Developments of new radioactive transport packages of Type B within the current EMBAL Plan in CEA

Author
Emmanuel Rigaut, *Expert safety transport – CEA, Risk Control Sector, MR/DPSN, BP6, F-92265 Fontenay-aux-Roses cedex – email: emmanuel.rigaut@cea.fr*

Involvements and acknowledgments:
Fabien Carteron, *DE25 project manager* – CEA, *DEN/DM2S/SEMT, F-91191 Gif-sur-Yvette email: fabien.carteron@cea.fr*
Alain Joudon, *EMBAL plan manager – CEA, DEN/DPIE, F-13108 Saint-Paul-lez-Durance email: alain.joudon@cea.fr*
Work supported by the Service of Transport of Radioactive Materials – *CEA, DEN/DSN/STMR, F-13108 Saint-Paul-lez-Durance*

Abstract

The designs of the packages have to take into account both the constraints of the nuclear facilities and the various natures of radioactive contents to be carried through areas outside such facilities. At CEA, the development of nuclear research programs and the objectives fixed on decommissioning operations of nuclear facilities lead to a renewal of the ancient packages.

The CEA is a nuclear operator in France by the installations built on the different sites. For the transport of radioactive materials, the CEA is an applicant for the issue of package approvals from the national safety authority. The CEA is also organizing many transports as the user of packagings and, often, as the owner of packagings, in particular the Type B packages.

The paper will review, for three designs, how the new CEA packages are meet the applicable requirements of the recent Regulation: *IR800 package* for the transportation of the irradiated nuclear fuels: *LR144 tank* with the high material performances to suit with the chemical properties of radioactive liquid waste: *DE25 design* in development for the transport of radioactive solid wastes with the possible hydrogen explosion in the cask due to the radiolysis risks. The main characteristics and the reasons associated to the technical choices will be discussed according to the available systems, the test materials and the safety demonstration requirements.

Finally, the paper will show an example of the complexity arisen during a safety assessment by the example of the SORG tank: a qualified method may not be shared as a common reference between the experts of the Applicant and the experience feedback of the safety expertise on the topic. For that reason, common approaches between the Actors (Applicants, Regulators, and Experts) should be shared as soon as possible during the assessment of the design in order to manage the risks of the licensing process of a radioactive container project.

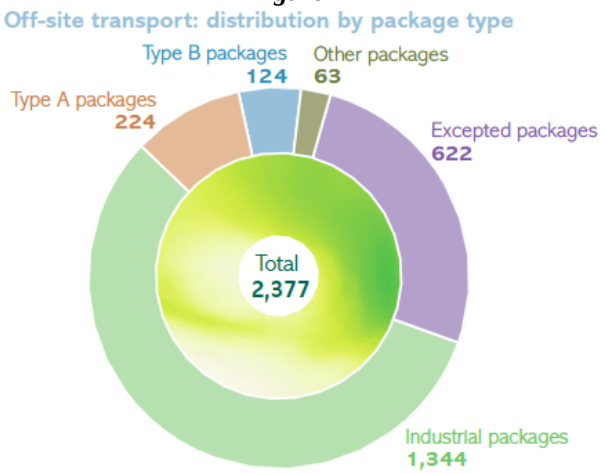
Introduction: background in CEA centres

The CEA is divided in 10 centres in various parts of France, ones for the defence sector and the others for the research activities in specific fields involving the nuclear developments. For that reason, the transports of dangerous goods, and Class 7- radioactive materials in particular, are linked with the nuclear facilities in France and with others facilities of our partners (AREVA industries in France for instance).

The experimental programmes involve many transfers of dangerous materials, within the CEA centres, on French roads or as part of many international exchanges with partners. In 2010, as far as concerning Class 7 - radioactive materials, more than *13000* transport operations were carried out on the CEA sites, representing around *17300* packages (*see figure 1*). Off-site, about *2400* transport operations involving radioactive materials shipped from the CEA sites: these operations involved the transport of around *6100* radioactive packages on public roads (*see figure 2*). This proportion represents less than one third of the transport operations involving high-level radioactive materials in France (irradiated fuel, plutonium from reprocessing, radioactive sources): about *124* type B packages transport were performed from the CEA sites via public roads.

