	Engineering Studies and Demonstration of Repository Designs
EURATOM	European Atomic Energy Community
GNB	Gesellschaft für Nuklearbehälter mbH
GNS	Gesellschaft für Nuklearservice mbH
HLW	High level waste
KBS3-V	Kärn Bränsle Säkerhet 3 – Vertical concept
PPB	Borated Polyethylene Plaster
SF	Spent Fuel
NRG	Nuclear Research & consultancy Group
PWR	Pressurized water reactor
WP	Work package

15 Appendices

15.1 Schedule of Module # 2 (update 06/10/2004),

15.2 Organisation of work,

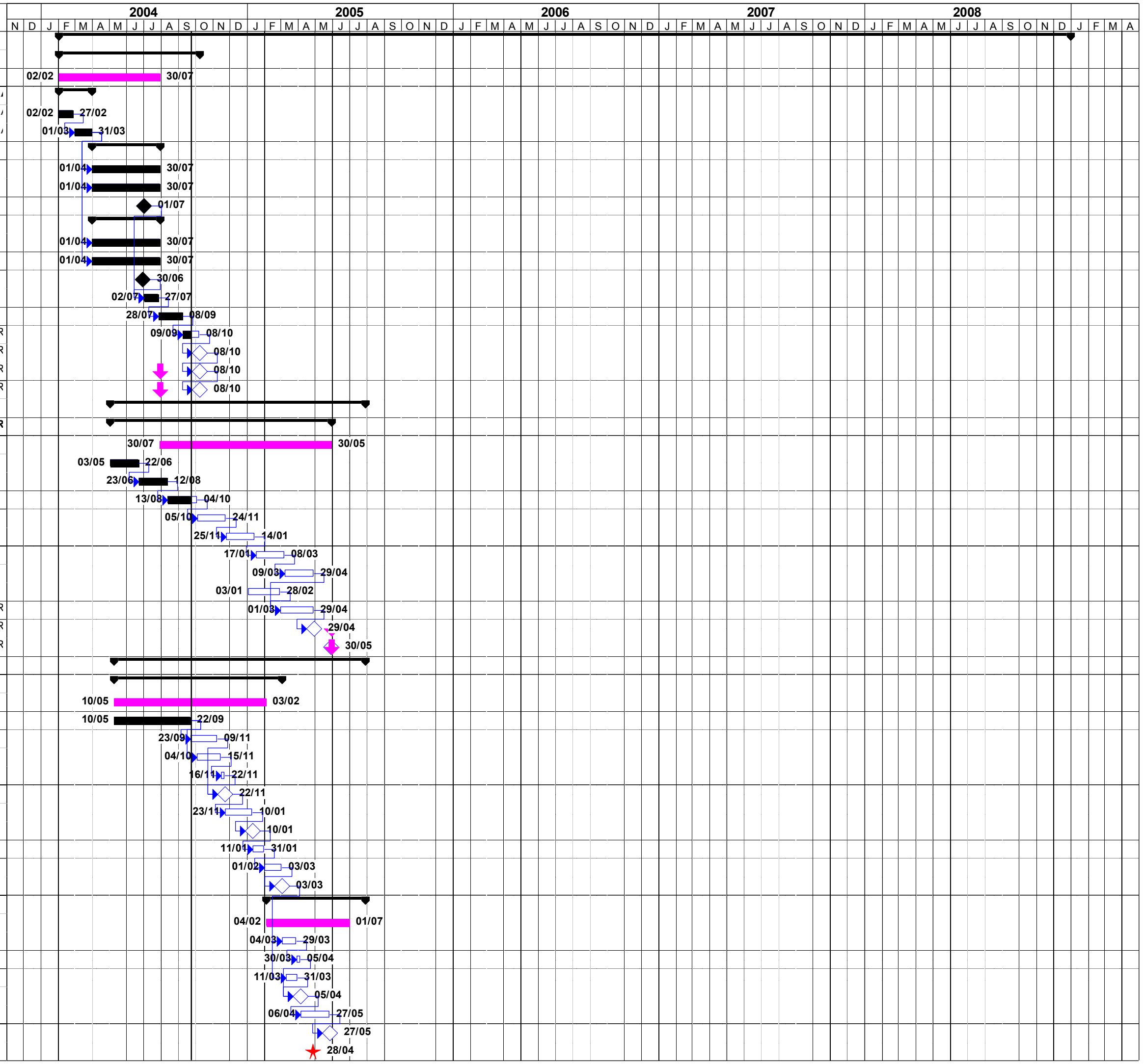
15.3 Subcontracting strategy.

