Proceedings of the 18th International Symposium on the Packaging and Transportation of Radioactive Materials
PATRAM 2016
September 18-23, 2016, Kobe, Japan

Paper No. 4017

I&HLW transportation and handling in a deep geological disposal

Camille Espivent
IRSN[1]

Michaël Tichauer
IRSN[1]

Marianne Moutarde
IRSN[1]

[1]Institut de Radioprotection et de Sûreté Nucléaire (IRSN), Fontenay-aux-Roses, France

Abstract

The reference solution for the long-term management of intermediate and high level long-lived radioactive waste in France is defined in the French law as deep geological disposal. IRSN is the technical safety organization whose responsibility is to assess the safety of the facility envisioned by the French radioactive waste management organization (WMO). IRSN bases its safety review on the safety case elaborated by the WMO, which is meant to evolve with the whole project development steps (conceptualization, siting, design, construction, operation and post-closure). With this regard, the demonstration of operational safety has to show evidence that, amongst other aspects, operations related to the transfer of the waste along ramp and drifts to its emplacement in disposal tunnels are safe.

Among the scenarios to be taken into account when evaluating the safety of waste handling in underground tunnels, the occurrence of a fire is particularly scrutinized by IRSN, because of its potential impact on waste containment that could lead to radioactive material releases. Moreover, fires in tunnels have specific features, as underlined by experience feedback in conventional tunnels (underground subways, railways, roads...), that need to be taken into account in terms of duration of the fire, pressure effect, temperature, smoke dispersion, etc. In turn, a geological disposal facility shows important challenges when dealing with accidental situations such as a fire because of its architecture and size associated with a potentially tremendous radiological source term: evacuation, intervention, mitigation of consequences, etc.

Therefore, waste transfer casks that will be designed specifically for underground handling in the geological disposal facility will have to withstand particularly severe accidental situations based on the occurrence of fire. The safety assessment related to these casks should at least embrace fire scenarios that are already scrutinized in transport of radioactive materials, especially in railway and road tunnels.

Introduction

The concept of deep geological disposal is the reference solution identified in the French law for the management of intermediate level waste, long-lived (ILW – LL) and for high level waste (HLW). Andra, the French waste management organization, is in charge of the disposal project development, named Cigeo, while IRSN is responsible for reviewing the safety of this project, based on the safety analysis from Andra. One aspect of IRSN’s review is to make sure that accidental situations considered for the design of nuclear facilities are representative of worst-case situations that may occur. Firstly, the design of Cigeo is very specific (long and narrow drifts for example). Secondly, the way that it may be operated makes handling the only type of nuclear activity that will take place in the underground facilities. Thirdly, French law prescribes that the deep geological disposal project has to be reversible; as a result, waste packages will have to be retrievable from their disposal emplacement, as a provision, until the end of the operational phase, for example in the case of a rise in technology that would lead to a future need for the recovery of the waste. Consequently, the safety of these handling operations is a major issue. These operations will take place inside the facility so they may not be subject to regulations dealing with radioactive material transportation in the public domain. However, when looking at fundamental principles of transportation safety in the public domain, such as the fact that the safety should rely primarily on the first containment system, the question of the opportunity of applying these principles to handling waste inside the facility arises. This paper aims at discussing how scenarios that are currently considered in the safety analysis of transportation of radioactive material are relevant with regard to the safety assessment of Cigeo, specifically regarding the occurrence of fires, and what are the perspectives in terms of considering extended scenarios.

The first paragraph describes the current project of geological disposal developed in France. The second paragraph gives insight of what the safety assessment of radioactive material transportation in the public domain should include, focusing on fire accident scenarios, while the third paragraph aims at discussing the potential need for adaptation of the fire scenarios to be integrated into the safety case of the geological disposal.

1. Cigeo: French project for a deep geological disposal

1 General overview of Cigeo

The French project of geological disposal for highly radioactive long-lived waste, Cigeo, is at the moment at the design phase. If the license is granted, the inception of construction would take place in a few years. Waste is planned to be disposed of 500 m below the surface. Long-term safety of such a facility is based on the ability of the host rock (an argillaceous formation called Callovo-Oxfordian), to maintain conditions that will limit the migration of the radionuclides. Waste packages have to be emplaced in excavated tunnels that will be sealed or backfilled at one of their ends.

Activities of excavating the rock, emplacing the waste in vaults and then sealing of the facility are projected to last over a century, given the number of packages to be disposed of. Those activities require support equipment and facilities. Figure 1 gives an overview of the current design of the Cigeo project.