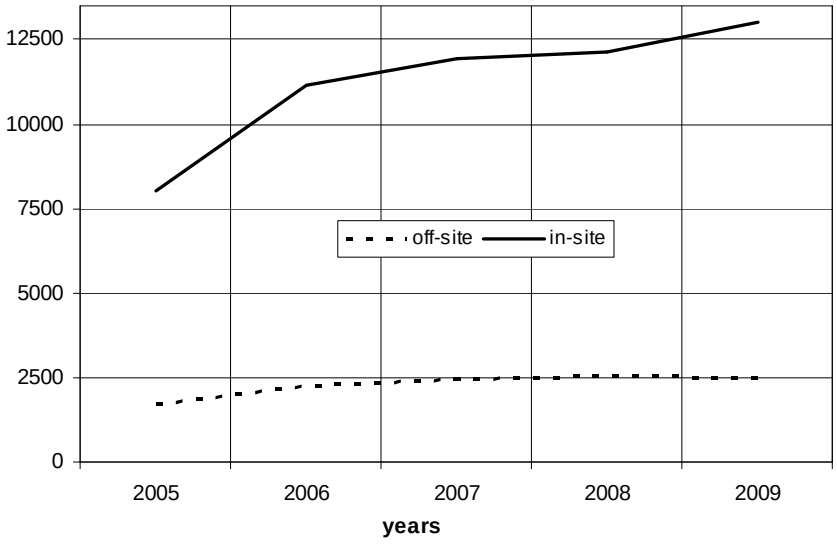
Figure 1

Figure 2



The CEA facilities generate waste, including "conventional" waste as well as "radioactive" waste. In addition, the dismantling and cleanup operations of old facilities lead to a large number of shipments on sites, between facilities for the conditioning processes or the storage, and across France too. So, the CEA removes its radioactive waste to existing facilities available to manage as it is produced (conditioning, storage). Replacement of old waste management facilities is underway with a construction programme in medium and long term plan for the new radioactive waste conditioning and storage facilities. <u>For that reason, the transport of radioactive materials will increase as part of the dismantling works of old research installations and the existing needs for transfers on-site and off-site.</u>

***Figure 3*:**
Overview in CEA of the total transports of radioactive materials <u>in-site</u> and <u>off-site</u> for the 5 last years



As an illustration of the CEA's Class 7 activity, the volumes of transport from the different CEA sites (*see figure 3*) show an increase, each years, for the transfers of the radioactive materials between facilities both in-site and off-site.

The operations for conditioning, treating and storing the radioactive materials are the main part of these transports. In particular, half of the total number of transports is shipping as industrial packages. These transports are usually identified for the very-low-level waste (VLLW, in French "TFA") and for the intermediate-level waste (ILW, in French "HLW") which

Author : E. Rigaut, CEA, Risk Control Sector, MR/DPSN, BP6, F-92265 Fontenay-aux-Roses cedex – email: emmanuel.rigaut@cea.fr

are shipping on French roads to ANDRA's national very-low-level radioactive waste disposal facility and to ANDRA's LILW disposal facility.

Finally, the high level waste requires to use the Type-B packages for the transport in-site or off-site. The packages for the transport of radioactive materials as type-B represents in CEA a strategic activity due to the research and development activities performed in the CEA installations for civil and defence nuclear programmes (nuclear reactors, dismantling activities of old facilities, research on nuclear wastes, treatment facilities, specialised installations for conditioning and storage of the radioactive materials for instance) : they are concerned with about 10% for the transfers inside the CEA's sites and with about 5% of the off-site transports, between the CEA's sites or received from the others operators. To meet these challenges, the renewal of the packages is an important safety issue to be able to operate the existing facilities and the future installations, and to dismantle the old ones.

