ALTERNATIVE DEEP REPOSITORY DESIGNS FOR DISPOSAL OF VERY HIGH LEVEL WASTE IN BELGIUM

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ABSTRACT

The objective of this paper is to describe the recent developments with respect to the conceptual design of repositories for disposal of VHLW in Belgium.

Since more then 25 years now, research in Belgium has been focused on the Boom Clay layer, located at a few hundred of meters depth in the north-eastern part of the country. An underground research facility constructed in Mol in 1985, contributed largely to the current knowledge of the behavior and the suitability of the Boom Clay as host rock for VHLW disposal.

The development of disposal concepts and repository designs for all radioactive waste types is the responsibility of ONDRAF/NIRAS[i], the Belgian Radioactive Waste Agency. These repository concepts are developed in close collaboration with SCK●CEN[ii] and EURIDICE[iii] in Mol and with BELGATOM[iv] in Brussels.

According to the initial disposal concept developed in the nineties, the canisters were disposed in long horizontal galleries. A central steel liner, placed inside hydrated bentonite blocks, would serve as a disposal tube for the insertion (and retrieval) of the VHLW packages. During evaluation of the above mentioned repository design, a number of unresolved questions were identified (mostly related to technological and operational issues) and these clearly indicated the need for further work and for some important modifications.

Recently, three alternative designs were developed for the disposal of high level vitrified waste: the Sleeve, Supercontainer and Borehole designs. The paper will describe briefly the different components and engineered barrier systems of these three designs. The most important design requirements will be discussed and some obvious pros and cons will be highlighted.

The different studies, carried out until now to evaluate the feasibility of these three designs, will be described. For these three alternative designs, a preliminary repository lay-out was completed taken into account different boundary conditions such as stability, operational safety, different disposal periods and phasing, ventilation, presence of other waste forms and disposal rate.

INTRODUCTION

Since more then 25 years now, research in Belgium has been focused on the Boom Clay layer as a potential host rock for the disposal of high level waste coming from the Belgian nuclear program. This poorly indurated clay layer is located at a few hundred of meters depth in the north-eastern part of the country. In the early stage of the research program, most attention was given to the study of this natural barrier and its properties to delay migration of radionuclides towards the biosphere. Although this research effort is not yet finished, a significant amount of data related to the properties of the host rock exists today. The underground research facility "HADES" constructed in Mol in 1985, contributed largely to the current knowledge of the behavior and the suitability of the Boom Clay as host rock for VHLW disposal.

The development of disposal concepts and repository designs for all radioactive waste types is the responsibility of ONDRAF/NIRAS, the Belgian Radioactive Waste Agency. These repository concepts are developed in close collaboration with SCK●CEN and EURIDICE in Mol and with BELGATOM in Brussels.

Although the relative contribution of the Engineered Barrier System (EBS) to the long term safety of the disposal system, in comparison with the Boom Clay layer, could be qualified as rather minor, it was recognized during the last years that a significant effort should be made in order to define more precisely the different components of the EBS and their (safety) functions during the different periods (operational, closure, long term) of the disposal system.

BELGIAN REFERENCE DESIGN FOR HIGH LEVEL VITRIFIED WASTE FROM THE NINETIES

Different designs have been considered since the beginning of the research program. These designs were all based on the assumption that the effective thickness of the Boom clay layer should be used in the most optimal way, meaning that the repository should be located in the median plane of the clay layer and that the waste should be disposed in horizontal disposal galleries.

Former reference design for disposal of vitrified HLW (SAFIR-2[v] reference design)
During the nineties, a specific design was developed for the disposal of vitrified HLW. A detailed description of this design can be found in [1] and [2]. This design envisages a network of horizontal rectilinear galleries. Access to the underground is by two shafts with an effective diameter of approximately 6 m and linked at their base by a connecting gallery, 400 m long and 2 m in diameter. The shafts give access to two transportation galleries of 3.5 m in diameter, which are located at right angles to the connecting gallery. The disposal galleries (length 800 m) that will receive the radioactive waste branch out from this H-shaped vertebral column. The plane of the disposal facility follows the dip of the clay layer, which is 1 to 2%.

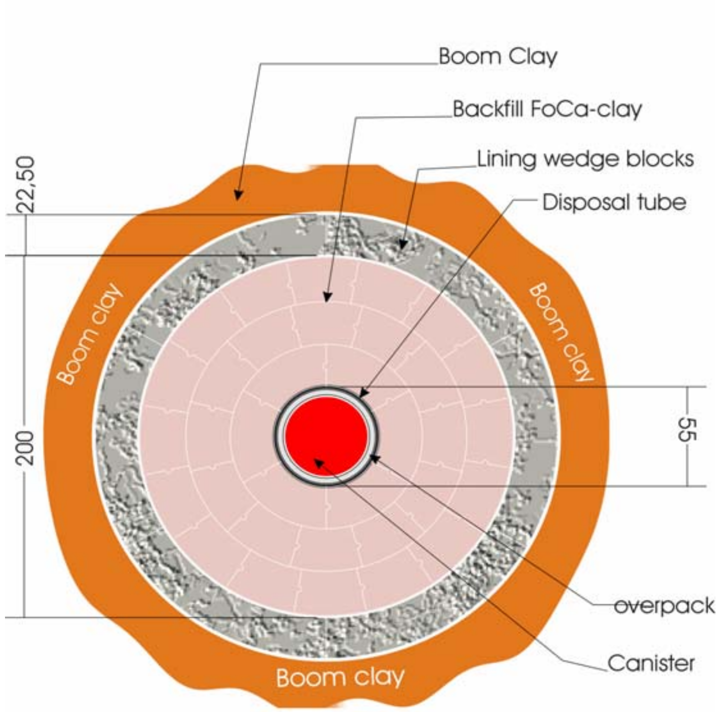

Fig. 1 Reference design from the nineties ("SAFIR-2"-design)