15.1 Appendix A: Schedule of Module # 2 (update 06/10/2004)

The work programme of Module # 2 will be performed according to the following detailed schedule.

ESDRED Project **Schedule Module 2 Waste Canister Emplacement / Module Leader : DBE TEC** 20206/DTP/010 Ind.H du 06/10/04

N°	WP	Task name	Resp
1		**MODULE 2-WASTE CANISTER TRANSFER & EMPLACEMENT**	**DBE TEC**
2	**WP1**	**Input data and functional requirements**	**DBE TEC**
3		Input data and functional requirements (Contract)	DBE TEC
4	**WP1.1**	**Set-up of the detailed organization and work schedule**	**DBETEC ANDR/**
5		Detailed work schedule	DBETEC ANDR/
6		Detailed organization	DBETEC ANDR/
7	**WP1.2**	**Input data / functional requirements for German concept**	**DBE TEC**
8		Input Data	DBE TEC
9		Functional requirements	DBE TEC
10		Elements for Preliminary Report on input data and functional requirements	DBE TEC
11	**WP1.3**	**Input data / functional requirements for French concept**	**ANDRA**
12		Input data for French concept	ANDRA
13		Functional requirements for French concept	ANDRA
14		Elements for Preliminary Report on input data and functional requirements	ANDRA
15		Preparation of preliminary report	DBE TEC
16		Experts Committee review of preliminary reports	EC
17		Revisions to draft report	DBE TEC ANDR
18		Issue of final report to IPC	DBE TEC ANDR
19		D1 = Set of input data and functional requirements	DBE TEC ANDR
20		M1 = Validation of a set of input data and functional requirements	DBE TEC ANDR
21	**WP2**	**Conceptual design and Pushing robot prototype test**	**DBE TEC**
22	**WP2.1**	**Conceptual design**	**DBE TEC ANDR**
23		Conceptual design (Contract)	DBE TEC
24		Conception of different technical options	DBE TEC
25		Selection of the most appropriate one	DBE TEC
26		Description of the emplacement process	DBE TEC
27		Mechanical design for the fuel rod container	DBE TEC
28		Conceptional design of the different single components	DBE TEC
29		Setting up the experimental program	DBE TEC
30		Planning of the licensing procedure	DBE TEC
31		Report on conceptual designs of transportation and emplacement process- French concept	ANDRA
32		Preparation of Deliverable D2	DBE TEC/ANDR
33		D2 = Report on conceptual designs of transportation and emplacement processes	DBE TEC/ANDR
34		M2 = Validation of a report on conceptual designs of components	DBE TEC/ANDR
35	**WP2.2**	**Pushing Robot Prototype test**	**ANDRA**
36		**Tender document & competitive bid process**	**ANDRA**
37		Tender document & competitive bid process (Contract)	ANDRA
38		Preparation of Technical specifications for RFP	ANDRA
39		Finalize RFP	ANDRA
40		Advertising EC Journal (37 c.d.)	ANDRA
41		Prequalification	ANDRA
42		Issue of RFP	ANDRA
43		Preparation of bids (42 c.d.)	ANDRA
44		Submission of bids	ANDRA
45		Bid Analysis	ANDRA
46		Contract preparation	ANDRA
47		Purchase order & Mob. of contractor	ANDRA
48		**Pushing Robot Prototype test**	**ANDRA**
49		Pushing Robot Prototype test (Contract)	ANDRA
50		Detailed studies / Definition of test programme	ANDRA
51		Analysis by Andra	ANDRA
52		Procurement list/workshop drawings	ANDRA
53		Validation Andra / decision milestone	ANDRA
54		Proc / fabric / assembly / preparation	ANDRA
55		Validation Andra / decision milestone	ANDRA
56		Develop Communication Action Plan (Mod2 - Pushing robot)	ANDRA



