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

No.1017

Radioactive Waste Transportation: Discussion on the Specific Safety Issues and Overview of Some Related Answers in Terms of Packaging

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Abstract

Background

Whatever the nuclear facilities activities (even in case of shutdown / renewal), challenges regarding waste management arise worldwide. First in matter of dismantling, reprocessing or storage of course, but also in terms of conveyance capabilities anyway.

ROBATEL Industries is a nuclear turnkey services provider, especially regarding the radioactive material transportation casks. For decades it has designed various package models, type B ones especially which require regulators approvals. Based on such a broad experience, the company has acquired a comprehensive knowledge of the technical issues related to safety and to international regulations.

Specific issues related to the design of waste dedicated packages

The waste transportation issues are nowadays more and more sensitive, whatever the customers or the countries. Each case requires suitable treatment depending on both the actual nature and properties of the waste or their origins and outfalls which all induce specific constraints.

Unlike other kinds of radioactive materials, the exhaustive characterization of waste is difficult and mostly constitutes the first challenge to overcome: it is the key point for the start of both the package design and the related safety analyses. The way the characterization is approached usually determines the following suitable methods and assumptions that may be implemented to demonstrate the package compliance with regulatory requirements.

Through its recent package designs (from R73 (2006) to R79 (2016)), ROBATEL Industries presents its 10 years expertise feedback regarding the design and the safety assessments of packages dedicated to various waste types by focusing on an overview of the main related technical issues.

Introduction

The radioactive waste management represents a strong challenge for the global nuclear activities. The main concerns deal usually with the waste reprocessing, disposal or storage. But, whatever the waste origins and outfalls, carriage issues necessarily arise, especially in terms of packagings which ensure the transport safety.

Within the "waste" designation is included a broad diversity of material with very different sizes, geometries, physico-chemical properties and radiological features. From the transport safety point of view, packages design must meet all the relevant regulatory requirements whatever the transport conditions: this also includes all the content specificities and configurations. Each transport need requires thus suitable treatment depending on both the actual nature and properties of the waste.

This is precisely one of the skills of the French firm ROBATEL Industries which designs and manufactures packages for the transport of radioactive material for decades. Founded in 1830, the business started in the early 50's with the development of the first transport packaging in France and is now exclusively working for the nuclear industry. It has thereby followed up the evolutions of this sector in terms of safety requirements and technical innovations. With its strong experience, it proposes worldwide turnkey solutions integrating all the technical and operational aspects of projects. Upon the last 60 years, the company has thus designed over 80 type B packages and manufactured over one thousand units (all types included), many of them dedicated to the waste transportation.

Unlike other kinds of radioactive materials, the exhaustive characterization of waste is pretty difficult and mostly constitutes the first challenge to overcome: it is the key point for the start of both the package design and the related safety analyses. The way the characterization is approached usually determines the following suitable methods and assumptions that may be implemented to demonstrate the package compliance with regulatory requirements.

Through some examples of the ROBATEL Industries recent casks designs during these last 10 years (Table 1), this paper aims to present an overview of some of the technical and regulatory issues that usually drive the development of radioactive waste transportation packages.

Table 1. ROBATEL's packages dedicated to the waste transportation: recent designs

Packages	Waste types	Countries
R73 – B(U)	Irradiated metallic waste in bulk from power plants dismantling	France
R74 – B(U)	Cemented waste drums from spent fuel reprocessing	Belgium, Scotland
R75 – B(U)	Irradiated metallic cluster guides from power plants	France
R76 – B(M)F	Historical technological HILW drums from experiments & laboratories	France
R77S – Onsite	Primary alpha waste drums	France
RT100 – B(U)	LLW Class B & C waste (spent resins & filters)	USA
R79 – B(U)/(M)	Historical waste vessels from experiments & isotope production	Netherlands, Belgium

The importance of the content in the package design process

Package designs must comply with all the relevant regulatory requirements [1]. Depending on their content (especially regarding to either the hazards levels or the quantities/activities of the radioactive material to be carried), they must withstand to more or less severe conditions and may furthermore require approvals from the competent nuclear authorities prior to be allowed to operate. That's especially the case for type B packages or packages which transport fissile material.

Within the regulations, distinction is made between the "package" and the "packaging": the packaging is the receptacle used to load the radioactive content ([1], §232) whereas the package means *"the complete product of the packing operation, consisting of the packaging and its contents"* ([1], §231). So, the regulatory requirements must be met, in particular in accordance with the relevant conditions on the design *"including consideration of the nature of the radioactive contents"* ([1], §104). This implies that it is impossible to design a packaging and to assess its compliance with the safety requirements without taking also into account its radioactive content and its related properties. The design process of a new package model so revolves mostly around the content to be transported. In the same time, it must also integrate the operating constraints. The first key point during the design process is thus to know or to define the content.