The design of the disposal galleries provides for a succession of concentric envelopes (the engineered barriers) around the waste packages (see Fig. 1). The primary package of vitrified waste, surrounded by its overpack, is pushed into a stainless steel tube, the "disposal tube", aligned on the centerline of the gallery. On each end of the overpack are four wheels mounted at 90°, with permanent brakes to prevent the package moving accidentally; a gripper head is also mounted axially at one end of the overpack. Each disposal tube consists of sections hermetically welded to one another so that water cannot come into contact with the waste, as this could generate steam and induce unwanted geochemical phenomena. The space between the tube and the gallery lining has previously been filled with a swelling bentonite backfill material that is naturally or, if necessary, artificially hydrated before the waste is placed. The gallery walls and the walls of the access shafts are lined with prefabricated concrete segments.

Problems Related to the SAFIR-2 Design

The experiences with the OPHELIE[vi] mock-up, the preparations for the PRACLAY[vii] experiment, and the redaction of the SAFIR-2 report resulted in the identification of a number of unresolved questions regarding the practical implementation of the reference design. In general, these questions were related to the practical feasibility to safely transport and emplace the highly radioactive waste packages from the above ground buildings into the relatively small disposal galleries. Especially the disposal tube and its interaction with the bentonite backfill material around it was an important source of concerns. Furthermore, the material choice and dimensions for some engineered barriers (e.g. overpack) seemed not sufficiently justified and documented.

These unresolved questions clearly indicated that the SAFIR-2 reference design still needed further development and modifications. To meet this need, and at the same time to provide for a broader basis of justification of a proposed design, a multidisciplinary working group "GTA" was created. This working group gathers people from different companies (ONDRAF/NIRAS, SCK-CEN and EIG EURIDICE) and from different fields of expertise (technology, phenomenology and safety performance). More information about the activities of the GTA working group can be found in [3].

GENERAL AND SPECIFIC REQUIREMENTS FOR A REPOSITORY DESIGN FOR HIGH LEVEL WASTE

Assumptions

The following basic assumptions are made:

- No decision on the selection of a site for the repository has yet been taken by the Belgian government. However, in line with the SAFIR 2 report [1], the reference repository is assumed to be situated in the Mol-Dessel area, in the North-Eastern part of Belgium, where the underground contains a layer of Boom Clay, approximately 100 m thick and starting at a depth of 180 m below the surface.
- The repository design work for HL vitrified waste is intended to serve as a reference for design work on the overall repository for the medium and high level radioactive waste in Belgium. The HL vitrified waste has been chosen because it is the most demanding type of waste from a thermal and radiological point of view.

Design Requirements Related to Safety

The safety-related requirements are based on the general design requirements and safety strategy as stipulated in the SAFIR 2 report (see Section 1.4 of [1]). Some of the more general rules of this report have been translated into more specific requirements, for some it was necessary to add a few specific requirements within the same context. The resulting set of requirements is presented below.

Design Requirements Related to Long-Term Radiological Safety

In brief, the system must provide physical containment (water tightness and limitation of water influx) during the thermal phase of the repository, delay and disperse the escape of radionuclides (from the waste matrix and through the disposal system), dilute the concentration of radionuclides escaped from the disposal system, and limit access to the disposed waste.

- The Engineered Barrier System (EBS) has been attributed the role in the disposal system of ensuring containment of the radionuclides during the operational and thermal phases of the repository. The following specific rules were added:

  - The waste overpack and its immediate environment should be designed to provide containment of the radionuclides for a period of at least 500 years for HL vitrified waste and 2000 years for Spent Fuel. Both time periods were derived from the consideration that complex interactions between components of the engineered barriers and also radionuclide migration under an important temperature gradient should be avoided during the thermal phase. Both phenomena are generally considered as potentially enhancing radionuclide releases.
  - In order to limit the duration of the operational phase, in which the waste overpack and its immediate environment are exposed to the corrosive effects of air, the different design options should guarantee a deposition rate of at least 4 canisters (i.e. 2 overpacks) of HL vitrified waste per day. An additional reason to minimize the duration of the operational phase is to minimize costs.

  - To ensure the reliability of the used materials and applied operations, a Quality Assurance and Quality Control (QA/QC) Program should be elaborated for each component (e.g. for welds).
  - For HL vitrified waste, a backfill is required to provide very long-term mechanical support of the gallery walls. The aim of this requirement is to prevent sudden breakdown of the gallery walls onto any of the waste, even in its post-conditioned form and even after very long time periods.
- The repository design should minimize perturbation of the barrier performance of the Boom Clay host rock. The role of the Boom Clay in the disposal system is to delay the migration of radionuclides from the waste matrix and through the disposal system. This general requirement has been translated into the following more specific rules:
- The specific characteristics of the Boom Clay may not be disturbed by mechanical operations. This will require the use of specialized excavation and construction techniques to realize the circular galleries with limited dimensions. The barrier performance of the Boom Clay has been extensively characterized by the SCK•CEN.
- The different components of the engineered barriers should be conceived and chosen in such a way that they do not adversely affect the performance of the Boom Clay.
- The horizontal disposal galleries are assumed to be located in the middle part of the Boom Clay layer in order to maximize the effective thickness of the layer of clay around the waste. This means that the disposal galleries will lie at a depth of about 230 m below the surface.
- The temperature increase in the Boom Clay near field should be limited. A maximum temperature requirement of 100°C at the interface between the overpack and the surrounding material has been set forth. This requirement minimizes the temperature impact on the performance of the engineered barriers and on the performance of the host rock.

