

**Andra's Strategy and Approach for Operational Safety of French Underground Facility Cigéo –
15127**

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ABSTRACT

According to the French Act on radioactive waste of 28th of June 2006 [1], Andra shall design a reversible repository. In response to this demand, Andra is developing the industrial project namely “Cigéo”, a reversible geological disposal facility for HLW and ILW located in Meuse/Haute-Marne. The previous safety cases of 2005 [2] , 2009 [3] and 2012 give a sound basis to assess Cigéo's safety both for the operational and post-closure periods. Regarding operational safety, in this new stage of the project, the challenging issues for the preparation of the safety case are the following:

- To adapt the various regulatory frameworks (nuclear and non-nuclear) to the underground facility
- To design the underground facility and handling equipment's to reduce at first risks in the underground facility as such radioactive particles release, gas explosion, fire and co-activity and limit their consequence.
- To establish waste acceptance criteria to be fulfilled by waste producers in line with operational safety and design options

The objective of the paper is to present the experience of Andra in operation safety of the underground facility of Cigéo.

Operational safety for Cigéo is assessed as much as possible according to the existing French regulations and guidance for nuclear facilities. Indeed, compared to existing nuclear facilities, a geological repository is a specific case due to the existence of underground facilities with particularities such as :

- ventilation management in a large scale underground facility,
- fire risk management. As an input for the industrial design of Cigéo for operation, Andra defined a fire guidance and a specific reference safety guidance, based on the adaptation of the French nuclear regulatory texts for and when feasible to mines and tunnels regulatory texts and on its own experience gained through safety operational reports since 2005 and their reviews by the Safety Authority.
- underground co-activity of nuclear operation with construction works.

According to the common “defense-in depth” principle for nuclear facilities, these guidelines for the industrial design of Cigéo for operation consider the successive levels of defense of:

- Preventing the risk and its spreading by design and construction;
- Detecting incidents and early fighting by design and operation dispositions (detection and control systems, survey procedure);
- Controlling incidents and limiting of their consequences by safeguarding systems, specific procedures.

At that stage, design options for Cigéo constitute an adequate response to the operational safety functions and requirements:

- Two levels of containment are set up: the first one is ensured by the waste package, the second one is ensured from the surface facility to the disposal vaults by the transfer cask during the transfer of waste packages in the disposal vaults by the disposal vault itself and a nuclear ventilation with HEPA filter;

- Favorable options for fire risk prevention and mitigation: transport system minimizing heat load (cable car for the transfer from the surface, electric transfer engines), twin access tunnels to ease fire-fighting and evacuation...;
- Permanent complete physical separation of nuclear zone and construction zone (including ventilation systems).

In practice, operation safety assessment of Cigéo, designed following the aforesaid reference safety guidelines, follows a common risk analysis (internal aggressions such as auxiliary losses, chemical and toxic risks, fall or collision, fire, human factors and external aggressions such as earthquake, air traffic, flooding) with the following steps:

- Identification of the major risks and the design basis scenarios that have to be considered for dimensioning of the installations and the safety devices;
- On the basis of these different situations, those who will have to be quantified are identified; one or more representative and envelop situations are chosen in order to evaluate robustness of the installation. Quantitative evaluation of these situations permits to:
- identify the consequences on man, environment and installation, and in particular to gain confidence in the maintaining of the safety functions;
- identify or define the technic and/or organisational dispositions classified as “important elements for protection” (IEP);
- Situations beyond dimensioning permit to verify the robustness of the installation. They permit, on one hand to identify possible complementary material or organisational dispositions; on the other hand, to define the “hard core” i.e. structures, systems and components that permit to maintain the confinement function of radioactive substance.

INTRODUCTION

The December 30, 1991 French Waste Act [1] entrusted Andra, the French national agency for radioactive waste management, with the task of assessing the feasibility of deep geological disposal. Several main iteration loops have been identified since 1991, each corresponding to a major milestone of the deep disposal program: License application for construction and operation of the underground research laboratory (in 1996), submission of the Dossier 2001, submission of the feasibility assessment report Dossier 2005 [3], and the submission of the intermediate Dossier 2009 mainly focusing on operational safety [4].

