DEVELOPMENTS OF DEPOSITION CONCEPTS FOR DISPOSAL OF HLW IN BELGIUM

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ABSTRACT

Belgium plans to store its canisters with High Level Vitrified Waste (coming from the recycling process of Spent Fuel Elements) in a final repository at a few hundred meters of depth in the Boom Clay layer in the north-eastern part of the country.

During evaluation of the repository design, a number of unresolved questions were identified and these clearly indicated the need for further work and modifications. Three alternative concepts were developed: the “Sleeve Concept”, the “Supercontainer Concept” and the “Borehole Concept”. For the two latter deposition concepts Babcock Noell Nuclear performed feasibility studies.

The aim and purpose of the feasibility studies was to develop and to evaluate feasible concepts for the handling of the waste packages from the above ground installation until final emplacement in the disposal galleries and to define the need for further investigations. An additional aim was to reduce the diameter of the transport and disposal galleries as far as possible.

Both studies demonstrated that it is feasible to transport and dispose the vitrified waste with the given requirements. Taking into account the dimensions and complexity of the machines, as well as the constraints due to radiation shielding and preparation work of the galleries (rails, boreholes) it was proposed to continue with the Supercontainer Concept.

INTRODUCTION

Since 1984 the HADES Underground Research Laboratory has been operating at Mol, examining the suitability of the Boom Clay as a host for a repository for spent fuel or vitrified waste respectively.
ONDRAF/NIRAS, the Belgian Radioactive Waste Agency, is, among other things, responsible for the development of disposal concepts and repository designs for all radioactive waste types. These concepts are developed in close collaboration with ***SCK-CEN***[1] and ***Euridice***[2] in Mol. According to the disposal concept for canisters containing vitrified waste developed in the nineties, the canisters will be disposed in long horizontal galleries. A central steel liner (disposal tube) allows the insertion (and retrieval) of the HLW packages after hydration of the bentonite blocks, placed between this tube and the concrete gallery lining.

During evaluation of the above mentioned repository design, a number of open questions regarding deposition of waste canisters were identified. Three alternative concepts were developed. For two of the deposition concepts, the “Supercontainer Concept” and the “Borehole Concept”, feasibility studies have been awarded to Babcock Noell Nuclear. Below the results of these studies will be reported.

General Requirements

For the Development and evaluation of concepts some general requirements had to be respected. These are mainly:

- The transport should disturb as little as possible the Boom Clay layer which is the most important barrier against radionuclide migration. The circular shape of the galleries should not be altered.
- The design of the transport and deposition equipment should be based on well known systems, subsystems or mechanisms that have proven their reliability and robustness. An overall estimated lifetime of at least 50 years is required.
- The reference waste type is vitrified waste. The cooling time before starting of disposal is 60 years.
- Approximately 2000 overpacks/supercontainers (3915 canisters) have to be disposed.
- A mean disposal rate of two overpacks/supercontainers per day (8 working hours) has to be considered as a typical value.
- After final disposal nearly all steel parts have to be removed as much as possible / reasonable. The transport rails can remain in order to facilitate the retrievability.
- No organic material at all is allowed to remain inside the disposal galleries.
- Climate conditions:
  - Temperature at the gallery level (-230 m): between 16°C and 25°C.
  - Relative humidity of 60 %, water coming out of the Boom Clay (very small volumes) is directly evacuated by the ventilation system. The air in the galleries contains no aggressive components accelerating the degradation of metal components of the handling equipment.
- The transfer equipment has to be as compact as possible. It has to be adapted to the maximum dimensions of the shafts and galleries
- The equipment has to be able to reverse disposal operations in order to retrieve the overpack at any location.
- The disposal equipment and its parts has to be able to resist the heat generated by the waste.
- The use of gasoline driven engines is forbidden.