Design Requirements Related to the Assessment of Long-Term Radiological Safety

- In order to limit the uncertainties related to the assessment of its long-term performance, the disposal system should possess certain robustness, i.e. the characteristics of its components should exhibit a certain stability or predictability. It is important to avoid as much as possible any occurrence of chemical or physical interactions between the waste, the engineered barriers and the host rock. Within this context, the specific rule has been adopted to: "Make a physical separation in the repository between the different types of waste. An additional reason for making such a separation is that it will simplify the waste handling problems".

Design Requirements Related to Safety During the Operational Phase

- The repository design should provide radiological protection to the personnel operating the repository facility. The Belgian legislation (ARBIS/RGPRI) with respect to the maximum allowed doses should be respected. In addition, the following specific rule has been adopted:
  The design should consider the repository as a non-contaminated zone.
- Also the conventional (non-radiological) safety of the workers should be assured during the construction and operational phases (e.g. handling) of the repository.

Design Requirements Related to Criticality

All the conditions of normal and contingency operation and all the conditions of long-term containment of the waste must be such that they take adequate account of the risks of criticality.

Design Requirements Related to Non-Radiological Environmental Impact

Since the Neogene aquifer above the Boom Clay layer is used for the generation of drinking water, any temperature increase caused by the dissipation of heat from the repository should be limited to a maximum value in line with applicable regulations on drinking water (i.e. 25°C). To comply with this, the requirement has been set forth to limit the temperature rise at the interface between the Boom Clay and the Neogene aquifer to 10°C. Further studies are needed to confirm this upper limit.

Design Requirements Related to Flexibility

As a general rule, the development and implementation of a disposal system should follow a step-by-step approach. The concerned time period covers many decades, during which new insights may be acquired or new technologies developed. It should therefore remain possible to reverse or to defer certain decisions on technical solutions.

Design Requirements Related to Retrievability Of The Waste

Retrievability of the waste, although not a legal obligation, should be considered for each of the lifetime phases of the repository. Necessary operations and associated costs should be among the elements to consider. However, design options introduced to facilitate retrievability should under no circumstances adversely affect the operational or long-term safety of the repository.

Design requirements related to technical feasibility

The repository design should be shown to be technically feasible. Therefore:

- To optimize safety, reliability, robustness and cost-effectiveness, the design of the repository components and transportation equipment should be based on well-known systems and mechanisms that have proven their effectiveness in the industry. In addition, the following specific rule has been adopted: "For the consideration of wear-and-tear of equipment, a duration of 50 years of the operational phase of the repository is assumed".
- Construction and assembly of equipment and components should occur as much as a possible in above ground conditions, since this will facilitate the QA/QC of used materials and operating procedures.

SHORT DESCRIPTION OF THREE DESIGN OPTIONS FOR A REPOSITORY FOR HL VITRIFIED WASTE

Introduction – common aspects

The repository design presented in the SAFIR 2 report [1] included a number of weak points regarding its technical feasibility. To respond to this problem, three alternative conceptual disposal designs have been developed, in line with the recommendations provided by the peer review of the SAFIR 2 report [2]. These designs are the Supercontainer, the Borehole and the Sleeve design.

In all of these three designs, the basic HL vitrified waste packages (150 liter canisters produced by COGEMA), are contained by a metallic overpack, containing two of such packages. The overpack is given in Figure 2. Note that the dimensions given on the Figure are preliminary and best-estimate. The material of the overpack can be stainless steel or carbon steel, depending on the disposal design.

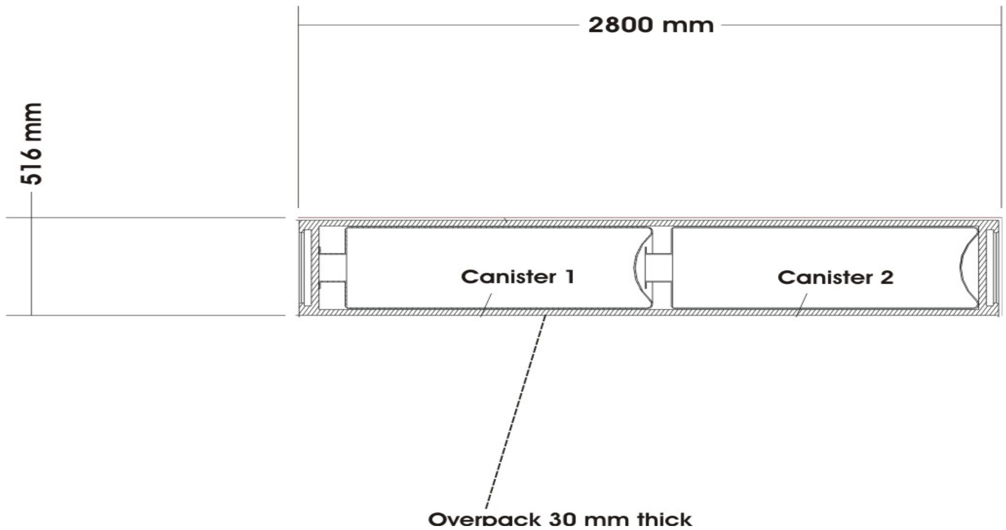

Fig. 2 Overpack with two canisters

Supercontainer design

The basic aims of this design are:

- To construct the different engineered barriers around the waste as much as possible in above ground conditions, thus facilitating the implementation of a QA/QC program,
- To enhance operational safety by separating nuclear and mining operations.