The feasibility “Dossier 2005 Argile” [3], presents the studies carried out for the deep disposal project and the repository design in the Callovo-Oxfordian clay host rock, a 150 m thick clay layer at an approximate mean depth of 500 m, located in the Meuse/Haute-Marne area, East of France. In this dossier, an area of 250 km² (transposition zone (ZT)) was defined.

Following the publishing of the Dossier 2005 Argile, the 28th June 2006 Act entitled “*Programme National de Gestion des Matières et Déchets Radioactifs*” (National program for radioactive waste and nuclear material management) [5] has set the deep geological repository in clay host rock as the selected solution for IL-LL and HL radioactive waste disposal in France. According to this 2006 Act, reversible waste disposal in a deep geological formation and corresponding studies and investigations shall be conducted with a view to selecting a suitable site and to designing a repository.

Following, the “Dossier 2009” [4], comprises among others, a safety option report and a site selection document which has proposed a 30 km² area (ZIRA) within the transposition zone for detailed geological investigations in view of the underground implementation of the repository.

Since 2011, the project has entered in an industrial design development phase and has become the Industrial Center for Geological Disposal namely “Cigéo”. In that framework an intermediate Dossier studying concept design has been transmitted to the Nuclear Safety Authority in 2012 presenting the main evolutions since 2009 as well as safety requirements to be fulfilled by the design including the engineered barriers (e.g. waste packages) and layout.

In 2014, the outcomes of the public debate (2013-2014) presented by Andra were approved unanimously by the Board of Administrators' meeting of 5 May 2014. The conclusions and follow-up actions are published in the Official Journal of 10 May 2014.

So, in order to take account of the opinions and expectations expressed during the public debate, and to continue the stepwise approach initiated by the Law of 1991, Andra has decided to pursue the Cigeo project with four changes to the project following the public debate as such:

- The integration of a pilot industrial phase at facility start-up. Cigeo will move to normal operation after a review of the pilot industrial phase.
- The establishment of a regularly revised master plan for disposal operations.
- Changes to the timetable (cf. figure 1).
- The involvement of civil society in the project.

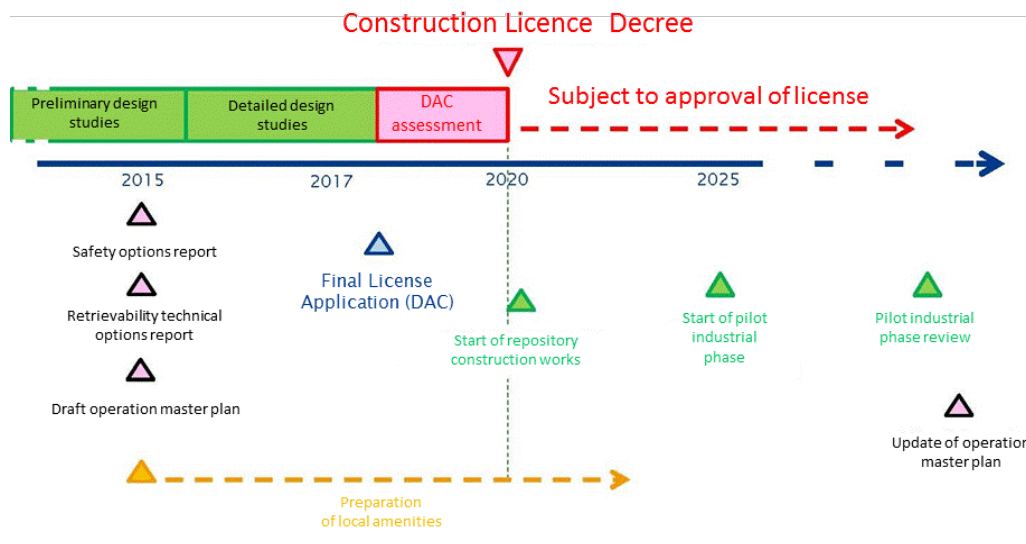


Fig.1: New timetable for Cigéo

Andra will thus submit in 2015 a Dossier of Safety Options to be reviewed before submitting in 2017 a safety report with respect to the French decree of 2007 the 2nd [5], in view of getting authorization for building the repository planned in 2020.

