

**Paper No. 1007 Design challenges for a new packaging for the
shipment of radioactive waste**

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Abstract

The design of a new packaging is a challenge regarding the ever increasing demands of the competent authorities to demonstrate full compliance of packagings with the safety regulations. CAROLINE-R80 is a new Type B(U) packaging, currently under design by Transnubel and Robatel Industries, for the shipment of large quantities of radioactive waste. This packaging will be designed, licensed and manufactured by mid-2017.

Due to the large dimensions of the internal cavity ($\varnothing 785 \times 1163$ mm), the packaging will be able to physically ship different kind of waste forms in 200l/400l drums or baskets, whether they are conditioned or not.

The biggest challenge is to accommodate the packaging design for the variety of contents which need to be shipped in the near future, in terms of isotopes, activities, physical/chemical form... Furthermore the dose rate evaluation of the non-conditioned waste will be a major challenge regarding the safety demonstrations, as the content could potentially move during routine and normal conditions of transport.

In order to load and unload the packaging in different kinds of nuclear facilities, many interface challenges have to be treated as well. Physical properties of the packaging such as dimensions and weight are limiting factors, as many facilities are not foreseen to handle such packagings. Different specific equipment will be designed in order to facilitate loading and unloading operations even by remote controlled operations to cope with high active content. Both a horizontal as a vertical (un)loading are foreseen.

Introduction

Many different parameters come into place when a new package design is developed. The content, the operational constraints and the transport specifications should be taken into account and will limit the package design. Most of these parameters will be, once fixed, limiting for the complete lifetime of the packaging.

The CAROLINE-R80 packaging is a Type B(U) packaging, according to [1], with a large cavity which is developed to be (un)loaded in wet/dry or horizontal/vertical conditions. Besides transport purposes, the packaging can also be used for on-site interim storage.

The initial proposed content are 200l/400l drums which contain solid materials from nuclear processes or baskets which contain activated or contaminated materials from nuclear spent fuel pools.

Design

A 3D-model of CAROLINE-R80 as a Type B(U) packaging is given in Figure 1. The shock absorbers cover the cask body completely and allow the stowage onto the transport conveyance. The package design takes into account two important configurations:

- Additional shielding (which results in a reduction of the useful cavity dimensions);
- A drain orifice which allows the easy removal of water during the loading operations while keeping the useful cavity at its maximum level.

Both design options take into account the same shock absorbers. The CAROLINE-R80 packaging is currently under design as a Type B(U) packaging according the IAEA SSR-6 recommendations [1]. Without its shock absorbers, the packaging can also be used as a Type A or Type IP-2 packaging.



Figure 1 – CAROLINE-R80 design

The different versions are referred to as follows:

- Standard version with the largest useful cavity: CAROLINE-R80/ST
- Extra Shielded version with smaller useful cavity: CAROLINE-R80/ES
- Standard version with Water drain orifice: CAROLINE-R80/WST
- Extra Shielded version with Water drain orifice: CAROLINE-R80/WES

CAROLINE-R80 will be used to refer to the general package design. Table 1 gives an overview of the main dimensions of the different versions.

Property	CAROLINE-R80/(W)ST	CAROLINE-R80/(W)ES
Overall height	2111mm	2111mm
Overall diameter	1700mm	1700mm
Body height	1485mm	1485mm
Body diameter	1060mm	1060mm
Internal height	1163mm	1008mm
Internal diameter	785mm	670mm
Maximal mass of empty packaging	7700kg	9700kg
Total mass of empty body	4780kg	6900kg
Maximum loaded mass	9900kg	10300kg

Table 1 – Main properties of CAROLINE-R80

The CAROLINE-R80/(W)ST is able to transport 200l or 400l drums, while the CAROLINE-R80/(W)ES is only able to ship 200l drums due to its increased shielding capacity.



The packaging consists of two shock absorbers, the upper shock absorber and the lower shock absorber. These absorbers, based on a foam in a stainless steel casing, protect the package against the accidental conditions of fire and mechanical impact.

The body of the CAROLINE-R80 is of cylindrical shape and made of stainless steel layers, lead and the ROBATEL compound PNT7™. The function of these materials is mainly radiological shielding (gammas as well as neutrons) and thermal protection.