The Supercontainer design provides radiological protection by means of a radiological shielding which permanently surrounds the waste canisters. An important requirement of the buffer material is that it should be chemically compatible with the nearest components (i.e. overpack and host rock). Further, it should remain stable under high temperature conditions (up to 100°C), have about the same expansion coefficient as the surrounding metal barrel, have a sufficient thermal conductivity, and preferably have a density that can provide radiological shielding without a need to overdimension the Supercontainer. The choice of the material for the buffer has not yet been made. Two options are being investigated. The reference option is a concrete based on inorganic phosphate cement (IPC). The alternative is a concrete based on ordinary Portland cement (OPC).

For mechanical rigidity, and in order to provide a casting form in the case of a cementitious material, the whole is packed in a metal barrel. This barrel also functions as a barrier that separates the buffer from corrosive agents resident in the Boom clay. As such, another function of the barrel is to provide chemical stability to the buffer material. Within this vision, it is important to limit uniform corrosion. Therefore, the use of stainless steel for the barrel is considered. When the overpack is in a stable environment, it can be more advantageous to use carbon steel, since its corrosion behavior is better studied than stainless steel. Final closure of the Supercontainer is performed by welding the cover part to the barrel.
No decision has yet been made on the means by which the Supercontainer will travel through the main gallery and disposal gallery. Based on a sensitivity study by BABCOCK NOELL, movement on air cushion is the preferred option. The Supercontainer will weigh between 25 and 35 tons, depending on the used buffer material.

Sufficient space between the outer radius of the Supercontainer and the concrete walls should be provided, thus allowing an easy movement of the Supercontainer through the length of the disposal gallery. The envisaged diameter of the disposal galleries is 2.5 m. Figure 3 presents a cross-sectional representation of a Supercontainer, emplaced in a disposal gallery. The figure also gives the reference choice of materials.

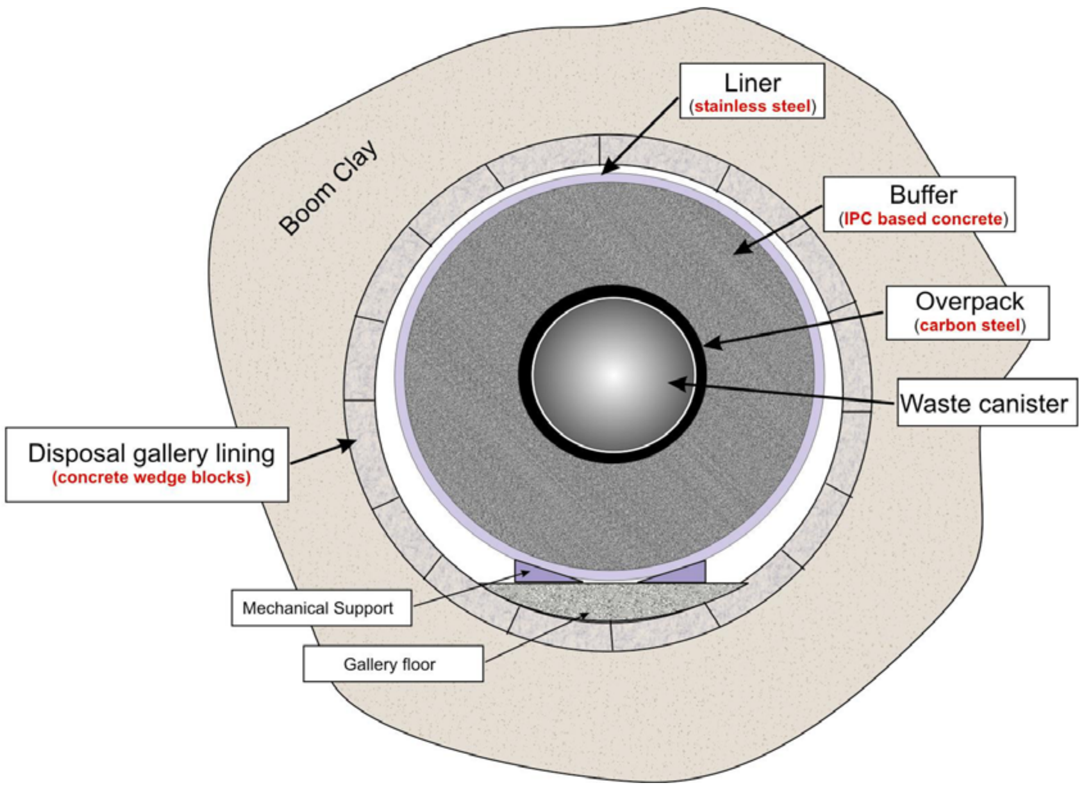

Fig. 3 The Supercontainer design (cross-section)

Borehole design

A second alternative to the SAFIR-2 reference design is the Borehole design. The main aim of this design is to keep the system of engineered barriers around the waste packages as simple as possible. This is justified by the consideration that the Boom Clay layer is the main component in the disposal system from a radiological safety point of view.

In the Borehole design, the disposition of the waste occurs in holes drilled perpendicular to the centerline of the disposal gallery and only long enough to fit one waste overpack. These are the so-called boreholes. After drilling, the boreholes are immediately equipped with a stainless steel liner, thick enough to withstand the forces exerted by the surrounding clay. The distance between the centerlines of the different boreholes of one disposal gallery has preliminary been set at 5 m, with the aim of limiting the maximum near field temperature to 100°C.

After the waste has been disposed, the borehole is closed off with a plug of radiological shielding material. On top of this plug then comes a lid in stainless steel, followed by a concrete block which is even with the floor of the disposal gallery. Since the overpack is embedded almost directly in the host rock, the use of stainless steel is considered, in order to minimize local corrosion.