Need for the new designs of the Type-B packages

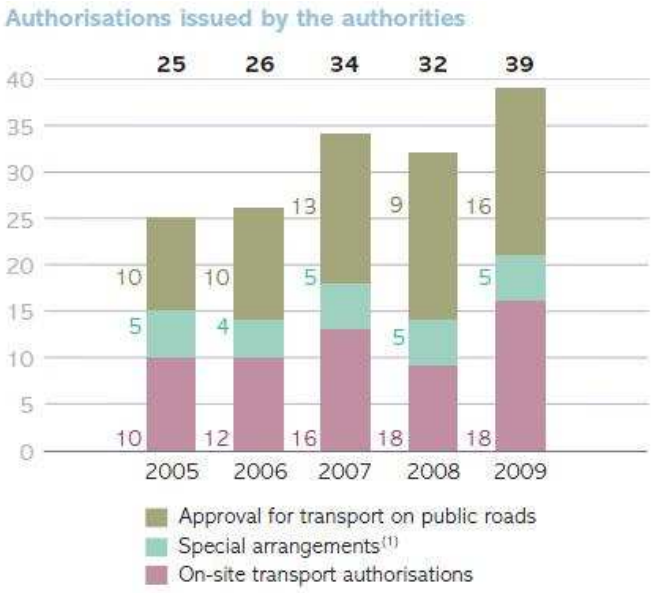
In the past, the CEA had developed many specific packagings which were well adapted for a little specific radioactive content to be shipped: this approach has introduced many limitation such as for the contents allowed (constraints with source terms) or for the type of installations (constraints with the handling systems). It's appeared to be very complex and difficult to maintain the ancient packages approvals by considerations on, the changes in the Regulations on one hand, and the roadmaps of facility's needs to ship several kinds of new contents on the other.

The CEA decided to identify the appropriate new packagings to be expected, in compliance with the regulations for the actual safe Transport of Radioactive Material (licensing management) and to be able to cover a large scale of high levels activities contents (design possibilities and risk management with the design). The use of more conservative approaches based on the evaluations with largest design margins was adopted and studied.

In 2009 (*see figure 4*), 39 authorisations have been issed by the French safety authorities and are required because of the types of radioactive materials. The nature of the contents to be transported is very heterogeneous in CEA such as:

- fresh fuels or fissile materials,
- irradiated fuels from the research reactors,
- high-level radioactivity waste with aqueous liquids, organics effluents and solid materials from the operating facilities or from the dismantling activities,
- many high-activity sources to be recovered, conditioned, stored or eliminated,
- a broad range of radio-nuclides by nuclear research facilities.

Figure 4



1 Special arrangements: road transport approval for a package that does not satisfy all regulatory requirements, but for which additional measures have been taken to ensure that the level of safety equals that of a package with a conventional approval certificate

According to such scheduled needs for the nuclear activities, the CEA has initiated in ***2001*** a program of renewal of its "specific" containers. This program called ***EMBAL plan*** has now ***10 years*** of safety development process with a large feedback on conceptual design studies by referring to Type B packages. ***25 projects*** (new packagings and modified concepts) have been analyzed with the high safety approach in the radioactive material transportation activities. In 2010, **13 packages** (6 new designs) have been manufactured with the *EMBAL plan* for the CEA's programs and have the approval certificate of the national competent authority. ***For the next 5 years, 12 more packages*** are expected to be licensing in

Author : E. Rigaut, CEA, Risk Control Sector, MR/DPSN, BP6, F-92265 Fontenay-aux-Roses cedex – email: emmanuel.rigaut@cea.fr

order to make possible the nuclear activities for the reactor's researches, for the dismantling and cleanup activities and for the fuel cycle process (*see table 1*).