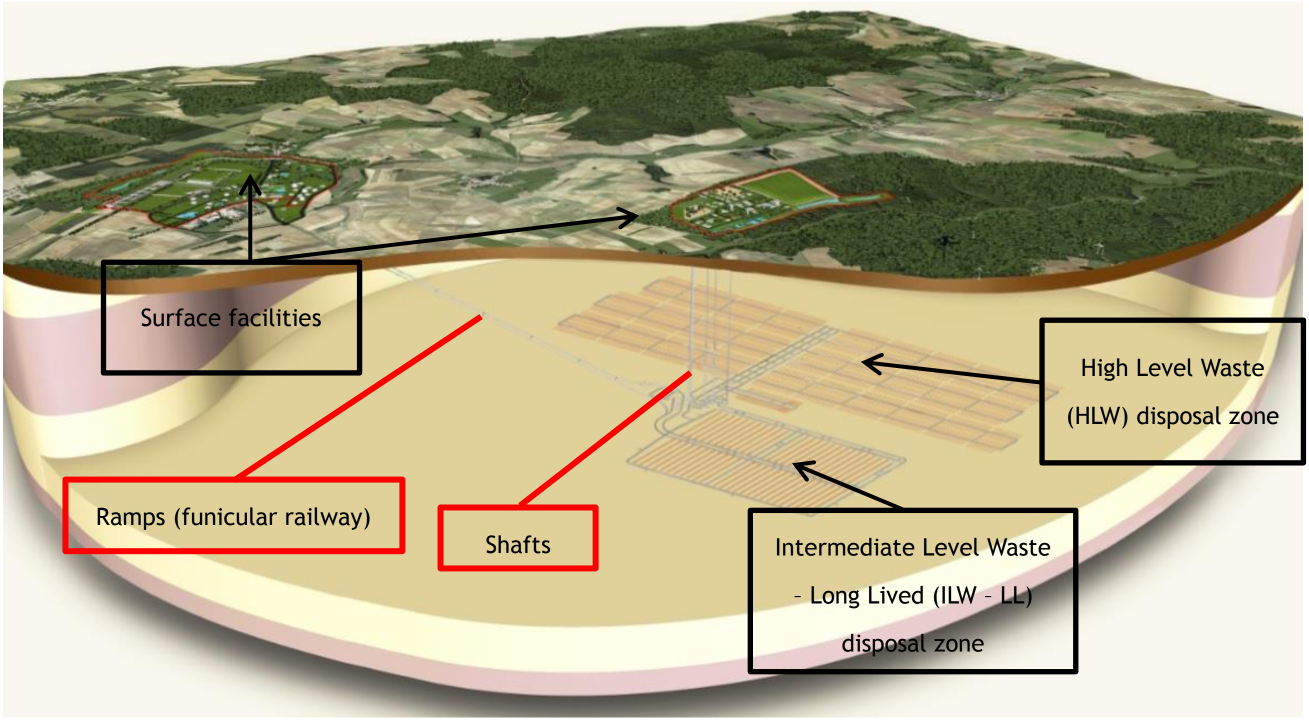


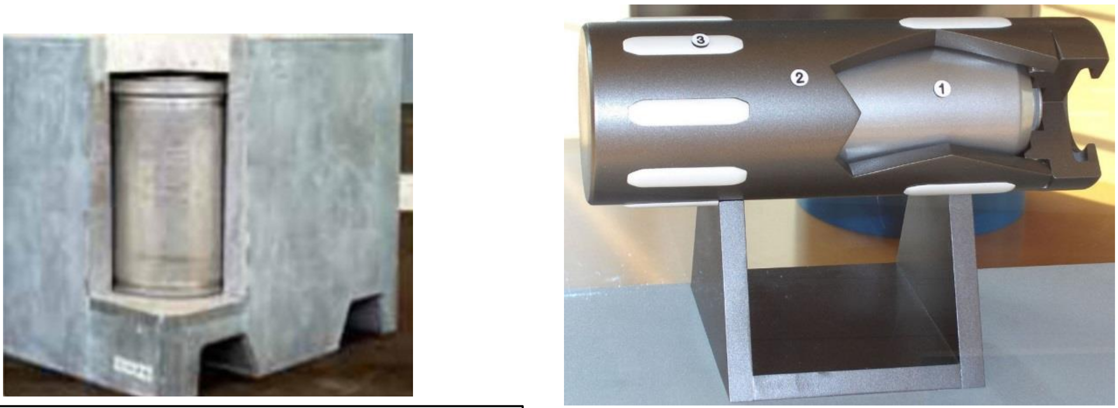
Figure 1 Overview of the Cigeo project, adapted from Andra [1]