In the preferred configuration of the Borehole design, the borehole is located at the bottom of the disposal gallery. An alternative configuration exists in the construction of two horizontal boreholes instead of one vertical borehole. The horizontal boreholes are located at equidistant intervals and in an alternating left/right sequence with respect to the disposal gallery. This configuration has the advantage over the vertical configuration that the borehole does not decrease the thickness of the enveloping layer of host rock. On the other hand, there are some operational disadvantages (e.g. no benefit from the force of gravity, friction between the overpack and the borehole liner). A selection still has to be made between the two alternative configurations.

No decision has yet been made on the means by which the overpack will travel through the main gallery. Based on a sensitivity study by BABCOCK NOELL, movement on air cushion is the preferred option. During its transportation, the overpack will be contained within a cask that provides radiological shielding. The overpack will be placed into the borehole by a specially designed machine, which will incorporate a radiological shielding, to allow underground workers to perform repair works in case of breakdown when loaded with an overpack. The design of this machine is similar to the disposition machine for the Swedish KBS-3 design. In order to have sufficient space for the deposition machine and to allow the insertion movement of the overpack, the envisaged diameter of the disposal galleries is 3.5 m. Figure 4 presents a cross-sectional representation of the design, with a waste overpack emplaced in a vertical borehole. The figure also gives the reference choice of materials.

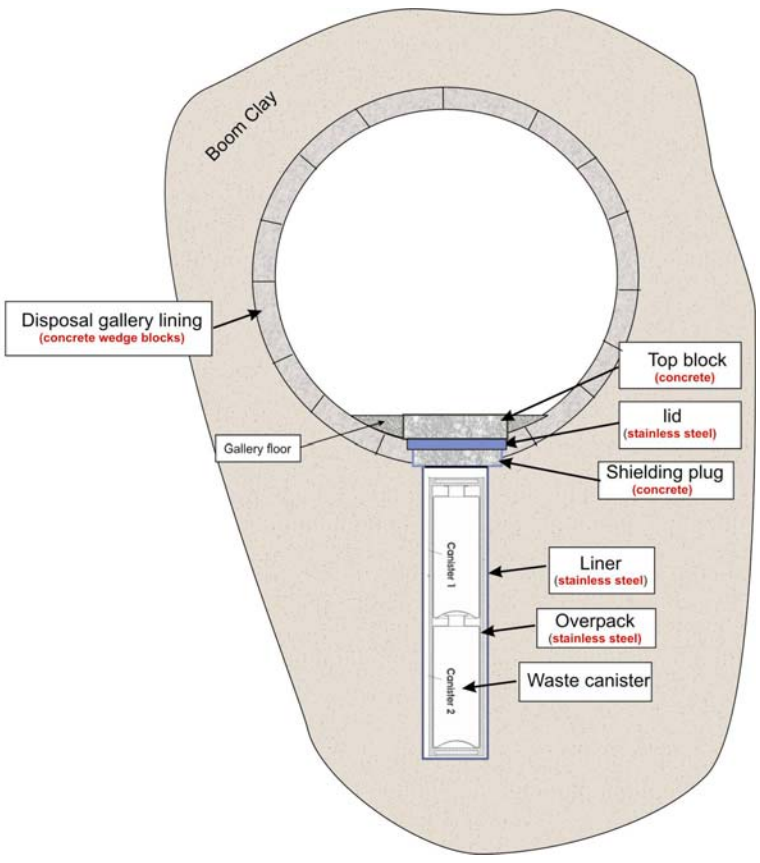

Fig. 4 The borehole-design (cross-section)

Sleeve design

A third alternative to the SAFIR-2 reference design is the Sleeve design. The main aim of this design is to minimize the perturbation of the host rock by minimizing the diameter of the disposal gallery. In the Sleeve design, the waste packages are disposed within rigid sleeves lying in the disposal gallery. Each sleeve contains one waste overpack. This sleeve is installed in the disposal gallery before the waste package is inserted. Each new sleeve is aligned against its predecessor by means of a key stone. A shielding plug closes off the already disposed waste in the gallery and thus provides radiological protection. The plug is removed before the arrival of each new waste package, and put back in place after the waste package is inserted.

The use of concrete has been excluded as the material for the sleeves, based on the consideration that this would leave a considerable void volume between the buffer and the overpack and also below the overpack. For HL vitrified waste, a backfill is required to provide very long-term mechanical support of the gallery walls. Moreover, the existence of voids between the overpack and the buffer is an adverse condition from a corrosion point of view. Also, it would at least locally create a preferential pathway below the waste. A Sleeve design in which the sleeves are made of a swelling material can provide in its own backfilling. The use of MX-80 (Wyoming bentonite) is being considered because of its relatively low content of impurities. The sleeves could be composed of cold pressure-compacted rings. There is still a need to develop technology for the envisaged dimensions. There are also still unresolved questions regarding the homogeneity of the material and its hydration. Since the overpack is embedded in a clay-based material, the use of stainless steel is considered, in order to minimize local corrosion.

The waste package, contained within a sleeve, will be transported through the disposal gallery by a specially designed forklift machine. The forklift machine also emplaces the sleeve and the waste package within its location of disposition. Within the main gallery, the forklift and its load are transported on the specially designed bridge wagon. To protect the underground workers during the transportation of the waste through the galleries, the forklift machine also incorporates a radiological shielding. The design of the bridge wagon and forklift machine has been the work of BELGATOM. Both machines will run through the galleries on rails.

The Sleeve design allows the smallest disposal gallery diameter; only 2.25 m is envisaged. Figure 5 presents a cross-sectional representation of the design, with a waste overpack emplaced in a sleeve. The figure also gives the reference choice of materials.