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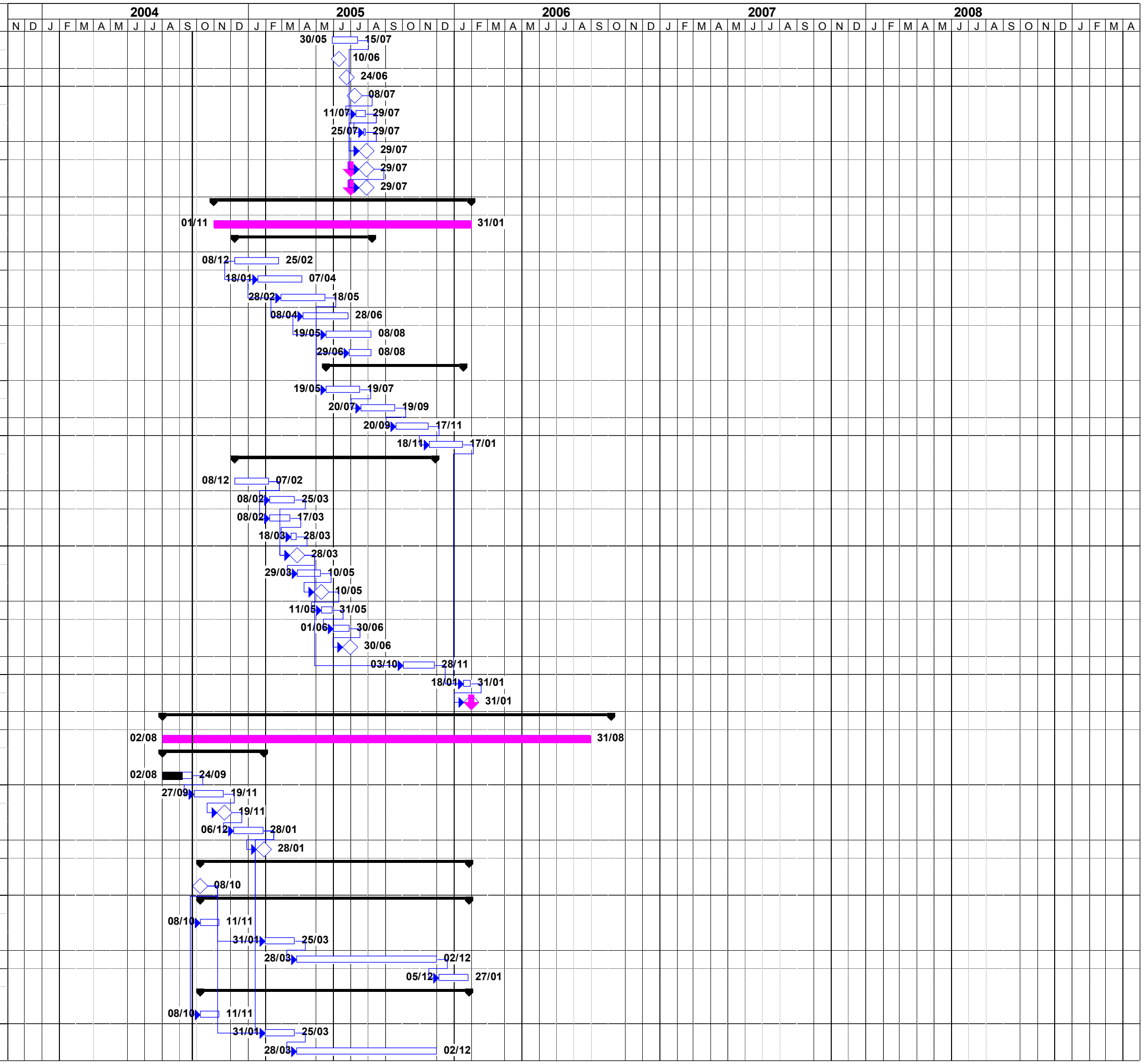
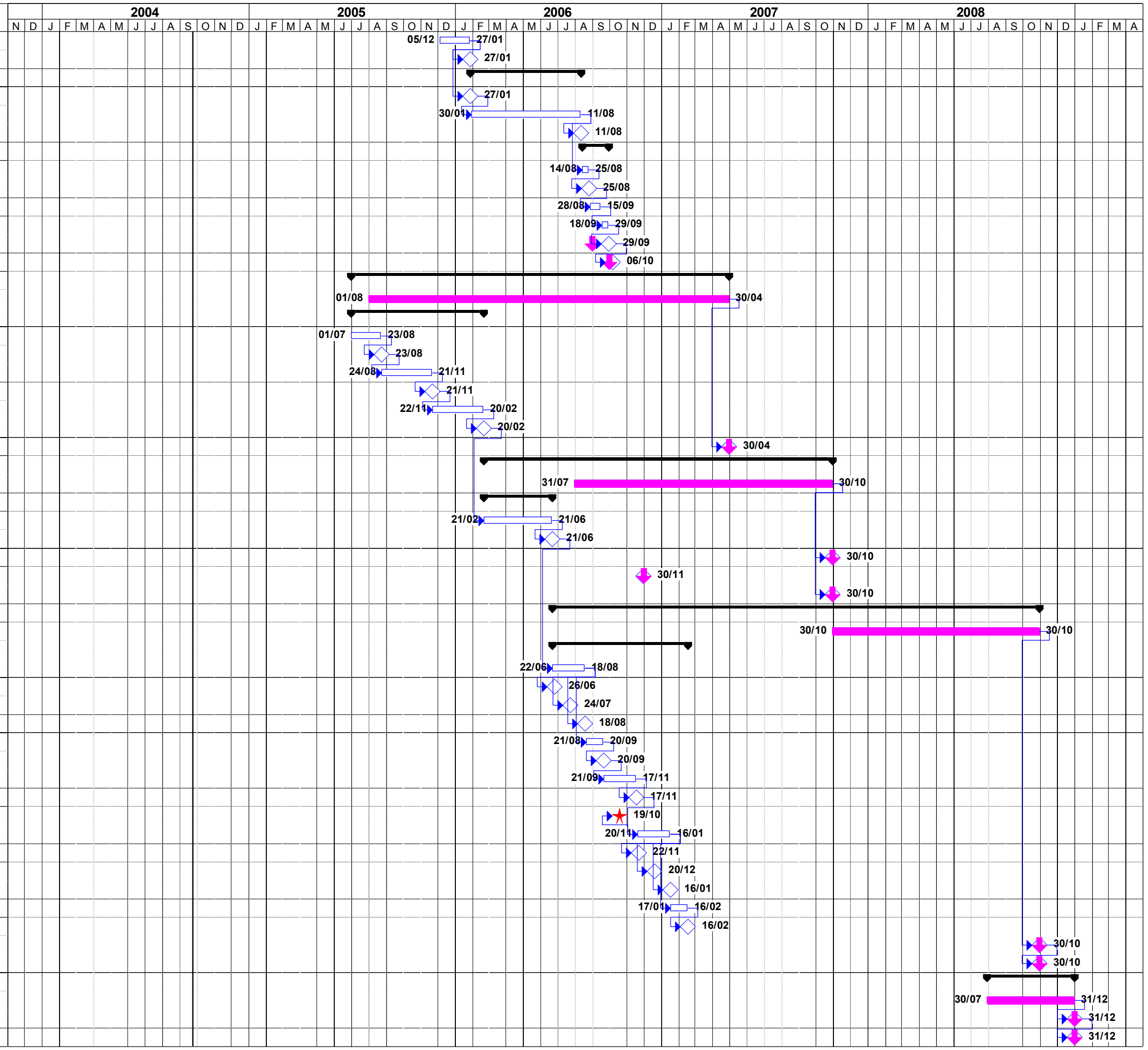
N°	WP	Task name	Resp
57		Implementation of test programme	ANDRA
58		Key milestone to be defined by contractor	ANDRA
59		Key milestone to be defined by contractor	ANDRA
60		Key milestone to be defined by contractor	ANDRA
61		Report on test programme	ANDRA
62		Validation by Andra + issue of final report	ANDRA
63		End of contract	ANDRA
64		D9 = Report on Prototype test of Pushing robot	ANDRA
65		M8 = Validation of a report on Prototype test of Pushing robot	ANDRA
66	**WP3**	**Basic design**	**DBE TEC**
67		Basic design (Contract)	DBE TEC
68		**Technical equipment specification**	**DBE TEC**
69		Transfer cask	DBE TEC
70		Emplacement device	DBE TEC
71		Borehole lock	DBE TEC
72		Borehole ventilation	DBE TEC
73		Drilling technology	DBE TEC
74		Alteration transport cart	DBE TEC
75		**Planning and analysis**	**DBE TEC**
76		Further development of experimental program	DBE TEC
77		Development of functional interlocking conditions	DBE TEC
78		Operational disturbances analysis	DBE TEC
79		Reliability examination of the whole system	DBE TEC
80		**Tender Process (French Concept Demonstrator at industrial scale)**	**ANDRA**
81		Preparation of Technical specifications for RFP	ANDRA