Requirements from Design of Underground Galleries

Beside the general requirements, requirements resulting from the design of the underground galleries had to be taken into account. The requirements were:

- The underground repository will be composed of horizontal galleries, one transport gallery, ten disposal galleries, two connecting galleries and one ventilation gallery. Some galleries will have a slope of 1%.
- The galleries are equipped with a concrete lining. The lining of the galleries consists of wedge blocks (prefabricated concrete blocks) placed against the clay host rock.
- The inner diameter has to be limited as much as possible taking into account the necessary space for handling and deposition.
- The diameter of the disposal galleries has to be less than the diameter of the transport gallery in order to control the stress distribution in the Boom Clay at the crossing, being locally reinforced by concrete and/or metal parts.
- Angle between transport gallery and disposal galleries: between 45° and 90°; preferable 90°.
- Necessary fixtures (e. g. supports, platforms, gangways, etc.) can be fixed to the concrete lining.
- Loads are to result in direct pressure only; there are to be no moments
- At the transition point from the transport shaft to the transport gallery a starting chamber will be constructed.
- The transport gallery has a maximum inner diameter of 5 m.
- The transport gallery has a length of approximately 450 m.
- Each disposal gallery has a maximum inner diameter of 3.5 m.
- Each disposal gallery has a length of approximately 1000 m.

BOREHOLE CONCEPT

For the borehole concept so called “overpacks” have to be placed in vertical or horizontal boreholes. An overpack contains two canisters with vitrified waste and has a diameter of 500 mm, a length of 2,800 mm and a maximum weight of 3 t. The following specific requirements had to be respected for the borehole concepts:

> The angle between the disposal galleries and the borehole is 90° and the minimum depth of the borehole is 2850 mm plus the length of the shielding plug. The vertical borehole will be closed with a stainless steel shielding plug with a thickness of 300 mm, a stainless steel lid which is welded after deposition and a shielding top block. The horizontal borehole will be closed with a stainless steel shielding plug with a thickness of 300 mm. The shielding plug will be fixed on the side wall of the disposal galleries. The shielding plug (dead load < 1 ton) for the borehole has to be transported and placed with the deposition machine. For horizontal disposal, two boreholes are arranged alternating on both side of the disposal galleries.

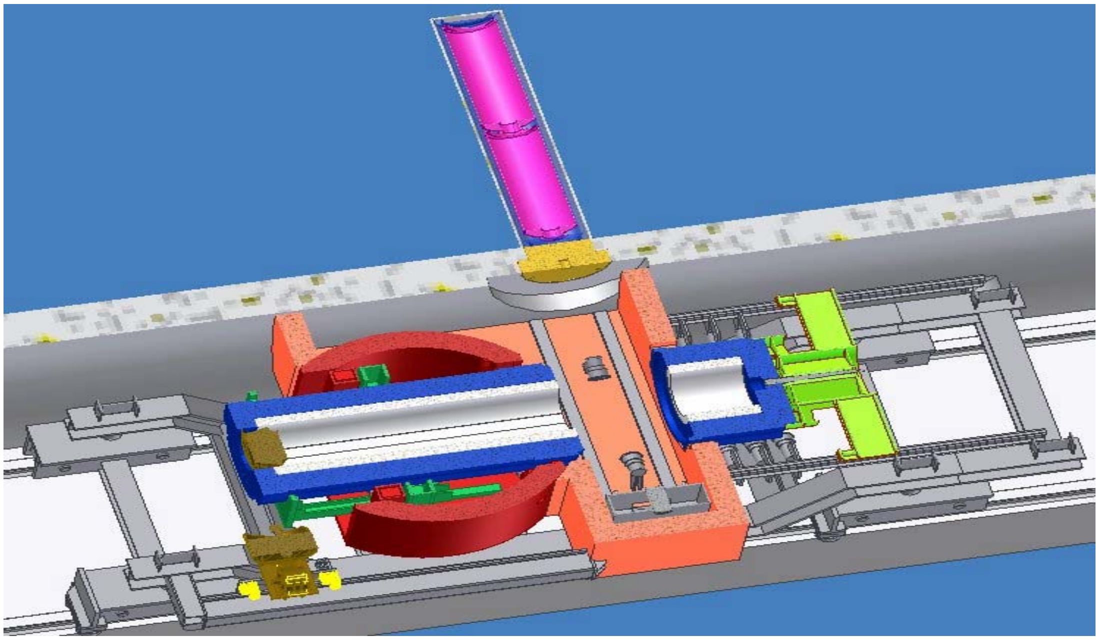

Fig. 1 Horizontal borehole concept. Overpack and shielding plug are placed in borehole.

To ensure that the single functions are completely described, a whole break down of the procedure starting from the transfer of shielded plug and shielding tube in the deposition machine to the final disposal of the overpack in the borehole has been performed.