Unlike other types of radioactive materials (such as sources or fuel for instance...), it is often rather difficult to provide an extensive or detailed description of radioactive waste. Many reasons can explain it: waste may come from various origins, it may mix numerous materials or components, or waste may have been produced years ago... Anyway, solutions must be found to define limits or bounding configurations to the packages content in such a way the designer can perform all the relevant safety analyses and the consignors can carry out all the related controls prior to shipments. In the following, focus will be done on some of the main specific constraints related to waste in terms of package design and assessments of the compliance with regulatory requirements.

Figure 1 Waste transportation packages: a large panel of sizes

Industrial background and operating constraints

Specifically when dealing with waste, one of the consignor's concerns is usually to optimize the waste removal, that means in particular to minimize the volumes of waste after conditioning in order to reduce the number of shipments and the repositories size. There are several ways to achieve it (waste compaction, waste sorting...): one of them is to increase the packaging's loading capacities. This can constitute a challenge for the design and the safety analyses of the package. This firstly determines the size of the packaging of course. In matter of waste, the packaging's dimensions can really differ depending on the customer needs: the R79 [3], which is designed to carry one 200L drum of waste (300 kg) is quite small (H 2.2 m x Ø 1.7 m; 10.5 tons) in comparison with the RT100 package (H 3.3 m x Ø 2.6 m; 41.5 tons) with its 4.6 m³ cavity for loading 6.8 tons of resins & filters (Figure 1, [4]).

Sizes and weights have a strong incidence on the package design also in terms of mechanical strength because the package must withstand the regulatory ACT drop tests. The containment enclosure must restrict the loss of radioactive content. That leads most of the time for type B packages to ensure that it remains leak tight. The heaviest the content is, the strongest the package must be. Its mechanical protections should also be more efficient, especially concerning its shock absorbers whose size consequently increases.

There is thus an optimum to be reached between the package loading capacities on one hand, and on the other hand, the operating constraints of the facilities which may be numerous: various interfaces and loading/unloading modes, available spaces, handling and conveyances capacities, operating convenience and costs... The largest packaging is thus not necessarily the best solution for the customers. Often, new design has to be developed specifically to meet all the expectations.

Figure 2 Packages designs depending on geometries & operating constraints

That was the case for quite all the ROBATEL's casks these last 10 years: the R74 was so developed to carry three 560L drums of cemented waste issued from the reprocessing of spent fuels. At the opposite, the R75 was designed to remove up to 5 irradiated cluster guides from the NPPs. These two examples show how the design may differ depending on the content features (Figure 2) but also because of the operating needs. The R75 packaging is indeed wet loaded after having been flooded: its design integrates thus specific devices to enable its emptying and drying [6].

But even focusing only on waste drums for instance, operating concerns can lead to very different designs: the R77S (which is an onsite package) had to deal with the loading of four 200 L waste drums placed inside a square metallic basket. Unlike the R74 (cylindrical shape), because of the facility's constraints, the R77S had to fit with the existing basket: the result is its cubic shape and its 8 spherical shock absorbers (Figure 2) which are fairly innovative for such a voluminous cask (1.9 x 1.9 x 1.7 m³; 3.5 tons).

One waste specificity: bulk loading

As mentioned above, concerning waste loading or waste conditioning, many configurations can occur: most of the time, it is drums (cf. R74, R76, R77S & R79 casks). Sometimes, waste consists in quite well-defined components (cf. R75, specifically designed for cluster guides). Waste could so be split into two main categories: "blocked" waste or waste "in bulk". The R73 package deals with this second category. The R73 cask is dedicated to the transportation of metallic waste issued from NPPs vessel internals dismantling [5]. It can carry up to 2 tons of waste. Its main specificity is that waste can be placed in bulk inside large baskets. It was indeed a key expectation for the customer: the waste generated by the internals cutting can have numerous shapes: even if forecast packing plans are imagined, the actual process of dismantling cannot foreseen the exact loading configuration prior to operations. In addition, the R73 should be used for decades to remove waste from several NPPs dismantling: none of them is at the same step and it is thus difficult to predict now all the potential configurations for the coming years. Last but not least, the dismantling of the internals are performed remotely within a radiation environment (it can even be performed underwater). In such conditions, the sorting of the waste or their accurate placement are neither easy nor suitable for industrial concerns. Of course, dealing with waste in bulk (it cannot be considered wedged into the