On top, the body has a two-lid system. The primary lid (plug) guarantees sufficient shielding to protect the operators during the first steps of the conditioning of the packaging. The lid can be fixed under water to allow a safe transfer of a loaded packaging through the nuclear facility without fixing the secondary lid. The latter can be put in place later on and makes the packaging leak tight for transport or interim storage. This two-lid system allows to change the secondary lid without unloading the content (for example when metal seals are put in place for interim storage). In this way, the dose rates for the operators will stay below acceptable values.

All CAROLINE-R80 designs have a top lid orifice for the conditioning of the packages in a dry environment. Some concepts do possess a drain orifice at the bottom to allow the easy removal of water after an immersed vertical loading of the packaging. An important asset of these packagings is the ability to use the complete cavity of the package design as a drainage tube can be avoided. In other designs, this drainage tube would take up a part of the useful cavity.

Content

The biggest challenge is to render the packaging design compatible with the variety of contents which need to be shipped in the near future, in terms of isotopes, activities, physical/chemical form... In fact, the approved content depends on the technical performance of the package design which is limited by operational constraints. The aim is to apply for an approval certificate which allows the transport of generic contents from different nuclear facilities.

The initial proposed content are 200l or 400l drums which contain solid materials from dismantling nuclear processes or baskets which contain activated or contaminated materials from spent fuel pools. Depending on the size of the drums or the baskets, CAROLINE-R80/(W)ST or CAROLINE-R80/(W)ES may be used. Alternatively speaking, the required radiological shielding determines the size of the drums or baskets to be used to ship the content.

The dose rate evaluation of the non-conditioned waste will be a major challenge regarding the safety demonstrations, as the content could potentially move during routine and normal conditions of transport. The movement of this content will be limited by specific baskets, spacers or drums. In the safety analysis report, a maximum gamma and neutron spectrum will be determined taking into account the applicable regulations [1].

The allowed content is limited to 2100kg for the CAROLINE-R80/(W)ST version and 600kg for the CAROLINE-R80/(W)ES version. These masses are maximal taking into account the severe accidental conditions of transport as defined in [1].

Handling

Making transportation packagings operational in different kinds of nuclear facilities is a big challenge, as none of the existing facilities are identical and so different interface constraints need to be taken into account for the original design of the package. The physical properties of the packaging, such as weight and dimensions, are of major importance as they are limiting factors for the operational aspect. The presence of overhead cranes or specific trolleys, the availability of free space to store the required equipment or to move the packaging around freely... determine the design of the required equipment.

During the design phase of the packaging, different specific equipment will be designed in order to facilitate loading and unloading operations on all potential sites. Horizontal or vertical loading and dry or wet conditions are two important drivers to design the equipment. The following list gives a short overview of some of the required equipment:

- A crane, installed on the same trailer as the packagings, could allow a remote controlled loading or unloading operation for high active content. The principle is shown in Figure 2.
- A specific gripper to load and unload drums into and out of the packaging. As the space between the drum and the cask body are limited to reduce the weight of the packaging, little free space is available for lifting the drum in or out.
- A lifting beam with adaptable lifting arms allows for the immersion of the packaging, including its supporting chair, in the spent fuel pool. The principle is shown in Figure 3.

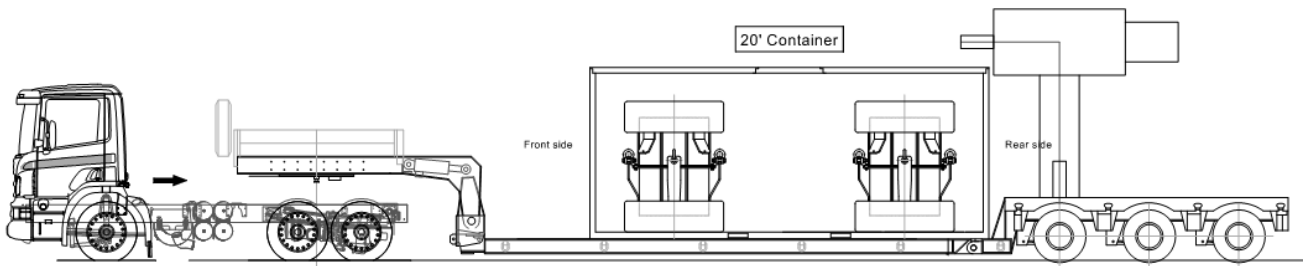


Figure 2 – Principle of telescopic crane for remote controlled (un)loading



Figure 3 – Principle of lifting beam and supporting chair

Storage

The CAROLINE-R80 packages are designed to allow an on-site interim storage, with or without shock absorbers. The need for these shock absorbers is linked to the storage requirements:

- Storage in a Type IP-2 or Type A packaging following [1] requires no shock absorbers;
- Storage in a Type B packaging following [1] requires shock absorbers.

The compliance with an IP-2 packaging already offers a decent basis for the specific on-site safety case. Leak tightness control, thermal protection, mechanical drop resistance and dose rate management are all taken into account to a specific level. Moreover, stacking of different packages, which is only allowed without shock absorbers, could reduce the required storage area as shown in Figure 4.

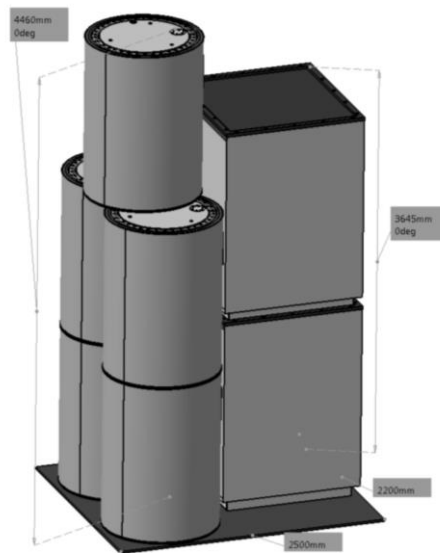


Figure 4 – Stacking of CAROLINE-R80 during interim storage

Due to its two-lid system, the practice to use metallic seals during interim storage can be easily implemented. For transport, one can change back to elastomeric seals due to the quick and easy changing of the lids without unloading the content.

Transport

The CAROLINE-R80 packages are transported vertically. The shock absorbers allow the stowage of the packaging onto the conveyance by using a specific transport frame.

The most important limit to determine the number of CAROLINE-R80 packages to be shipped at once by road is the weight limit. In France and Germany for example, the weight limit for the complete conveyance is 40T. Taking into account the weight of the truck and trailer, only two loaded CAROLINE-R80 packages can be shipped at once in the Type B configuration, as schematically

shown in Figure 5, or three packages in the IP-2 or Type A configuration.

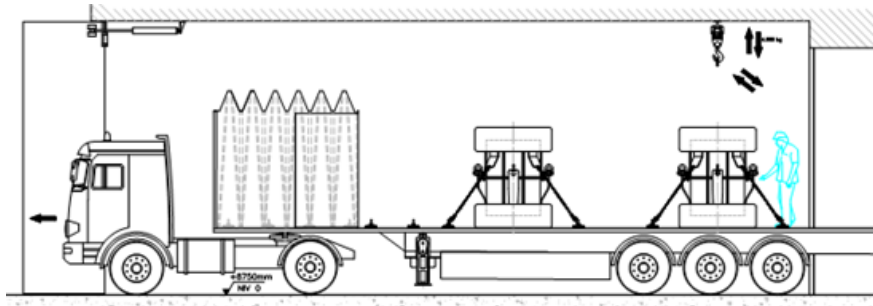


Figure 5 – Schematic view of the transport configuration for Type B packages

Conclusion

For the radioactive content, full compliance has to be demonstrated, together with the packaging design, regarding the safety regulations. The technical performance of the package design will be the limiting factor which determines the approved radioactive content. Difficult topics are the displacement of the content in the packaging and the content description. An additional limit for the amount of radioactive material to be shipped will be imposed by the technical transport specifications.

Having fixed the approved content of the packaging, the operational constraints can be tackled by designing additional equipment which takes into account site-specific constraints.

As the design of a new packaging is decisive for the complete lifetime of it, the above mentioned aspects need to be investigated in an early stage and for all sites susceptible in receiving or sending this package.

References

[1] IAEA SSR-6 Regulations for the Safe Transport of Radioactive Material 2012 Edition