82		Finalize RFP	ANDRA
83		Advertising EC Journal (37 c.d.)	ANDRA
84		Prequalification	ANDRA
85		Issue of RFP	ANDRA
86		Preparation of bids (42 c.d.)	ANDRA
87		Submission of bids	ANDRA
88		Bid Analysis	ANDRA
89		Contract preparation	ANDRA
90		Purchase order & Mob. of contractor	ANDRA
91		Report on basic design - French concept	ANDRA
92		Preparation of report	DBE TEC
93		D3 = Basic designs	DBE TEC
94	**WP4**	**Retrievability desk study**	**NRG**
95		Retrievability desk study (Contract)	NRG
96		**a. Review current disposal concepts**	**NRG**
97		Studying CA report on retrievability	NRG
98		Preparing country specific questionnaire	NRG
99		Sending questionnaire to partners	NRG
100		Processing results of questionnaire	NRG
101		Internal memorandum on findings	NRG
102		**b. Design criteria for retrievability**	**NRG**
103		Input (conceptual) designs from WP 1 and WP 2	NRG
104		**Vertical emplacement method**	**NRG**
105		Defining specific case studies	NRG
106		Data definition and data collection	NRG
107		Analysing specific case studies	NRG
108		Reporting results case studies	NRG
109		**Horizontal emplacement method**	**NRG**
110		Defining specific case studies	NRG
111		Data definition and data collection	NRG
112		Analysing specific case studies	NRG



