Operational safety impacts on the design of the Belgian geological disposal facility for B&C wastes

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Summary

For more than 40 years, ONDRAF/NIRAS (the federal agency responsible for managing radioactive waste and enriched fissile materials in Belgium) has been studying geological disposal in poorly indurated clays as an option for the long-term management of category B waste (low-level and intermediate-level long-lived waste – LILW-LL) and category C waste (high-level waste – HLW and spent fuel). In the absence of a political decision regarding the management of category B and C waste, a geological disposal facility (GDF) in poorly indurated clays (either Boom Clay or Ypresian clays) is still the current reference option considered for the Research, Development and Demonstration (RD&D) programme.

The RD&D programme for the geological disposal for category B&C waste has been implemented in a cautious, stepwise process, punctuated by the production of key documents such as the SAFIR reports in 1989 and 2001, the waste Plan in 2011 and the RD&D Plan in 2013. In the future, in line with international practices, ONDRAF/NIRAS will produce Safety and Feasibility Cases (SFCs). The first SFC will be a safety and feasibility case (SFC-1 V1) methodology. This SFC will aim to test the methodological tools that have been developed, and illustrate the safety and feasibility of a GDF for category B&C waste in poorly indurated clays at a depth between 200 and 600 m.

The SFC-1 reference option design results from an update of the former GDF layout dating from 2003. The updated layout integrates the most recent development of the GDF construction design and also derives from the optimisation of the GDF operational safety. It also takes into account the update of the reference programme of the wastes producers and the proposed reference option for the long-term management of category B and C waste.

The objectives of the paper are to present:

- The main outcomes concerning operational safety optimisation from the Hazard Identification (HAZID) study performed on the 2003 design and their related impacts on the GDF layout
- The initial results from the ongoing operational safety analysis based on the SWIFT (Structured What if) methodology, which is performed on the SFC-1 reference design.

Introduction

The Belgian Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS) is responsible for managing radioactive waste in Belgium.

Currently there is no Belgian national policy regarding the long-term management of category B waste (low-level and intermediate-level long-lived waste – LILW-LL) and category C waste (high-level waste – HLW and spent fuel) in Belgium. Due to the absence
of a political decision, the reference option considered by ONDRAF/NIRAS is a geological disposal facility (GDF) in poorly indurated clays.

ONDRAF/NIRAS intends to develop its GDF for category B and C waste according to a cautious, step-wise decision-making process, punctuated by the submission of key documents to the relevant authorities. The aim of the present step is the submission of the first methodological safety and feasibility Case, SFC-1. Within the framework of SFC-1, the reference option is a GDF in poorly indurated clays. This reference option implies either the Boom Clay or Ypresian clays as a reference host rock. The proposed reference option for the management of category B and C waste is thus geological disposal in poorly indurated clays at a depth between 200 and 600 m. ONDRAF/NIRAS considers currently three reference depths (200 m, 400 m and 600 m) for the development of the reference disposal concept to cover the full range of possible depths.

The SFC-1 reference disposal concept design is an update of the former GDF layout dating from 2003, and is based on the outcome of operational safety optimisation, the update of the reference programme of the wastes producers, and the proposed reference option for the long-term management of category B and C wastes.

The 2003 GDF layout (shown in Figure 1) is a fishbone layout consisting of three shafts, one access gallery (AG) and 1-km long disposal galleries (DG) connecting to the AG by rectangular branches (X-crossings between AG and DG).

Figure 1: Former GDF layout dating from 2003

The paper focuses on the operational safety optimisation of the 2003 GDF design. The optimisation was based on a Hazard Identification (HAZID) study and led to the update of the 2003 GDF design. The paper also presents the first results of the current operational
safety study of the new layout. This ongoing study identifies the risks and the associated risks mitigation, according to the SWIFT (Structured What If) methodology.
2003 GDF design description

The main characteristics of the 2003 layout (Figure 1) are as follows:

- Two separated sections for B & C wastes, operated over two successive periods
- One AG – 6 m diameter
- Three shafts (one for the wastes (8 m diameter) and two service shafts (6 m diameter). Only two shafts are operated at the same time
- X-crossings between AG and DGs
- DG length of 1 km and DG diameter of 3 m
- The scenario for the 2003 design layout was a full reprocessing (former wastes producers reference programme) and a reference depth of 230 m.