The following flowcharts give an overview of the main operations of both concepts:

Vertical Borehole Concept Horizontal Borehole Concept

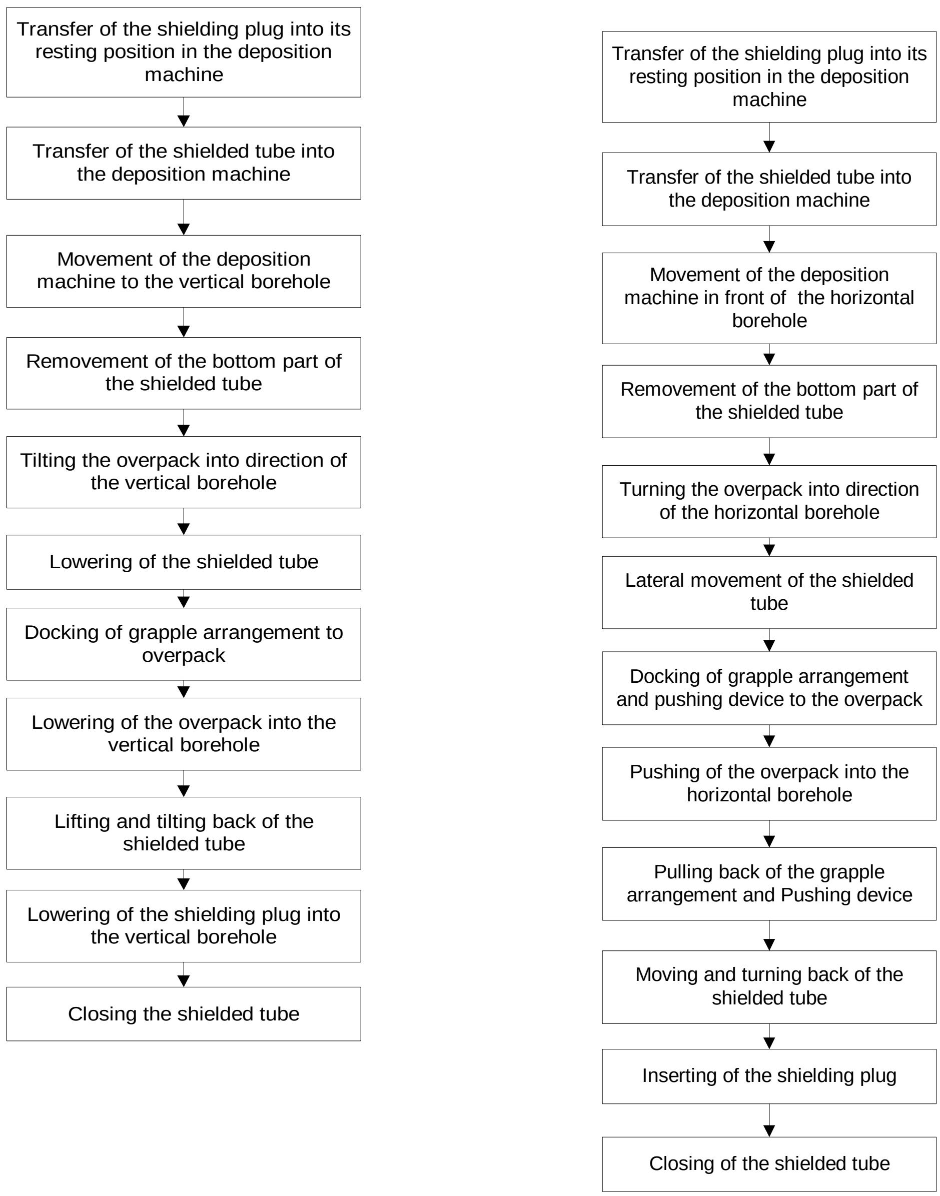

Fig. 2 Flowcharts for vertical and horizontal borehole concept

Summary for the Borehole Concepts

In the evaluation of both concepts the vertical borehole concept got a better score but the advantage was less than 10%. The advantages and disadvantages of the concepts are:

- It is easier to grip the overpack in the vertical borehole in case of retrieval of an overpack
- The hoist equipment of the vertical deposition machine is more robust.
- The hoist equipment of the vertical deposition machine is more proven (cranes) than the pull / push chain of the horizontal deposition machine.
- The investment costs for the horizontal borehole concept are higher (less standard components)
- It is more difficult to provide shielding for the curved sidewalls of gallery concept, than for the flat floor as would be done for the vertical borehole concept.
- The deposition machine for the horizontal borehole concept is bigger and heavier (more shielding).