Surface facilities are divided into two main sites on different places. The first main facility, on the left of figure 1, is designed for the following purposes: storage of waste before being transferred underground, controls and conditioning activities as well as preparing the waste for being transported to the underground via the funicular railway system that will be installed in the ramp linking the surface to the underground level (see figure 1). As for the second main facility on the right of figure 1, it is emplaced right above the shafts and is dedicated to supporting various activities such as underground construction works, maintenance and staff transfer.

The two main disposal zones spread across 15 km² underground. They are linked with drifts of different dimensions according to their functions (supporting the airflow, housing the transfer of the waste packages underground, sheltering the emergency equipment…). The two main disposal zones are dedicated to each of the waste types described below: the ILW-LL emplacement tunnels are 500 m long, with a diameter around 10 m, and the HLW tunnels are 100 m long and their diameter, of less than 1 m, make them a lot narrower.

2 Waste types and packages

The Cigeo project is being designed for a disposal capacity of approximately 55,000 HLW and approximately 175,000 ILW-LL primary waste packages. Waste that will be received at Cigeo from producers' sites will be transferred from their transport casks into specifically designed surface buildings mentioned above. HLW and most ILW-LL waste will not be ready for direct disposal: primary packages will then be conditioned into disposal containers (overpacks) as shown in figure 2 before being transferred underground.



Dummy ILW-LL primary package in a section of its disposal overpack

HLW disposal package

Figure 2 Examples of two types of waste packages expected to be disposed in the Cigeo facility (adapted from [1])

3 Waste transportation: from surface facilities down underground

Waste is bound to be transported from the surface facilities to the emplacement vaults, via a funicular railway system and through underground drifts: in total, waste will be transported along several km until it reaches its disposal emplacement. Such operations are not considered to be public transportation as the waste's path will remain inside the facility.

The design of the funicular railway system is inspired from available technology applied to equipment used in ski resorts such as illustrated in figure 3. The expected slope of the Cigeo ramp (around 10%) is however not as steep as the ones generally designed in mountain ranges (50% or more).

Figure 3 Example of a funicular railway system [3]

In addition to the unusual distances of waste handling (several kilometers), it is noteworthy that ramps and drifts are narrow pathways for waste packages. In fact, the diameter of these pathways are by design not large enough so that two waste packages can pass each other, as the schematic view of the underground station of the funicular railway in figure 4 illustrates.

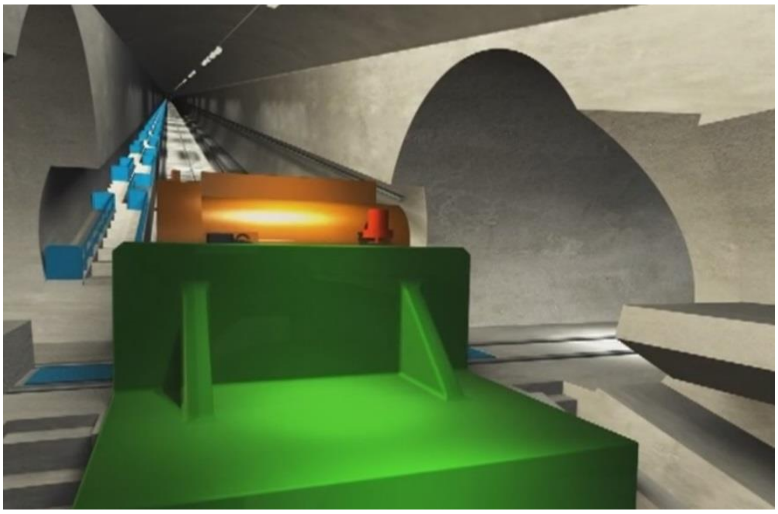


Figure 4 Schematic view of a waste package arriving down the funicular next to transfer drifts [4]

The waste package illustrated in figure 4, on the funicular system, is actually depicted inside a specific cask (in orange in figure 4), which is dedicated to handling operations of the waste inside the facility. Such a cask is envisioned to host the waste packages for their transfer from surface facilities to the emplacement tunnels, all the way through the ramp and drifts. Two types of transfer casks are designed: one dedicated to ILW-LL transport and the other one to HLW transport. They are meant to act as a protection for the handled waste packages against mechanical effects of potential collisions as well as a protection against irradiation for workers. Yet not finished, the design of these casks is complex since they are intended for different purposes related to handling, such as docking with the entrance wall of the emplacement tunnels and, in the case of the HLW-specific cask, hosting the mechanism dedicated to inserting waste packages into their own tunnels and to some extent hosting waste packages that would have been retrieved from their disposal emplacement. Therefore, the design of the transfer casks is a major issue and needs to take into account Cigeo's peculiarities.