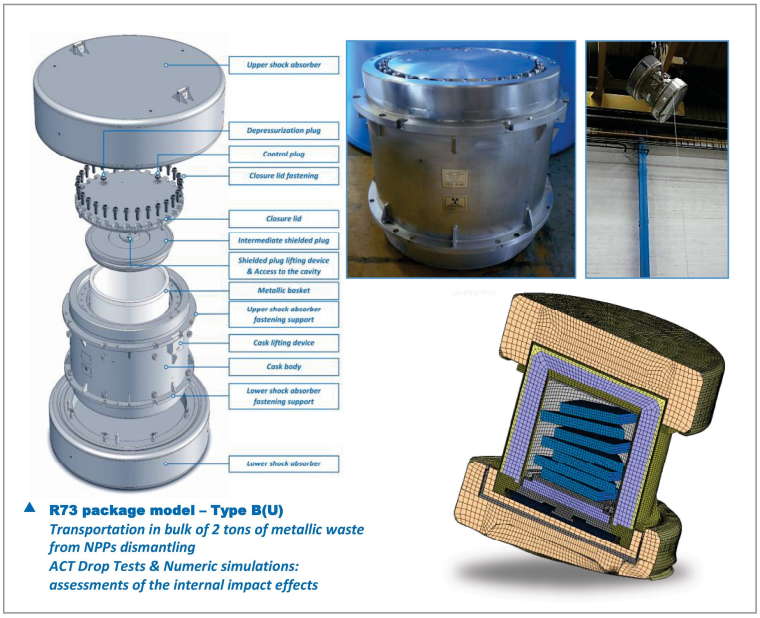

Figure 3 Internal impacts of the content during ACT drop tests

cask) has strong consequences on the design and safety assessments of the package. The two major incidences are related to the mechanical strength and the shielding performances of the cask, especially because waste displacements in the cavity under ACT or NCT cannot be excluded.

From a mechanical point of view, internal impacts of the content on the containment enclosure or on the closure lids could occur during the 9 meters drop tests. Because of both significant gaps within the cask's cavity and a heavy content, these secondary impacts might damage the inner enclosure integrity. For the R73, specific assessments (in addition to drop tests performing) have been carried out to ensure that the package and its closure system do actually withstand such events. These analyses were performed thanks to FE models by conducting dynamic crash simulations based on the drop tests feedback and benchmarks (Figure 3). This led to a reinforced design of the R73 closure system. For other casks (R75, Figure 2), it can also drive specific features integration to prevent the internal impacts occurrence or effects (i.e. internal wedging, retainer systems or shock absorbers).

Concerning the shielding assessments, potential internal moves within the content can modify the activity distribution inside the cask and so possibly the dose levels surrounding the package. Specific provisions should thus be made to carry out the safety analyses in order to cover such configurations and to ensure the regulatory requirements are met whatever the conditions. Insofar as no "limitation" can be stated regarding to the waste position, bounding cases must be defined. In addition to the internal displacements concerns, the shielding assessments must also deal with the potential heterogeneity of the spatial distribution of the activity within the waste components. Depending on the cases (especially on the available waste data or on the types of control during operation), different solutions can be chosen. For the R73, content limitations and safety assessments are for instance mainly based on the sum of the maximum dose levels surrounding each of the waste components (Figure 4). Such kind of definition can be thus quite directly related to possible controls during the loading (dose rates measurements or dose levels assessments based on dismantling feedbacks).