ESDRED Project **Schedule Module 2 Waste Canister Emplacement / Module Leader : DBE TEC** 20206/DTP/010 Ind.H du 06/10/04

N°	WP	Task name	Resp
113		Reporting results case studies	NRG
114		Internal memorandum on design criteria	NRG
115		**c. Verification and demonstration**	**NRG**
116		Definition of activity (depends on detailed design work)	NRG
117		Verification and validation activity	NRG
118		Internal memorandum on verification and demostration	NRG
119		**Reporting (Deliverable Mod2-WP4-D4)**	**NRG**
120		Prepare draft final report WP 4	NRG
121		Draft final report	NRG
122		Review of draft final report	NRG
123		Adapt draft report	NRG
124		D4 = Report on retrievability	NRG
125		M3 = Validation of desk study on retrievability	NRG
126	**WP5**	**Detailed Design**	**DBE TEC**
127		Detailed Design (Contract)	DBE TEC
128		**Detailed Design French concept**	**ANDRA**
129		Preliminary design studies	Subcontractor
130		Validation Andra / decision milestone	ANDRA
131		Detailed design studies	Subcontractor
132		Validation Andra / decision milestone	ANDRA
133		Workshop drawings	Subcontractor
134		Validation Andra / decision milestone	ANDRA
135		D5 =Detailed design (set of documents)	DBE TEC
136	**WP6.1**	**Fabrication of 2 full scale equipments**	**DBE TEC**
137		Fabrication of 2 full scale equipments (Contract)	DBE TEC
138		**Fabrication of French concept Demonstrator**	**ANDRA**
139		Procurement / Fabrication / Assembly / Preparation	Subcontractor
140		Validation Andra / decision milestone	ANDRA
141		D6 = Commissionning report of fabricated prototype equipment	DBE TEC
142		M4 = Choice of demonstration sites (surface & underground)	DBE TEC
143		M5 = Commissionning of fabricated prototype equipments	DBE TEC
144	**WP6.2**	**In situ implementation**	**DBE TEC**
145		In situ implementation (Contract)	DBE TEC
146		**Testing & Demonstration French concept in situ (URL)**	**ANDRA**
147		Testing & Demonstration in Workshop	Subcontractor
148		Key milestone to be defined by contractor	ANDRA
149		Key milestone to be defined by contractor	ANDRA
150		Key milestone to be defined by contractor	ANDRA
151		Test reports	Subcontractor
152		Validation Andra / decision milestone	ANDRA
153		Preparation of Test	Subcontractor
154		Validation Andra / decision milestone	ANDRA
155		Develop Communication Action Plan (Mod2 - In situ implementation)	ANDRA
156		Testing & Demonstration in situ (URL)	Subcontractor
157		Key milestone to be defined by contractor	ANDRA
158		Key milestone to be defined by contractor	ANDRA
159		Key milestone to be defined by contractor	ANDRA
160		Test reports	Subcontractor
161		Final Validation Andra	ANDRA
162		D7 = Report in situ (URL and surface facilities)	DBE TEC
163		M6 = End of demonstration test	DBE TEC
164	**WP7**	**Evaluation & Final Report**	**DBE TEC**
165		Evaluation & Final Report (Contract)	DBE TEC
166		D8 = Evaluation & Final Report	DBE TEC
167		M7 = Validation & Final Report	DBE TEC