The challenging issues for the preparation of the safety case are the following:

- To identify the various regulatory frameworks (nuclear and non-nuclear) and guidance applicable to the facility ;
- To insure that the industrial design complies in particular with the safety requirements and with the elements presented in the safety case and its supporting safety assessment ;
- To identify crucial inputs (R&D, tests...) needed to support the authorization application, in particular, to bring convincing arguments to assess the technical feasibility of the design and when appropriate its ability to meet the safety requirements ;

- To insure that all the requirements from previous regulatory and peer reviews (national and international) are taken into account.

SAFETY GUIDANCE ADAPTED TO THE SPECIFICITY OF CIGEO

Operational safety for Cigéo is assessed as much as possible according to the existing French regulations [e.g. reference 6] and guidance for nuclear facilities.

Indeed, compared to existing nuclear facilities, a geological repository is distinguished by its underground facility (cf. figure 2) with particularities such as its geometry (e.g. limited diameter), ventilation system and the containment of radioactivity during the transfer of the waste package from the surface to the underground disposal cell and during its emplacement in the disposal cell, operation conditions in case of fire and the need for an underground co-activity of nuclear operation with construction works.

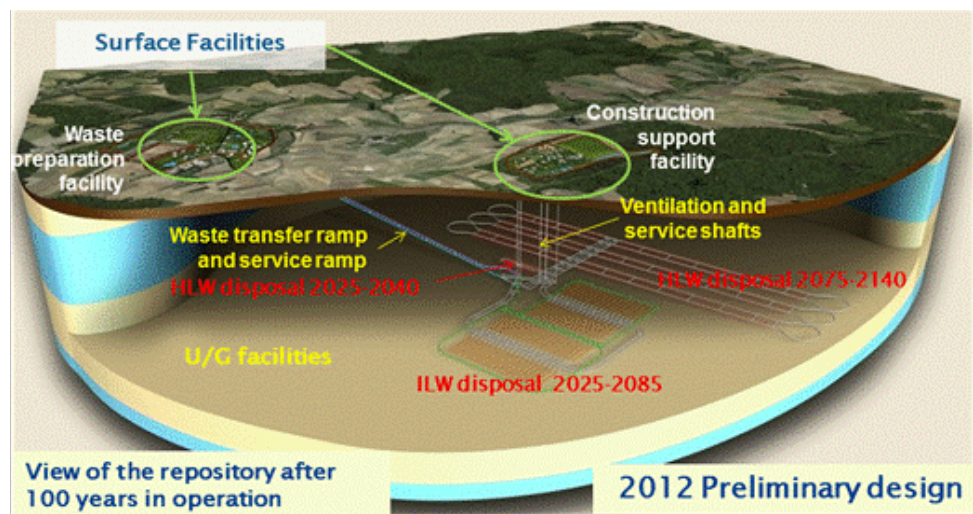


Fig. 2: Schematic illustration of Andra's Operational Safety Approach

As an input for the industrial design of Cigéo for operation, Andra defined reference safety guidelines, based on:

- the analysis of the French regulatory texts for nuclear facilities (particularly the 2012 decree [6] setting the general rules to be applied for nuclear installations) ;
- the analysis of French basic safety rules generally applied on nuclear surface facility (e.g. criticality, seismic, ventilation..) looking at their potential adaptation to Cigéo;
- when feasible to mines and tunnels regulatory texts and on its own experience gained through the previous iterations and corresponding inquiries and recommendations for the Safety Authority
- the analysis of IAEA guidance as such the defense in depth principles of INSAG-10
- the participation to international groups (EG-OS, IAEA, IGD-TP).