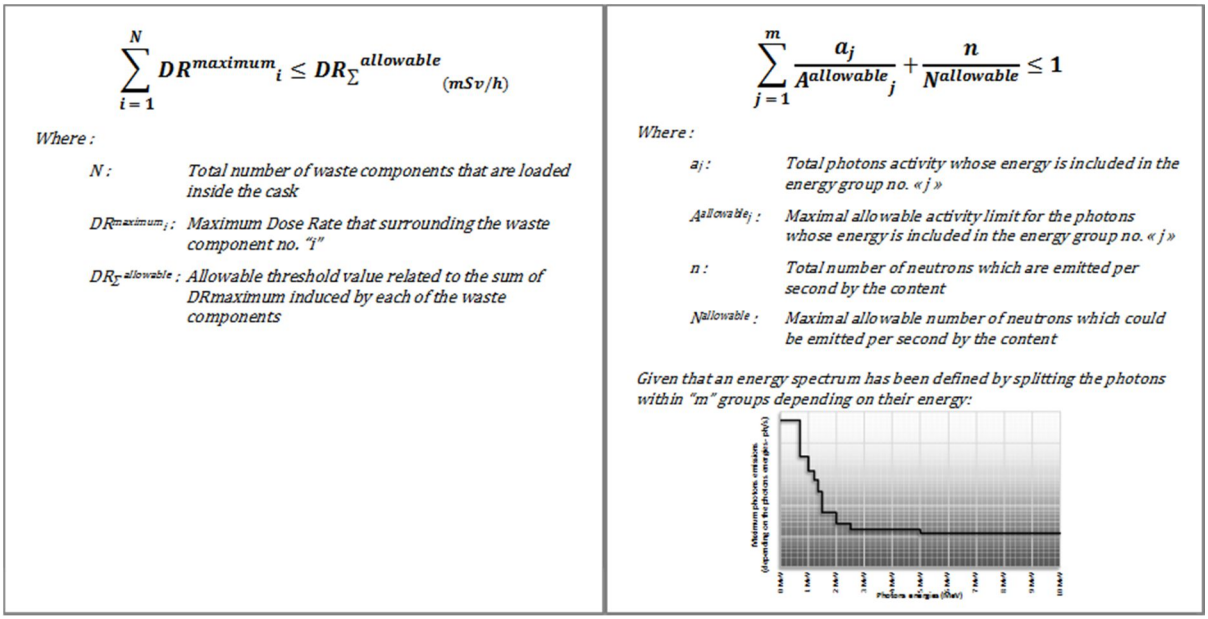

Figure 4 Content shielding limitations: radiation levels vs spectrum of the waste

Other ways are however also possible: content limitations can also be based on an allowable gamma/neutron activities spectrum depending on the energies (Figure 4; it's the R79 case) or on allowable nuclides inventories (R74 or RT100). The choice depends mainly on the knowledge level the customers have about their waste and on their control possibilities.

A choice to be done: defining a detailed or a generic content

Of course, defining generic limitations in order to overcome issues related to broader content induces that conservatisms must be taken regarding to both the limitations but also to the assumptions to be considered for the safety justifications. Consequently, a generic content is more convenient for customers in terms of loading constraints but conversely it restricts the loading capacities of the package regarding its actual shielding performances. At the opposite, for the cluster guides (which are components with well-defined geometry and activation), it was possible to optimize the cask design by fitting with the actual spatial distribution of the content activity. The R75 has thus a non-homogenous shielding (Figure 2) to maximize its performances taking account also the other operational constraints. This approach is consistent with the ALARA principle in accordance with regulatory advisory provisions *("exposures are to be kept as low as reasonably achievable, (...) (optimization of protection)"* [2], §301.2) but is not always possible when dealing with waste in bulk.

Radioactive waste: a broad panel of material

Waste raises many other issues even when they are blocked or conditioned into drums rather than in bulk. Their nature is often problematic because they usually mix miscellaneous materials without knowing exactly their proportions or quantities. That can be especially the case for so-called "historical wastes". Those types of waste can consist of various contaminated and/or irradiated material (such as plastics and rubbers, cellulosic materials, metallic pieces, glass or rubble for instance) and can also be blocked inside the drums thanks to concrete or organic matrices: radiolytic or thermolytic decomposition of hydrogenated materials can possibly occur. It generates a gas production inside the cask during its transport, among which hydrogen which is especially flammable or even explosive. Specific provisions, either about the package design, about the content limits or about the shipment constraints, must be taken to deal with this issue. In the case of the R76, a mix of all these provisions has been considered in order

Figure 5 Assessments related to the explosion risks for hydrogenous waste

to maximize the loading capabilities of the cask and to make its operation more convenient and flexible for the consignor. But its most outstanding particularity is probably that it was designed to withstand to a potential internal explosion of hydrogen (Figure 5). Its mechanical strength was assessed thanks to FEM simulations based on explosion tests results [7]. This specificity enables the R76 to carry safely a very large panel of waste drums.

Conclusions

Because of waste diversity, safety issues must be assessed case by case and each packaging must be specifically designed or adapted. Various approaches are possible, from casks dedicated to very specific waste types to those developed in order to be more flexible and to enable broader panels of waste. Anyway, the key point is always the level of knowledge the consignors have about their waste. Depending on this, the most effective solution in terms of packaging design and content definition can be built. Consignors should keep in mind that the best they can characterize their materials, the most optimized the packaging will be and the most efficient the operation and transport will be as well. These issues are not new [8], but as cask designer & manufacturer, our feeling is that the awareness of the nuclear players about waste transportation concerns has rather progressed these last years. The needs about transport are nowadays usually anticipated. Indeed, the design, the safety report write up, the application for approval and the manufacture of radioactive waste transportation packages is a fairly long process. It can be nevertheless a successful one when all players work together by sharing common objectives.

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