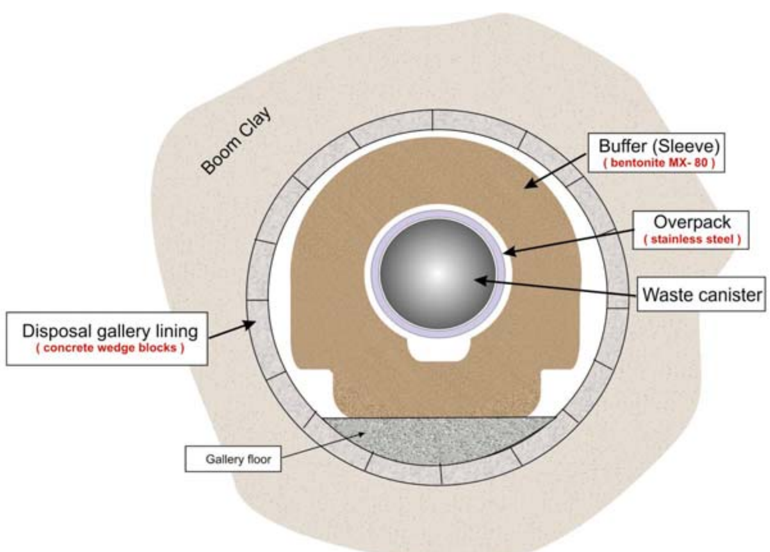

Fig. 5 The sleeve design (cross-section)

PRELIMINARY REPOSITORY ARCHITECTURE FOR HIGH LEVEL VITRIFIED WASTE

Basic assumptions and their implications

The conceptual repository design is made for the three packaging alternatives. This exercise aimed at providing basic information in order to make a rational choice between the three options for this type of waste.

Although a repository only dedicated to vitrified waste is not realistic, the reflections and methodology used will highlight the fundamental problems and interfaces which will be directly applicable for a search for an architecture encompassing all the other waste types.

The architecture is based on some basic but limited assumptions such as:

- The underground infrastructure is considered as a controlled but not contaminated nuclear zone
- There is no forced ventilation after disposal gallery closing
- The disposal rate is about two overpacks per day
- The access gallery is a 6 m internal circular tunnel

The host rock is a very soft deep overconsolidated clay with a limited thickness and an overall 1% dip. It has strong implications on the design mainly to limit the rock convergence and the EDZ:

- The necessity to lay the structures in a single middle plane
- A circular shape for all galleries
- A careful approach for the crossing of any underground structure, not only at the final stage but also at all intermediate construction stages. A reasonable diameter ratio of ½ between intersecting structure is considered as a technical-economical limit. A 90 ° crossing, if compatible with operational requirements, is the most economical.
- This type of host rock, with natural water content of 24 % must also be protected against overheating and phase changes: the linear thermal output is thus limited to about 300 W per gallery meter. This figure is also compatible with thermal temperature requirements at various interfaces with the geosphere and the biosphere if the galleries are laid out at about 40 to 50 m spacing.

The simultaneity between construction and operational phases was also investigated to analyze implications on the ventilation, safety and shafts layouts. For this aspect, we have opted for the following principles:

- Separating each specific working zone (nuclear controlled zone and construction zone), even if this physical limits moves with time
- Avoiding a change of function (for example, the waste shaft will never be reused as a construction shaft, but only as an exit route in case of emergency).

Shafts requirements

In this preliminary stage, at least three shafts were considered necessary:

- A high capacity waste shaft, to be maintained under negative pressure compared to atmospheric pressure, either to anticipate a direct safety request, or during vertical handling of waste as to reduce the consequences of an accidental drop. This shaft serves as construction shaft at the early stage of the project. When finished, it must be equipped for the ventilation and as escape route for the personnel, either from the "nuclear", or the "construction" side.

- A high capacity construction shaft, the first one built on the site. It is intended exclusively for construction and used for the descent of the tunneling machine (TBM), various equipment, segments, contractor's personnel and ventilation. It is also needed for spoil removal. It serves as escape shaft for any category of personnel.
- A smaller diameter personnel shaft, exclusively intended for the "nuclear" personnel and for ventilation. It provides, in operational phase, a permanent fire exit for both "nuclear" and "construction" personnel, whatever the disposal phase may be, and especially during the waste descent

A permanent separation of functions between construction and nuclear shafts is important for reliability: the operation constraints are completely different between a nuclear controlled shaft and a construction shaft. The latter is often filled with dust and subject to a more intensive and less delicate use than its counterpart. Moreover, the surface installation has a different function: working site for one, controlled nuclear zone for the other.

Construction stages

The following phases are proposed for the "sleeve" concept. The construction/operation simultaneity is illustrated on Figure 6. Minor changes are necessary for an extrapolation to the "borehole" options.

- **Construction of the three shafts, a rectilinear main gallery, the access gallery and the first disposal gallery.**
  This stage is only constructive.
  The main gallery is built in one stage using a tunneling machine assembled at the construction shaft bottom. At the future intersections with disposal galleries, a reinforced cast iron lining is immediately installed with no excavation slowdown in order to limit the EDZ which is time dependant in the Belgian clay.
  For a concept which only takes into account the vitrified wastes, this main gallery can be very short (200 to 400 m) and completely lined with cast iron. If other types of waste are taken into consideration, the gallery will be longer, with alternates concrete/steel linings and the two main shafts farther apart.