***Table 1**: map of packagings through the EMBAL plan in CEA*

Packagings for the transport of radioactive materials in CEA	Past	**EMBAL plan**	*Manufactured and used*	*Under conception*
For fresh fuels or fresh fissile materials	8	5	*2*	*3*
For irradiated fuels or fissile used materials	14	6	*4 (IR800)*	*2 (1 off)*
For radioactive solid wastes	8	4	*1 (1 used from past)*	*3 (DE25, TIRADE)*
For radioactive liquid wastes	2	3	*2 (LR144,SORG)*	*1*
For nuclear sources or radio-nuclides	3	2	*0*	*2*
TOTAL	35	**20**	*9*	*11*

The number of new packagings is expected to decrease from **35 to 20 operating packages** due to the conservative evaluations on source terms and the testing of design margins in accordance with the Regulations. Moreover, the CEA is cooperated through a partnership association with TN International, for the maintenance and the services on packagings in order to make a better information and share for using the packagings fleet in commun.

Safety analysis to comply with the current Regulations

The designs of the packages have to take into account:

- the constraints of the existing nuclear facilities, some of them are ancient with 30 years old and others are recent with less than 10 years old,
- the various natures of radioactive contents to be carried through areas outside such different facilities,
- the necessary anticipation for the needs expected from the research and development programmes as : the needs for new contents to be carried, the ability to carry with the existing packages, the evolution in the safety demonstrations in accordance with the current and the Regulations changes...

So the ability to use the same packaging has to be modulated by the design margins first, and by the main options to be fixed as soon as possible to make possible the assessment beginning : the conditions resulting from the mass package, the loading conditions, the consistence with the receipt constraints with handling systems, the investigations on the characteristics for the contents (potential subsidiary risks, uncertainty on the quantities) will determine the main choices for the design and for the safety demonstrations to comply with the regulations. A lack of well defined source terms have to be managed in the design project by risk analysis: the project has to identify the margins on design and to share the opportunities by the options on the different families of contents needed by the various facilities.

Of course, the previous aspects have an important impact during the assessment of the design both for the analysis in normal and accident conditions of transport required for the Type-B safety demonstrations:

- the criticality safety : choices of barriers ;
- the heat transfer : choices of material allowances ;
- the radiation safety : choices on shielding ratio ;

Author : E. Rigaut, CEA, Risk Control Sector, MR/DPSN, BP6, F-92265 Fontenay-aux-Roses cedex – email: emmanuel.rigaut@cea.fr

- the structural integrity : tests for performances of the Type-B, analysis to take into account the subsidiary effects with radioactive materials that is to say explosion with radiolysis risk, fire with pyrophoricity hazard, corrosion with high-activity effluents…

Examples of the new packaging designs:

To design, develop and manufacture the packagings, the CEA's partners are reviewing among the industry with enforcement activities in class 7 materials: designers, applicants, manufacturers, suppliers, owners...

The CEA needs several solutions (*see Table 2*), available with the time, to optimize the ability to ship, with many natures of high-level activities objects on one hand, and with the evolutions of the specifications on the contents which will occur with the research's programmes on the other. So, in the example of the design of new packages in the field of the radioactive waste, the contents fixe the main options for the new packaging by taking into account a scope of additional dangerous physical properties such as:

- the high level of corrosiveness for the radioactive aqueous effluents or for the organic effluents (example of the LR144 tank),
- the explosiveness and the flammability due to pyrophority or hydrogen potential risk for the solid wastes of old drums stored (example of DE25 container)
- fissile condition in compliance with the regulation requirements (example of IR800 cask)

***Table 2**: map of the type-B models planned*

Map of the contents found for the type-B models	Packaging designs	Who is involved ?
Fresh and fissile materials	PN-UO2, PN-CN, FS110, CN2700, CTIV	- the teams of CEA with expertise in the fields of radiolysis, corrosion, mechanics… - the nuclear industry with skills and feedback for developing and manufacturing packages - all the owners of packages that are available/can be used for the nuclear facilities in CEA (packaging material adequacy)
irradiated fuels	IR001, IR100, IR200, IR500, *IR800*, AM738	
radioactive wastes	*DN10*, *DE25*, DE30, TIRADE	
radioactive liquids	*LR144*, LR154, *SORG*	
nuclear sources	PN-SN, over packs	