2. International regulation for transportation of radioactive material: fire accident scenarios analysis

In IAEA regulations [5], the package (constituted with the radioactive contents and the packaging components) shall withstand different levels of stress or events, corresponding to routine conditions, normal transport conditions (mishaps such as small impact or collision) or accidental transport conditions (severe accidents scenarios). In the case of packages of type B, whose activity is not limited, they have to pass compliance tests (drop test, fire or "thermal" test…) dedicated to the demonstration that the packages are able to withstand severe accidental situations, in other words that they are robust enough to ensure limited release of activity.

The thermal test is described by IAEA regulations [5]: the package has to be exposed to a thermal environment equivalent to a fire all around it (engulfing fire), at a temperature of at least 800°C and in ambient conditions providing an average emissivity coefficient of 0.9, during 30 minutes. Then, it is exposed to an ambient temperature of 38°C for a sufficient period of time to ensure its cooling to eventually reach approaching initial state conditions. Furthermore, the consignor is advised to take into account the maximum rate of internal heat generation within the package, coming from the content. The way this test is defined and its conditions (duration of the test, fire temperature…) is intimately linked to the envisioned surrounding conditions of the transport: it is tailored to encompass worst accidental situations related to fire during transport.

After the test, the assessment of the physical response of the package has to be investigated by the consignor to complete the robustness analysis of the package. As for the consequences, prescriptions exist in terms of required performance, such as the dose rate around the package. In the case of the type B, the maximum activity release allowed in accident conditions of transport is 1 A_2 in a week, A_2 being an activity limit per radionuclide defined in the regulation [5]. As for the dose rate, it should be no more than 10 mSv/h at a distance of 1 meter of the damaged package.

Among the categories identified by the international regulation, the transport packages that will arrive from producers' sites to the surface facilities of Cigeo will be of type B. Inside the facility, the packages ready to go to the underground will be composed of primary packages, emplaced in most cases disposal containers, and the transfer cask (see above). These packages are somewhat comparable to the packages transported in the public domain at least when considering the total radioactivity content. Furthermore, handling transfer casks along a specific pathway to a disposal emplacement and transport operations from a nuclear facility to another are activities of the same nature. Moreover, some of the waste dedicated to disposal in Cigeo is featured in such a particular manner that bitumen waste contains internal reactivity that should also be taken into account: indeed, as for now, the knowledge of legacy waste does not allow to systematically exclude, in the safety analysis, situations where chemical exothermic reactions are initiated inside waste packages, leading to a thermal excursion. The principle mentioned above of considering, for the thermal test, the maximum internal heat generated by the content of a transport package is totally in accordance with IRSN standpoints when reviewing the safety case of Cigeo and more particularly the assessment of fire risk related to these packages. Besides, the assessment of the robustness of the package to pre-established environment conditions, representative of worst-case accidents, is a classical approach when the safety of nuclear facilities is assessed and is applicable to the safety assessment in the case of handling operations in Cigeo. In a word, there are similarities between the safety assessment methodology for public transport of radioactive material and IRSN's views on what should be the safety assessment by the WMO for waste handling in Cigeo. However, as the specific features suggested by its current design and underlined above, the underground facility is likely to offer quite different conditions from radioactive material transportation in the public domain, which may influence to a certain extent the fire accident scenarios that need to be anticipated by the WMO in its safety analysis.

3. Safety evaluation of handling waste in Cigeo – fire risk

One of the main outcomes of a bibliographic review carried out by IRSN on experience gained from fire accidents in tunnels is that their features are somewhat different than comparable fires (same fire load) occurring in the open field.