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15.2 Appendix B: Organisation of work

The work programme will be managed by the following staff of the three Module # 2 members, i.e. ANDRA, DBE TECHNOLOGY and NRG.

ESDRED Module 2 (Waste transfer & emplacement)

Telephone number to ANDRA video equipment + 33 1 41.13.03.13 (room C.110)
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15.3 Appendix C: Subcontracting strategy

ANDRA:

As an implementer, ANDRA relies on subcontracting for most of the work envisaged.

For WP2, a Request for Proposal (RFP), a bid evaluation and a contractor selection are carried out in order to design, fabricate and test the Pushing Robot Prototype.

The same process is followed in WP3, where a tender is issued for the design (WP5), fabrication and test (WP6) of the demonstrator at an industrial stage.

In the 2 cases, a negotiated procedure is looked after (preliminary advertising in the European Journal, pre-qualification of a limited number of candidates, issue of tender documents, receipt of offers, negotiation with bidders, submittal of ANDRA ‘s choice and of the project of contract to the Bid and Tender Commission, execution of contract).

DBE TECHNOLOGY:

Most of the design work, in particular the conceptual and basic design, will be done with DBE TECHNOLOGY personnel. Subcontracting tasks are foreseen for the detailed design and the manufacturing of components. According to the conditions of the contract with the German Ministry for Economics and Labor (represented by the Projektträger für Wassertechnologie und Entsorgung, PtWT+E), DBE TECHNOLOGY is committed to launch a competitive bid process for subcontracted tasks which require a budget of more than 50 k€. Small consulting services involved in the design, manufacturing and test phases with a lower amount are identified in Annex 1 to the Contract (Description of Work) and can be subcontracted without competition.

NRG:

All the work considered by NRG will be carried out in house.