After consideration of the above advantages the vertical borehole concept was recommended.

SUPERCONTAINER CONCEPT

The main difference of the supercontainer concept compared to the borehole concept is that in case of the supercontainer the canister with the vitrified waste has its own shielding which is deposited with the canister. The dimensions of such supercontainer are 2.0 m diameter, 4.4 m length and 42 t weight.

For the deposition of supercontainers, 5 concepts were developed and evaluated. The interfaces for the concepts were a conditioning plant on ground level and the deposition of the supercontainer in its final storage position. All necessary work-steps between these two interfaces were investigated. The heavy duty elevator is not described in detail, since the same type was chosen for all concepts.

Concept 1: Transport of the Supercontainer with a Low-loading Truck and an Air Cushion Transport System

The transport procedure consists of the following steps:

- Positioning of the low-loading truck with an air cushion transport system on it at the conditioning building.
- Placing the supercontainer on the air cushion transport system.
- Drive of the low-loading truck to the platform at the transport shaft.
- Backing the low-loading truck against the platform.
- Floating the air cushion transport system inclusive the supercontainer into the heavy duty elevator andlowering of the air cushion transport system inclusive the supercontainer to the underground disposal area.
- Floating of the air cushion transport system inclusive the supercontainer from the transport shaft through the chamber and the transport gallery to its final position in the disposal galleries.
- Placing the supercontainer on a support structure in the disposal galleries.
- Return of the air cushion transport system to the initial point at the conditioning building.

Concept 2: Transport of the Supercontainer with an Air Cushion Transport System only

Transport procedure:

Positioning of the air cushion transport system at the conditioning building and placing the supercontainer on the air cushion transport system and floating of the air cushion transport system into the heavy duty elevator at the transport shaft. Then lowering of the air cushion transport system inclusive the supercontainer to the underground disposal area.

Floating of the air cushion transport system inclusive the supercontainer from the transport shaft through the chamber and the transport gallery to its final position in the disposal galleries.

Placing of the supercontainer on a support structure in the disposal galleries.

Return of the air cushion transport system to the initial point at the conditioning building.

Concept 3: Transport of the Supercontainer on Rail-bound Transport Vehicle

Transport procedure:

Positioning of a transport vehicle at the conditioning building and placing of the supercontainer on the upper trolley. Driving the transport vehicle into the heavy duty elevator at the transport shaft and lowering of the transport vehicle inclusive the supercontainer to the underground disposal area.

Driving the transport vehicle inclusive the supercontainer from the transport shaft through the chamber and the transport gallery to the entrance of the disposal galleries.

Turning of the upper trolley with the turning device into the direction of the disposal galleries and set down of the upper trolley on height adjustable feet. Then connecting the supporting structure of the upper trolley with the rail supporting structure in the disposal galleries.

Driving of the upper trolley from the bottom trolley onto the rails in the disposal galleries.

Placing the supercontainer on a support structure in the disposal galleries by lowering the lifting cushions.

Return of the upper trolley to the bottom trolley.

Return of the transport vehicle to the initial point at the conditioning building.

Concept 4: Transport of the Supercontainer on a Rail-bound Transport Vehicle Combined with an Air Cushion Transport System

Transport procedure:

Positioning of the transport vehicle at the conditioning building and placing the supercontainer on the upper trolley. Driving the transport vehicle into the heavy duty elevator at the transport shaft and lowering of the transport vehicle inclusive the supercontainer to the underground disposal area.

Driving the transport vehicle inclusive the supercontainer from the transport shaft, through the chamber and the transport gallery to the entrance of the disposal gallery.

Turning of the upper trolley with the turning device into the direction of the disposal galleries.

Set down of the upper trolley on height adjustable feet and connecting of the transport vehicle to the disposal galleries.

Floating of the upper trolley from the bottom trolley into the disposal galleries and placing of the supercontainer on a support structure in the disposal galleries.

Return of the upper trolley to the bottom trolley.
Return of the transport vehicle to the initial point at the conditioning building.

Concept 5: Transport of the Supercontainer on a Rail-bound Transport Vehicle to the Disposal Galleries afterwards Pushing the Supercontainer on its Final Position

Transport procedure:

Positioning of the transport vehicle at the conditioning building and placing the supercontainer on the transport vehicle.

Driving the transport vehicle into the heavy duty elevator at the transport shaft and lowering the transport vehicle inclusive the supercontainer to the underground disposal area.