Firstly, fire in tunnels generates heat and smoke which cannot be diluted in the surrounding environment as in the surface. Smoke concentration, causing rapidly poor visibility, and heat accumulation thus make any human intervention particularly difficult. For example, a fire in the Mont-Blanc tunnel in 1999, whose size is comparable to underground drifts in Cigeo, generated a temperature reaching locally 1000 °C in some places of the tunnel.

Secondly, the feedback experience related to the duration of fire accidents shows that ambient conditions in tunnels when a fire occurs make emergency response difficult and that in average, fires last much longer in tunnels and become out of control when they are not extinguished from their very start, i.e. in a 15-minute time [6]. Among examples that could be given, the fire accident in the conventional toxic waste disposal of StocaMine, in eastern France, in 2002 lasted more than 2

months, from September 10th until November 21st [7]. This fire, as some other examples in tunnel history, could never be brought under control and stopped by itself.
Thirdly, supporting operational equipments in tunnels, such as electrical equipment, monitoring and ventilation devices or communication network, are more likely to be gathered by design in the confined space of the tunnels. This tends to cause their quick loss in case of the start of a fire and make emergency response actions more difficult, which is not the case for fires occurring in the open range environment.

For similar fire sources, fires in tunnels are thereby more severe than fires in the open field. Although fire tests that the packages have to pass in the context of transportation in the public domain (described above) are certainly representative of very severe fires, their representativeness of conditions if the fire occurs in a tunnel, and by extension in underground facilities of Cigeo, is questioned.

Beyond effort made by the WMO on prevention, IRSN's role is to make sure that fire scenarios presented in the safety case are severe enough, that is to say that they cover worst-case situations. In that context, the features of fires and consequently the scenarios that are needed to support the safety demonstration by the WMO may be different than the ones considered in the radioactive material transportation in the public domain. For example, the relevance of taking into account, in those scenarios, longer duration and higher intensity of the fire than the ones suggested in the thermal test for transportation in the public domain (see above) has to be further investigated. Besides, in the WMO safety analysis, the safety of the retrieval of the waste, after a century spent in the emplacement vaults, may need to take into account different performances of the package and therefore might change the consequence assessment of fire scenarios.
These perspectives might lead to a change in the design or to adding operational provisions to the existing design. Consequently, the integration of the fire scenarios studies and by extension the accident scenarios early in the design process of a facility such as a geological disposal is a major issue.

Conclusions

IRSN's vigilance in the review of Cigeo's safety case includes making sure that fire scenarios developed are representative of worst-case situations. Handling waste, which will be the core activity in such a facility, is similar to activities of the transport of radioactive material in the public domain, for which the safety assessment approach is already described in French and international regulation. However, Cigeo's peculiarities such as long and narrow drifts and vaults make the underground facilities look more like tunnels than open field. The experience feedback from conventional mines or tunnels shows that fires are more severe and could lead more quickly to extensive damage than comparable fires in open field. Therefore, although the safety analysis of radioactive material transport in the public domain constitutes a solid basis, a further assessment is needed to show the representativeness of fire scenarios in the conditions of the underground facilities of Cigeo.

Acknowledgments

The authors would like to thank their colleagues for sharing their comments, improving the quality of this paper.

References

[1] Overview of the Cigeo project (http://www.andra.fr/pages/fr/menu1/les-solutions-de-gestion/concevoir-un-centre-de-stockage-pour-les-dechets-ha-et-ma-vl-84.html)

[2] Waste packages (http://www.andra.fr/index.php?id=article_6609_4_1&site=4&langue=1&pagePrint=les-dechets-de-moyenne-activite-a-vie-longue--mavl--6609-popup.html&site=4) & (https://fr.wikipedia.org/wiki/Cig%C3%A9o)

[3] Funicular system illustration (http://www.poma.net/solutions/produits/funiculaire-2/)

[4] Illustration of the funicular system carrying a transfer cask (Andra) (http://www.dailymotion.com/video/xjyy7k_projet-cigeo-principe-de-stockage-des-dechets-de-haute-activite_tech)

[5] Regulations for the Safe Transport of Radioactive Material – 2012 Edition, Specific Safety Requirements No. SSR-6, IAEA

[6] Lessons learnt from Tunnel accidents – Alessandro G. Colombo – EUR 19815 EN – 2001

[7] Conceptual Design for Dam Constructions and Partial Backfill for the Isolation of the StocaMine Underground Waste Disposal Site – Ercosplan – EGB 07-042.N01 (http://www.concertation-stocamine.fr/images/telechargements/12-ercosplan-conceptual-design-for-dam-constructions-06-2013.pdf)