The fire guidance:

Regarding fire aspect, following the Dossier 2009 and its review on behalf of the nuclear safety authority, Andra decided in 2011 to set-up a fire guidelines dedicated to the Cigéo underground facility to drive the design and if necessary impose technical requirements. These guidelines was set up with the contribution of experts from both nuclear facilities operators and concerning fire, from various bodies such as the French institute for industrial risks (INERIS), the French centre for tunnel studies (CETU) and firemen.

The guidelines deal with four main objectives that were not only for safety:

- Protecting the live and health of the persons present in the installations,
- Preserving the environment (including protection of the nearby population),
- Maintaining safety functions ,
- Maintaining the industrial activities and the installations,

The nuclear safety functions to be protected against fire are similar to classical nuclear facilities (e.g. containment of radioactive materials, radioprotection, criticality risk control...).

According to the common “defence-in depth” principle for nuclear facilities, these fire guidelines for the industrial design of Cigéo for operation consider the successive levels of defence of:

- Preventing the risk of any start of fire and its spreading by limiting the fire load when designing the fixed and mobile equipment (e.g. the guideline mentions the favourable cable car in the ramp), limiting the areas having a high fire risk (e.g. the guidelines requires that the underground maintenance and underground storage areas will be limited as much as practically achievable).
- Detecting fire and early firefighting (detection and control systems, survey procedure) such as implementation of detection devices as close as possible to the potential hazard sources , implementation of fire-fighting systems to limit the spreading of fire (e.g. the guideline mentions that in- board automatic fire fighting system on vehicles will be utilised as much as practically achievable).
- Controlling fire incidents and limiting of their consequences by safeguarding systems, specific procedures to be implemented according to the reference fires and the selected “envelope” scenarios such as ventilation and smoke extraction systems managed from a central control room, presence of fire compartments, especially for areas entailing a risk of radioactive substances dispersion or for areas presenting a major fire hazard, presence of passageways to evacuate persons and to enable access for fire-fighting and rescue teams.

The safety guidance:

In addition to the fire guidelines, Andra set up in 2013 safety guidelines for the design of Cigéo during operation. According to the specificity of the underground facility as showed in Figure 2, the major aim of these Andra guidelines is to compile the existing French basic safety rules that may be directed applied to surface installations and in some case be adapted to the underground facility including the ramp and shafts. In practice (cf. figure 3), operation safety assessment of Cigéo, designed following the aforesaid reference safety guidelines, looks at the common nuclear safety functions.

The nuclear safety functions for which the Andra safety guidance provides requirements adapted are :

- Confining radioactivity in order to prevent dispersion risks,
- Protecting people against irradiation,
- Maintaining sub criticality,
- Releasing the residual thermal pressure of the waste,
- Managing radiolysis gases.

According to the safety functions, the Andra safety guidelines provide requirements imposed to the designers (e.g. maintain a level of contamination as low as possible in premises with a dose constraint value as a fraction of the regulatory limit , avoid the direct contact of the workers with not stuffy radioactive substances, discharges and radioactive particles and exposure from gases the lowest possible, maintain the durability of at least a system of containment between zones contaminated on one hand, and not contaminated zones on the other hand). It also clearly mentions that the disposal waste package is the 1st containment system and the 2nd containment system depends on the characteristics of primary waste package (e.g. only one containment system for the vitrified waste package that consists in two containment

barriers such as the vitrified matrix, the canister and the thick/robust overpack...). The operational safety follows a common risk analysis (e.g. internal aggressions as such auxiliary losses, chemical and toxic risks, fall or collision, fire, human factors and external aggressions as such earthquake, air traffic, flooding). The guideline describes the methodology of the operational safety risk analysis that may be conducted with the following steps:

- Identification of the major risks and the design basis scenarios that have to be considered for dimensioning of the installations and the safety devices;
- On the basis of these different situations, those who will have to be quantified are identified; one or more representative and envelop situations are chosen in order to evaluate robustness of the installation. Quantitative evaluation of these situations permits to:
- identify the consequences on man, environment and installation, and in particular to get insured of the maintain of the safety functions;
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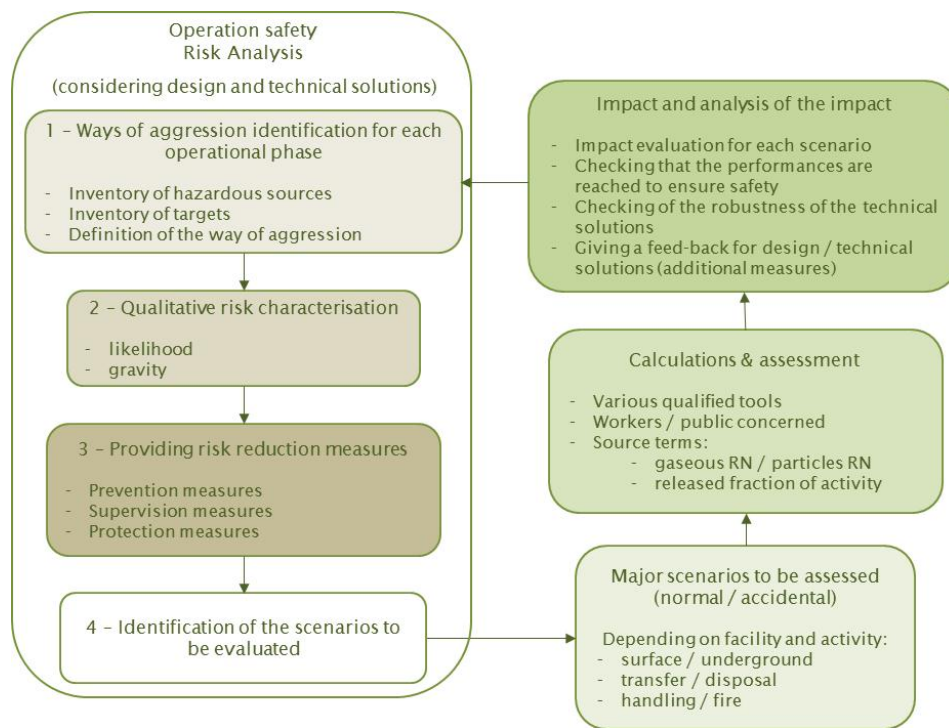


Fig.3: Schematic illustration of Andra's Operational Safety Approach

KEY OPERATIONAL SAFETY ISSUES TOWARDS THE LICENSING:

Since the Dossier 2005, Andra developed its own guidance's that were submitted to the nuclear Safety authority "ASN". For instance as a response to the "ASN" demand of 2010 after the review of the Dossier 2009, Andra submit in advance to the licensing application, the fire guidance (see section above) that has

already been applied by Andra designers in view of Cigéo and that was reviewed by the technical support organization “IRSN” in 2014.

In addition, Andra assesses in parallel to the development of technical solutions, the operational safety analysis in view of preparing for and ensuring the transition to an industrial mode of construction and operation. According to the main outcomes of the Dossier 2009 and its subsequent review by the national safety authority, the following aspects will be developed further prior to 2015 as such:

- Potential failure of the first containment barrier,
- Co-activity risks (construction + nuclear operation),
- Fire risks.

The industrial design needs to bring answers to these issues above. As an illustration on co-activity management, the facility is designed to ensure physical separation of nuclear and construction operation during the whole life of the facility (cf. figure 4).

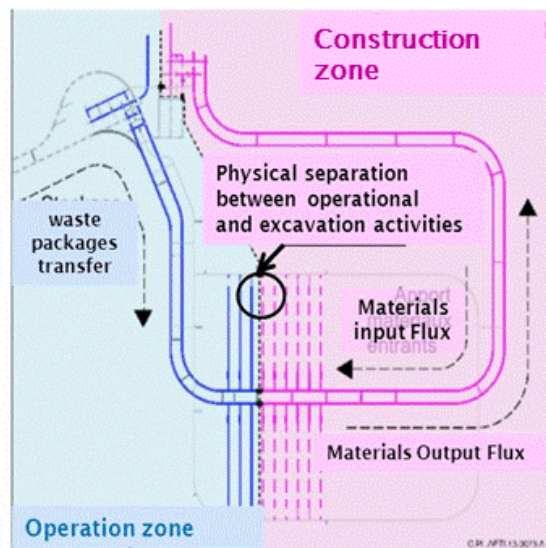


Fig.4: Schematic illustration of Andra's technical solution to manage co-activity risks