Construction and operational safety optimisation

Within the framework of SFC-1, the 2003 GDF design has been optimised with regard to operational safety, construction phase safety, long-term safety, and reversibility & retrievability (R&R). Concerning the R&R topic and according to societal consultations around the ONDRAF/NIRAS waste plan and the law of 3 June 2014, ONDRAF/NIRAS is committed to ensure reversibility during the operational phase and to consider provisions to facilitate retrievability beyond the operational phase.

The construction and operational safety optimisation is a sequential process with the following phases:

- A HAZID study to identify the main construction risks and to propose risks mitigation
- Operational safety optimisation integrating the HAZID outcomes.

HAZID study

Based on the 2003 GDF design, a HAZID study of the underground construction provided the following recommendations to update the design in order to improve its safety:

- The wastes shaft-AG connection zone at the repository level is a complex mechanical structure, presenting safety risks during the construction phase. In order to reduce safety risks, the connection zone between the shafts and the AG needs to be modified by shifting the shaft away from the AG axis.
- In order to provide safe escape route in case of fire during construction or during operational phase, a safety distance of 400 m length is required for the SFC-1. The 400 m length safety distance is based on:
  - The Directive 2004/54/CE
  - The risk analysis performed in the French Cigeo project (Andra)
  - German mining regulations.

It implies that the DGs have a maximum length of 400 m (the length of blind galleries is limited to enable a safe escape path for the workers).

- Increase the number of AGs in order to reduce the operational safety risk by increasing the escape path for workers.
The HAZID study also highlighted improvements not directly related to construction or operational safety, but which would facilitate the engineering and construction activities. These improvements are:

- Use of T-crossings instead of X-crossings in order to improve the construction feasibility of the AG-DG crossings, considering the geomechanical parameters of the poorly indurated clays.
- The ratio between the AG diameter and the DG diameter should be greater than 2:1. This ratio results from review of experience of the London underground, developed in a similar clay to the Belgian poorly indurated clays (London Clay).

**Operational safety optimisation**

Based on the HAZID outcomes and starting from the 2003 reference design of the GDF for category B and C wastes, the operational safety of the GDF was optimised in two steps.

In a first step, several alternative layouts (see Figure 2) were identified, meeting the HAZID study recommendations. All proposed layouts considered limiting the length of a DG to a maximum of 400 m. The alternative layouts proposed were as follows:

- **Type A**: similar to the 2003 reference design reference design with one AG
- **Type B**: two parallel AGs connected with crossing passages (emergency route) at regular intervals
- **Type C**: similar to Type B but with the two AGs in a U shape to allow the shafts to be located in a limited area between the two waste zones (i.e. B-zone and C-zone)
- **Type D**: characterised by the use of three or several AGs, each AG connected to a defined number of DGs
- **Type E**: consisted of two AGs located at the outside of the disposal area
- **Type F**: similar to type B but with the DGs connected to the same AG.
Figure 2: Schematic overview of the alternative designs (shafts in coloured zones)

Within this first step of optimisation, these layouts were assessed during a workshop by experts from ONDRAF/NIRAS, DBE-Technology, Tractebel Engineering and EURIDICE (EIG EURIDICE is an Economic Interest Grouping, an economic partnership between ONDRAF/NIRAS and the Belgian Nuclear Research Centre (SCK•CEN). EURIDICE manages the underground research laboratory in Mol, Belgium). The assessment considered construction, operational and long-term safety. The assessment retained the layouts that could present a reasonable technical solution, even in case of drastically reduced DGs length (i.e. DGs length drastically lower than 400 m). The advantage of reduced DGs length is to allow a total reversibility, meaning the possibility to retrieve all emplaced wastes with a minimum working effort (and cost). This is possible when filled DGs with disposal waste packages are not backfilled. As the maximum length of the DG that may be filled with disposal waste packages without having to be backfilled is 50 m (this length is related to backfill curing issues), a 50 m DG length is considered to be the optimum for reversibility.