Author : E. Rigaut, CEA, Risk Control Sector, MR/DPSN, BP6, F-92265 Fontenay-aux-Roses cedex – email: emmanuel.rigaut@cea.fr

Key points with the examples of new packages: figures and main characteristics (see below and see sump-up in table 3)

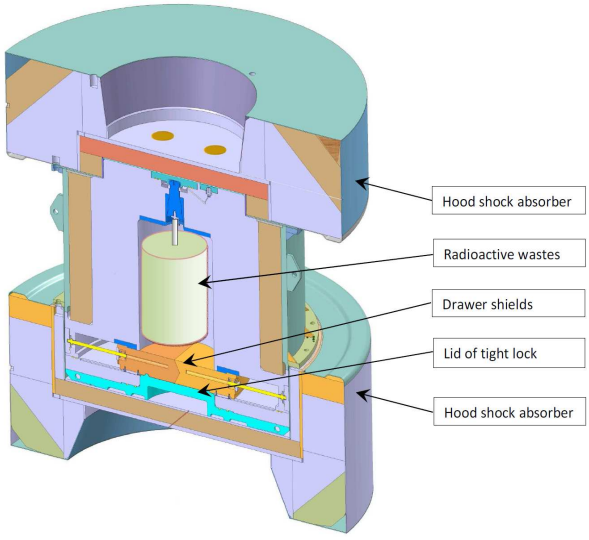
***Figure 5**: IR800 cask*

The IR800 packaging is available in CEA since 2007 with 2 manufactured models: these packages can be loaded and unloaded under water. The cash is associated with 2 different specific baskets in order to load 5 or 6 irradiated fuels. They are transported dry. The properties of the contents include heat output, fissile elements, and high level of irradiation. The innovative design features a double containment vessel capable of accommodating several irradiated fuels per transport operation. The number of required transport has been reduced by the project requirement.

***Figure 6**: LR144 tank*

The LR144 tank is the last new concept developed in the CEA for the transport of the very high-level radioactive liquids and manufactured in 2009 for one model. The package meets the regulatory requirements applicable to the type B model: it contains fissile materials and the specifications of the radioactive effluents include hazards other than radioactivity such as the chemical corrosion and the radiolysis effects. The tank of LR144 has been manufactured with a duplex stainless steel grade (URANUS material) to provide a sufficient capability with the corrosiveness of the effluents. More over, because of the high level of liquid activity, the radiation shielding has been carefully calculated to achieve the required radiations allowed in contact with the package for transportation of any king of specified effluents.

***Figure 7**: DE25 packaging*



DE25 is a packaging developed for the high-level radioactive wastes and road transport. The contents are dry, solid forms and are in various materials (metals, papers, plastics …). The design has to take into account the potential hazard with radiolysis and the explosion situations with hydrogen generation should be considered due to a large scale of waste inventory, but actually the demonstration of the safety analysis will be based on a limitation of the time of transportation.
This container is adapted for several vertical loading configurations (roof shield enclosure, storage hole and pool) and it meets volume and mass limits compatible with several nuclear facilities. It is designed with two tungsten alloy drawer systems for shield and is loaded by the bottom with a top winch tool. During transport, the drawers are locked by the lid.
A reduced model of the DE25 has successfully undergone the drop tests which have consisted in fifteen drop sequences to cumulate normal condition and accident condition heights). The commissioning of the first copy of the DE25 packaging is planned in 2012.

Author : E. Rigaut, CEA, Risk Control Sector, MR/DPSN, BP6, F-92265 Fontenay-aux-Roses cedex – email: emmanuel.rigaut@cea.fr

***Figure 8**: The SORG's case*

The main issues of the SORG design are to conciliate the requirements of a Type-B package (drop tests, structural integrity, fire test, radiation shielding, and containment of radioactive products…) on one hand, and to comply with the chemical properties of the organic solvents to be transported on the other (corrosiveness, flammable mixture, radiolysis effects). One packaging has been manufactured and is available at CEA since 2007.