- **Operation of the first disposal gallery, simultaneous construction of the second.**
  The main shafts purpose diverges.
  Two ventilation scenarios were studied, based on the same basic idea: to prevent air charged with dust or fume (in the event of fire) present in the construction zone from polluting the nuclear zone. The following describes the most probable which consider that "construction" and "nuclear" air flows are never mixed in normal operation (distinct flows)

The nuclear zone is supplied by air through the personnel shaft. This supplied air flows through the main gallery, where it is extracted near the airtight door between "nuclear" and construction zone. From there, it passes through ducts (located or in invert or in gallery). These ducts bring the air at the bottom of the waste shaft, from where it is extracted by means of an exhaust system were HEPA filters are inserted. Isolation and fire dampers are installed in these ducts. An airlock is also needed between the main gallery and the waste shaft. The construction zone is supplied by air through ducts (or in invert, or in gallery). This air is blown into the gallery near the airtight door between both zones, flows through the main gallery and the construction shaft out to atmosphere.

This ventilation system assures a negative pressure within nuclear zone with respect to construction zone, and in the waste shaft with respect to atmospheric pressure. It also allows a filtered exhaust of all "nuclear" ventilation air.

This option also eliminates the consequences of a fire in the construction zone for the nuclear zone and vice versa.

During the first gallery waste filling, the second may be safely built with minimal interferences.

- **Operation of the second gallery, construction of the third one**
  Once the second disposal gallery is filled with waste, the airtight door is relocated. In case of ducts in the invert, plates allow to close / open the air supply and to make the use of air cushion transport possible. In case of ducts in the gallery, these ducts are either extended or shortened.

  The proposed staging is repeated until the last gallery is brought into operation. The airtight door is then located at the bottom of the construction shaft. A small amount of air is blown into this shaft to allow using it as an emergency exit.

Application for the borehole concept:

The disposal scheme consisting of overpacks installation in vertical drillings 5 m apart implies much longer galleries.

The necessity to weld the stoppers inside the disposal gallery implies a permanent ventilation system during the placement process and thus a much more demanding ventilation system with booster fans placed at the intersections. The disposal gallery internal diameter is about 3.5 m. For this scheme, crossings design with the main galleries is not compatible with a small controlled EDZ. It is thus desirable to envisage a local reduction in diameter down to about 2.5 m (this diameter seems compatible with the handling of the shielded tube itself). The transportation carrier must then be assembled in the disposal gallery itself.

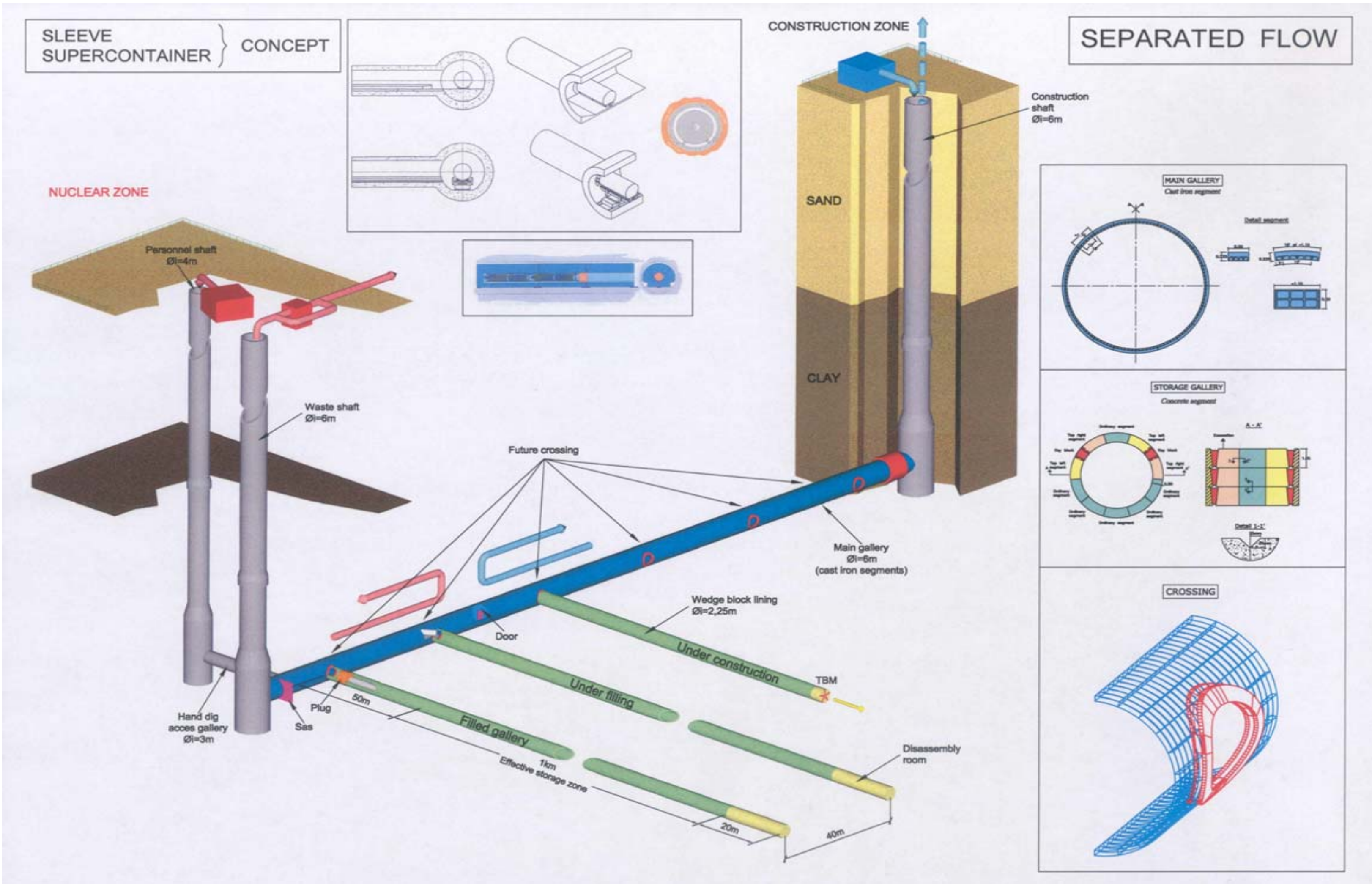

Fig. 6 Construction stages

Ventilation schemes

Without developing the detailed approach used for ventilation, preliminary calculation (air speed, thermal loads,..). the study has demonstrated that combining a ventilation shaft and a personnel access shaft is at the limit of feasibility if higher thermal loads are supposed, thus for an extrapolation to other waste types. To obtain sufficient free space within the shaft, drilling a larger diameter may be necessary. Extension of the repository will most likely impose the construction of a dedicated additional ventilation shaft.