Because operational safety is part of the licensing process, it must be adequately considered in the design, and documented for the licensing. It may present:

- Risks both for surface and underground facilities,
- Scenarios impacts,
- Demonstrators,
- Requirements during construction,
- Monitoring requirements,
- Preliminary waste acceptance.

As support to the safety demonstration, the nuclear waste package transfer & emplacement technologies are very well known processes throughout the nuclear industry (on road, on rail or at sea and also commonly in nuclear surface facilities), but they have to be adapted to the underground conditions prevailing in a deep geological repository.

The main goals of the R&D programme in view of demonstration of safety on the waste packages and their related emplacement systems (cf. Figure 5) are:

- to prove the mechanical feasibility of the various waste package emplacement processes thanks to the design, construction and test of a full scale industrial prototype,
- the compatibility of the processes with the various pre-determined waste.



Fig.5: Schematic illustration of Andra's Technological experiment to support safety demonstration

Engineering a completely proven operational solution, for such concepts is not only a technical challenge with many issues still pending, but it is also a progressive and slow process of confidence building with the various stakeholders (, evaluators, national and local political representatives, NGO's, public at large, etc...).

CONCLUDING REMARKS

The operational safety assessment of an underground facility repository requires accounting for some peculiarities:

- The taking into account of underground facility compared to classical nuclear surface facilities as such restricted geometry, length of gallery, duration of operational phase for about 100 years ;
- The necessity to develop own guidance to adapt classical nuclear regulations and mining practices as such fire guidance, safety guidance ;
- The strong relationship between technical design, scientific knowledge acquisition and safety assessments (utilisation as much as practical of existing technics and demonstrators...).

Andra's project is now focusing on three main targets:

- Developing Cigeo's industrial design ;
- Preparing the authorization process, through increased exchanges with stakeholders ;

- Preparing the safety case to support authorization application.

The challenging issues for the preparation of the safety case are the following:

- To identify the various regulatory frameworks (nuclear and non-nuclear) and guides applicable to the facility,
- To insure that the industrial design complies in particular with the safety requirements and presented in the safety case and its supporting safety assessment. The challenging issues for Cigéo development of technical solutions will be the co-activity management (works activity and nuclear activity), the fire risk (technical solutions must be found to limit as much as possible fire source and consequences), the explosion risk (limitation of source terms...).
- To identify crucial inputs (R&D, tests...) needed to support the authorization application, in particular, to bring convincing arguments to assess the technical feasibility of the design and when appropriate its ability to meet the safety requirements,
- To insure that all the requirements from previous regulatory and peer reviews (national and international) are taken into account.

At the end, the balance between long-term and operational safety requirements will also be a prime consideration in terms of optimisation.

REFERENCES:

- [1] Loi n°2006-739 du 28 juin, 2006 de programme relative à la gestion durable des matières et déchets radioactifs.
- [2] Andra (2005). Dossier Argile 2005 ». Reports Available in English on Andra's site www.andra.fr
- [3] Andra (2009). "Options de Sûreté" – Report available only in French on Andra's site www.andra.fr
- [4] Conclusions of the public debate on the following site : http://www.andra.fr/download/andra-international-en/document/press_release/press-release-on-the-cigro-public-debate-follow-up.pdf
- [5] Décret n°2007-1557 du 2 novembre 2007 relatif aux installations nucléaires de base et au contrôle, en matière de sûreté nucléaire, du transport de substances radioactives. <http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000469544&fastPos=9&fastReqId=1823499311&categorieLien=cid&oldAction=rechTexte>
- [6] Arrêté du 7 février 2012 fixant les règles générales relatives aux installations nucléaires de base, <http://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000025338573&dateTexte=&categorieLien=id>