At the end of the assessment (2009), the package meets the requirements for the Type-B model excepting for one point which have justified, to the point of view of the national competent authority, to deliver an approval under a special arrangement transport operation. Indeed, a debate was focused on the specified contents between the experts of the national competent authority and the CEA's specialists in order to *prove the design with a qualified method.*

The reason for the special arrangement is precised in the approval certificate delivered in November 2009 by the French nuclear safety authority (ASN):

"the proof of the qualification of the method for testing the thermal stability of the contents transported was not considered satisfactory". In french langage: *"La démonstration de la qualification de la méthode de test de stabilité thermique pour les contenus transportés n'a pas été jugé satisfaisante.*

That means: the specialists in France are not agreed with the methods to be used for testing the stability of the organic effluents; there are not agreed between those of the Applicants and those of the Regulator; there are not agreed between those dealing with the facilities requirements and those considering the transport aspects.

The complexity risen by the licensing process comes from the "no-common reference" between the Regulator (the competent authority and experts) and the Applicant (the CEA and specialists) as far as concerning the experimental method to demonstrate the thermal stability of the contents: one reference is the calorimetric methods based on the respond in high temperature (*DCS*), and the other experiment measurements, used on the facilities, is the thermal screening unit (*TSU*) with a respond on pressure.

The qualification was performed on the CEA nuclear facility with the *TSU method* that was performed on the installation with these organic effluents; the comparisons between the two methods (*TSU* and *DCS*) were not enough to prove the stability. The experimental results must refer to a well-known method even if the advantages are quite demonstrated to use another one such in this case (improvement of the experimental conditions of testing, better accuracy because of a large scale respond).

Design but also prove: the qualified method has to be a "common reference", that is to say if TSU became a new reference for transportation, SORG's tank should be a type-B model with an approval.

Summary and conclusions:

The nuclear facilities of the CEA are located in various parts of France. For that reason, the transports of dangerous goods, and Class 7- radioactive materials in particular, are linked with these facilities in France and with others facilities of our partners. The transport of radioactive materials is necessary to sustain the different branches of our research programmes and the dismantling objectives of the ancient facilities : the ability to carry is a part of the strategy for the CEA's teams of the Nuclear Energy Division.

The fundamental principle applied to the transport of radioactive materials is that the protection comes from the design of the package regardless of the radioactive contents to be transported. In the long process of development, radioactive contents and packaging have to comply with the recent requirements

Author : E. Rigaut, CEA, Risk Control Sector, MR/DPSN, BP6, F-92265 Fontenay-aux-Roses cedex – email: emmanuel.rigaut@cea.fr

and changes in the Regulations. The whole process of licensing a radioactive container for the Applicant must be conducted by referring to:

- the latest transport safety regulations,
- the appreciation of the national competent authority to meet the requirements,
- the use of large design margins and the conservative evaluation methods in order the minimize the risks due to the change with the facilities contents and/or the lack of fully defined on the contents.

For that reason, common approaches between the Applicant on the one hand, and a sharing of experiences on the application of requirements on the other, should ensure a better consistency and understanding to The Regulator. The principle of safety improvement global approach has to be established with a common approach for the Applicants and for the Regulation.

The current EMBAL plan in CEA has to solve the difficult equation to optimize the fleet of packagings by defining the design with lower mass but with the upper constraint with the radioactive contents. After 10 years on conceptual design studies, the trade off is obtained between various facilities: 6 packages has been manufactured in 2010 and 13 new design expected to be used in 2015. The number of packagings of type B model is actually decreased from **35 before EMBAL to 20 operating type-B packages** due to the conservative evaluations on source terms and the testing of design margins in accordance with the Regulations.