Driving the transport vehicle inclusive the supercontainer from the transport shaft through the chamber and the transport gallery to the entrance of the disposal gallery.

Turning of the supporting structure inclusive the supercontainer on the transport vehicle with the turning device into the direction of the disposal galleries.

Set down of the supporting structure on height adjustable feet and clamping of the pushing rail on the trolley supporting structure with the rail of the supporting structure in the disposal galleries.

Pushing the supercontainer into the disposal galleries with a pushing device on the transport vehicle (e. g. spindle driven).

Loosening of the clamping system.

Turning of the turning device in its initial state.

Return of the transport vehicle to the initial point at the conditioning building.

Positioning of an additional hydraulic pushing device in front of the disposal galleries.

Clamping of the additional pushing device to the rails in the disposal galleries.

Pushing the supercontainer from the entrance of the disposal galleries to its final position on a Teflon-coated rack.

Return of the pushing device to the entrance of the disposal galleries.

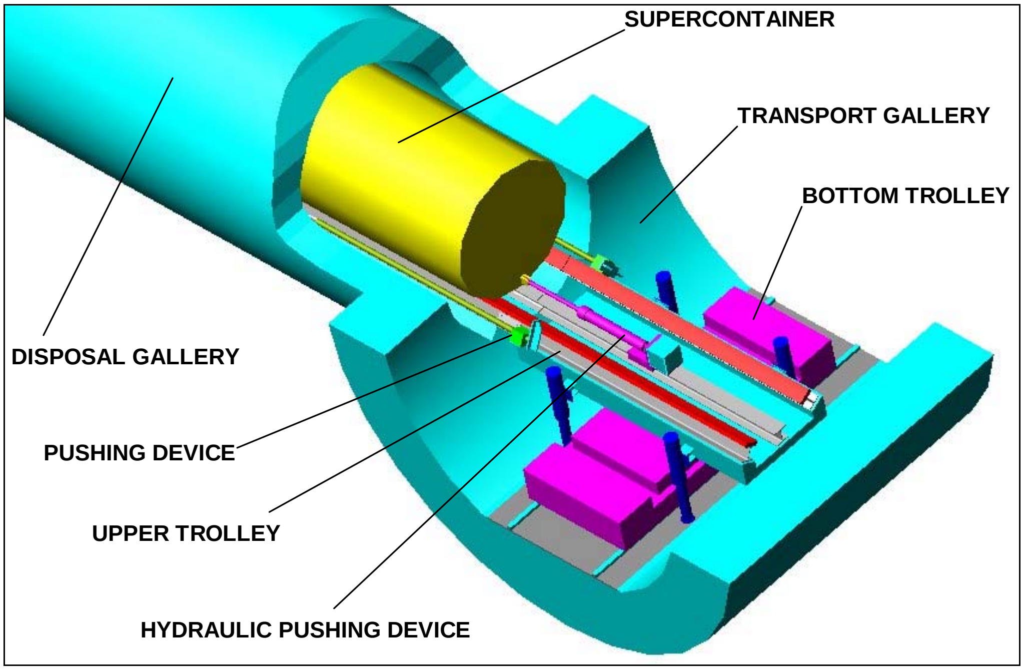

Fig. 3 Concept 5 combined railbound and sliding transport

Functional Sequences Scheme of Operation

To ensure that the single functions are completely described, a whole break down of the procedure starting from the transfer at the conditioning building up to the final disposal of the supercontainer has been performed. The deposition of the supercontainers inside the repository will be done step by step filling one disposal gallery after another. The following flowchart gives an overview of the main operations:

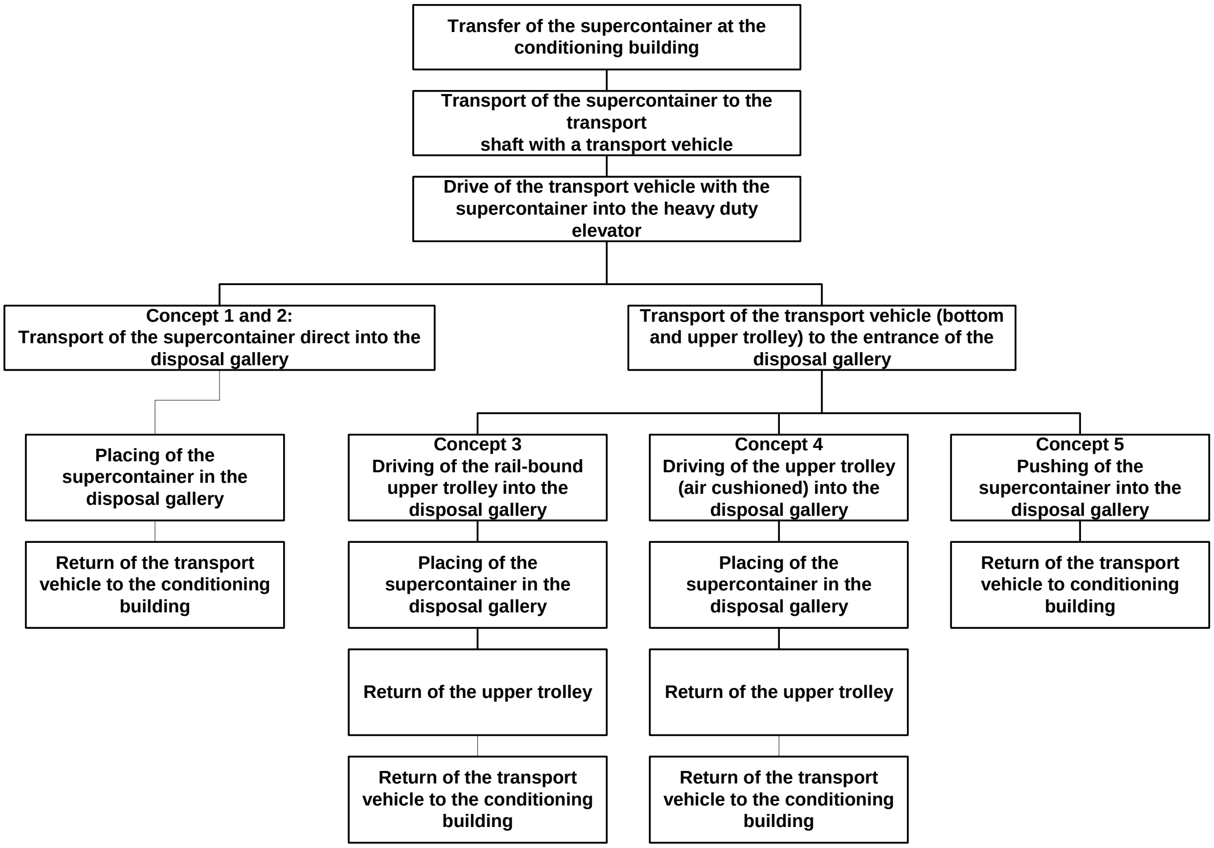

Fig. 4 Flow chart for main operations of supercontainer concepts

Summary for Supercontainer Concepts

The analyses of the evaluation matrixes showed that the Concept 2 with the air cushion transport system is the most favourable solution. The main reasons are:

The air cushion transport system is a simple machine with less different components, which are a proven equipment and which is used in a wide range of application e.g. transport of whole buildings or heavy machines. The control of the movements is standard in use and therefore reliable and robust. In case of a malfunction of one air cushion, the air cushion could be easily replaced. In case of a malfunction of the drive, the transport vehicle could be moved by manpower.

The space between the disposal galleries and the disposed supercontainer could be minimised. The handling steps are easy. The retrievability is guaranteed. There is rather no risk of leaving material in the gallery since there would be no requirement for rails. This conforms with the general requirement to minimize the amount of foreign material left in the galleries.

It is recommended to continue with this kind of transport vehicle in the basic design.

The evaluation matrix showed, that Concept 1, truck with air cushion, is the second choice. But it is better to change the truck against a cheaper and faster rail bound transport vehicle for the transport between conditioning building and elevator. The main disadvantages of Concept 4 in respect to the proposed Concept 2 are the access to the machine and the complexity of the handling steps.

SUMMARY

The feasibility of the borehole concept and the supercontainer concept was demonstrated. For both concepts a preferred option was recommend. In the evaluation between the both concepts the supercontainer concept scored higher and was recommended for further design steps. The main reasons for the higher score were:

The waste canister is shielded during the whole handling process. In case of malfunctions access and repair is possible without prior shielding measures.

Handling is easier since no shielding has to be opened or closed during the transport and deposition procedure.

The needed equipment is simpler for the same reason as mentioned before, the waste can be retrieved easily.