Backfill

This preliminary study did not yet envisaged the backfill requirements. This problem is tackled within the ongoing study. It will have important consequences due to possible dust presence, modification of the internal diameter, reversibility, quality control, disposal rate, ventilation schemes.

CONSIDERATIONS RELATIVE TO THE DESIGN AND REPOSITORY ARCHITECTURE FOR OTHER WASTE FORMS (HLW AND MLW)

The ongoing study aims at providing a catalogue of architectural solutions for the whole ranges of Belgian waste, including vitrified wastes. The study will consider the reprocessing or no reprocessing option. Two main waste groups are considered:

- Category B wastes (MLW) , including cemented, bituminized drums of various shapes, weight and origins. It mainly consists, however of 200 and 400 liters drums.
- Category C heat generating wastes (HLW) , including the spent fuel and the vitrified waste canisters

For Category B Waste

A preliminary phase aims at classifying the different streams in terms of dose, heat, gas potential leakage problems, weight and dimensions. The dose release and heat generation will be calculating at the planned time of disposal.

Two packaging options remain, both made of concrete: a large and heavy high capacity drum or a smaller container. The choice between the two will be made for each waste streams according to the following criteria, while keeping a high standardization approach for the whole scheme:

- 300 W/m thermal power limitation in the disposal gallery
- dose release of 25 μSv/h at 1 m distance
- associated gallery length
- structural package integrity
- handling requirements and cinematic (through shafts and crossings).

Figure 7 shows a crossing solution for the filling of a large container while respecting EDZ related requirements.

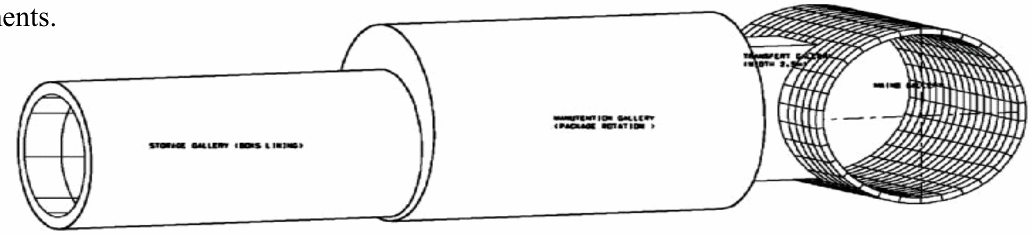

Fig. 7 Crossing between disposal and transport gallery

For Spent Fuel

Several alternatives will be integrated in the layouts, mainly based on a concrete "Supercontainer". They will depend on issues related to criticality, backfill solutions, dose, structural strength of concrete under thermal loading and long term corrosion of the overpack itself. Four assemblies are today considered per gallery section.

The chosen concrete must present high tensile strength and/or high thermal conductivity. When combined to the dose requirements during handling, several dimensions are possible.

An alternative based on the sleeve concept used for the vitrified waste is also investigated.
For these global architectures, more refined software tools are used to design the ventilation at all stages and will include fire hazard. They will also tackle branch airflows, frictional pressure drops, airway resistance, thermodynamic and psychometric properties of air, disseminated source of heat,…

CONCLUSIONS

ONDRAF/NIRAS recently reviewed their repository design for the disposal of vitrified High Level Waste. Three different options were developed: Supercontainer, Borehole and Sleeve design. Each of these design options shows some pros and cons. A multi-criterion analysis will be performed to choose the design that will be developed more in detail in the coming years.

A preliminary repository architecture was developed for the vitrified HLW taken into account specific requirements related to shaft, ventilation, operational safety and construction phases. This lay-out will be further extended to all MLW and HLW waste types.

REFERENCES

1 NIROND_06 E, "SAFIR-2; Safety Assessment and Feasibility Interim Report 2", ONDRAF/NIRAS report, December 2001

2 NIROND_05 E, "Technical overview of the SAFIR-2 report", ONDRAF/NIRAS report, December 2001

3 NIROND 2003-01, EBS Architecture for disposal of cat. B and C waste in Boom Clay, Progress report on activities between October 2001 and December 31 2002, February 2003\

FOOTNOTES

[i] ONDRAF/NIRAS: Belgian Agency for Radioactive Waste and Enriched Fissile Materials
[ii] SCK●CEN: Belgian Nuclear Research Centre
[iii] EURIDICE: Economic Interest Grouping established between ONDRAF/NIRAS and SCK●CEN
[iv] BELGATOM: Nuclear Engineering company of TRACTEBEL and BELGONUCLEAIRE
[v] SAFIR-2 : Safety and Feasibility Interim Report published by ONDRAF/NIRAS in December 2001
[vi] OPHELIE : On surface Preliminary Heating simulation Experimenting Later Instruments and Equipments
[vii] PRACLAY : Preliminary demonstration test for CLAY disposal of highly radioactive waste