Part of the difficulties to develop the new packagings is the various types of nuclear facilities in CEA including research reactors, laboratories, waste and effluent treatment installations…With this large scale of installations, the contents are quite different each time for the quantity and the level of activity, for the physical properties, for the exhaustiveness of the inventory including the initial specifications. The complexity of the licensing process come also from the difficulties to fix the contents allowed because of lack of well-defined materials with the diversity of facilities: the evaluation methods considered should be among the references recognized by the regulator's experts even if others references exists in the community of the experts (the feedback of SORG cask for the CEA). The qualified methods have to be shared between the Applicant, the Designer and the Actors of the Regulator in order to improve the safety evaluations on one hand, and to enhance the demonstrations of the level of the packages performances on the other.

Author : E. Rigaut, CEA, Risk Control Sector, MR/DPSN, BP6, F-92265 Fontenay-aux-Roses cedex – email: emmanuel.rigaut@cea.fr

***Table 3**: sum-up of the key points*

Packaging design	key points during the assessment	Examples of the technical choices for the issues of the regulation
IR800 - 26,3 t - type B-F Fissile materials 6 irradiated fuel elements – 920 W 5 irradiated fuel elements – 2200 W specific baskets *certificate : F/394/B(M)F-96T*	Containment systems Neutron absorbers Criticality evaluation Radiation shielding Thermal evaluation, including surface heat flux	*requirements for special features including the containment system: TS-R-1 para. 677 ed. 2009* Criticality risk related to the presence of water when loading the fuel materials Technical choices : independent *double barrier* as requirement; testing and demonstrating the sealing of barriers, operational draining and drying procedures, double verification for the leakage tests (first and second barrier), double verification for the vacuum drying operations
LR144 - 23,8 t - type B-F radioactive liquids as waste 1 m3, 23 W Neutrons sources based on isotopes of Pu isotopes of Am, isotopes of Cm. Contents based on radioactive mixture with nitric acid and sulphuric acid. *Licensing under progress (end 2010)*	Behaviour of radioactive material Containment system Radiation shielding Evaluation of the radiolysis effects Corrosiveness Thermal effects on gaseous production in the volumes of the containment system	*Requirements for the risk of corrosion and deterioration including the containment system, and the combination of moisture and heat effects: TS-R-1 para. 651 ed. 2009* Evaluation of the corrosion Technical choices : Tank material with URANUS 76N (Duplex Stainless steel grade 1.4501) For the accessories and the supplied elements : austenitic stainless steel (904L and 316L)
DE25 - 9 t - type B Radioactive solids as waste *Assessment process ongoing (end 2012) : drop tests programs performed in July 2010*	Behaviour of radioactive materials Containment system Effects of radiolysis Potential hazard with radiolysis and explosion situation Structural evaluation Containment evaluation	*Requirements for the risk of losing the radioactive contents: TS-R-1 para. 657 ed. 2009; drop and tests for demonstrating ability to withstand accident conditions of transport: TS-R-1 para. 727 ed. 2009* Technical choices : Design with two tungsten alloy drawer systems for shield and is loaded by the bottom with a top winch tool. The drawers are locked by the lid. Limitation with the time of transportation because of radiolysis effects and explosion risks
SORG - 9 t – type B High-level Radioactive waste, organic liquid mixture 400 l < 1W, < 15g fissile materials *Assessment process ended in 2007* *Special arrangement transport operation due to non common point of view about the thermal stability demonstration of the effluents : F/816/X*	Behaviour of radioactive material Effects of radiolysis Containment system Corrosiveness Thermal stability of the contents until 400°C	*Feedback: lack of well-defined contents at the beginning of the project; the safety analysis depends on the qualification of the contents and the limits of knowledge for these contents* Evaluations with testing Methods on Corrosion and thermal stability Design but also prove : - using of a qualified method for the measurements witch is not a common reference between CEA and Experts of the national competent authority - necessity of new validations of the results by referring to a well-known methods

Author : E. Rigaut, CEA, Risk Control Sector, MR/DPSN, BP6, F-92265 Fontenay-aux-Roses cedex – email: emmanuel.rigaut@cea.fr