Layouts Type B and Type F were discarded because they would not cope with a 50 m DG length as the footprint of the layout becomes unreasonably large.

Several layouts (seven in total) based on Type A, C, D and E were identified in the first step of the optimisation process. The seven layout designs were:

- Type A.1 – 1000 m: 2003 reference design (one AG and 1000 m - DGs)
- Type A.2 – 400 m: same as 2003 reference design (one AG and but 400 m - DGs)
- Type C – 400 m: two AGs with DGs limited to 400 m
- Type D.1 – 400 m: multiple AGs and DGs limited to 400 m
- Type D.2 – 50 m: multiple AGs and DGs limited to 50 m
- Type E.1 – 400 m: outside AGs and DGs limited to 400 m
- Type E.2 – 50 m: outside AGs and DGs limited to 50 m.

In the second step of the optimisation process, these seven layouts were compared in a multi-criteria analysis. The multi-criteria analysis was performed by each expert of the group and was based on the following aspects: operational safety (during the construction and the operation), long-term safety, reversibility, flexibility and security.

All experts concluded that the Type C – 400 m would be the preferred layout (See Figure 3), based primarily on the operational safety, the long term safety and the security of the surface area.

**Figure 3: schematic view of the new proposed reference layout**

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**Conclusions of the operational safety optimisation – SFC-1 reference layout**

The SFC-1 reference GDF layout is derived from the preferred layout resulting from the operational safety optimisation of the GDF. The SFC-1 reference GDF layout considers use of a two-shaft zone, no DG between the AGs, and a symmetrical shape to simplify its modelling (see Figure 4).
This new proposed reference layout presents the following advantages:

- Improvement of the operational safety during construction and operation due to additional escape routes (i.e. two AGs connected with several crossing passages) and the limitation of the length of the DGs to 400 m
- Central localisation of the shafts allowing a concentration of all surface facilities in a limited area (i.e. limitation of the security area/perimeter)
- Possible use of two centralised shafts to limit the presence of potential pathways and improve long-term safety.
Further developments

Operational safety of the reference GDF layout – SWIFT methodology

The GDF design is an iterative process. Within this framework, ONDRAF/NIRAS has started an operational safety assessment of the SFC-1 reference GDF layout based on a SWIFT methodology. The SWIFT process is conducted by experts working groups and considers flowcharts describing all relevant processes during the operational and closure periods. The multi-disciplinary working group (Andra, DBE-Technology, EURIDICE, ONDRAF/NIRAS and Tractebel) preparing the SWIFT analysis has not identified any unacceptable risks, but several recommendations have been made to optimise certain scenarios, processes and design features connected to risk levels that are considered as acceptable (or undesirable), but with potential for improvement. In addition to the general results of this analysis, two major outcomes will be assessed in the future in more detail:

- Development of a transport system for the waste disposal packages that combines the turning function, and a self-propelled transport device, to reduce operational complexity and risks (by reducing the number of operations)
- Further study concerning fire safety of the GDF during operations and specifically the possibility to use rescue chambers within the DGs.

Optineering

Eventually, complementary to the operational safety studies, optineering studies are ongoing within the SFC-1 framework. The objectives of these optineering studies are to further optimise the GDF layout based on a multi-criteria assessment. The optineering methodology is a robust and transparent tool that documents the rationale behind the choices between multiple design options.

References


ONDRAF/NIRAS (2016), “Optimisation of the repository design for geological disposal (part 1)”, NIROND-TR 2016-03 E

