Autonomous loading of content in a type B packaging

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Abstract

Loading high and intermediate-level radioactive waste into type B packaging is challenging. Often waste is stored in drums that need to be loaded into a type B packaging for transfer to a waste facility. To protect the workers, the dose uptake needs to be as low as reasonably achievable. The loading/unloading systems and the type B packaging need to be designed, allowing the autonomous loading/unloading of the waste to minimize dose uptake by the workers during the operations.

After one year of design and construction, the autonomous system is ready for the loading and unloading of two new-build type B packagings CAROLINE-R80. The autonomous system's design is based on the experience gained during many years of nuclear transport of drums.

In order to load and unload the drums in different kinds of nuclear facilities, many interface challenges have to be treated. Physical properties of the autonomous system such as dimension and weight are limiting factors, as many facilities are not equipped to handle such large and heavy packagings. Different specific equipment is designed in order to facilitate remote loading and unloading operations to cope with the high dose rate waste.

Different tests have been executed in Belgian nuclear facilities to optimize the autonomous loading/unloading of drums. In future, other contents, such as high level radioactive liquid or hospital sources, can also be loaded with this autonomous system.

Introduction

The high and intermediate-level radioactive waste produced in Belgium is often stored in 400l drums. Waste in these drums can origin from nuclear power plants, research activities (historical/recent), production of radioisotopes or high active sources from the industrial or medical sectors. Due to the high radioactive doses that may occur, drums can be conditioned or non-conditioned. The different origins of the waste results in an extensive range of 400l drums with different internal configurations.

In Belgium the waste of the producers are transferred from the producer's facility to an interim storage facility. This can be done after the competent authority responsible for the waste accepts the waste according to Belgian acceptance criteria. The drums are then stored in the facility, waiting for their final disposal.

After the acceptance of the waste by the competent authority, the 400l drums can be collected and transported to the interim storage facility. Currently this transfer is done by use of a shielded ISO 20ft container, equipped with an autonomous loading/unloading system (figure 1).

Figure 1. Shielded ISO 20ft container equipped with autonomous loading/unloading system

The system has a weight of 65 ton and can transport a maximum of 14 drums, depending on the activity and dose rate. Due to this heavy weight, the speed during the transport is limited to 30 km/h.

Not all the requirements specified in the SSR-6 (Regulations for the Safe Transport of Radioactive Material) are met. Therefore transports are executed under special arrangement with compensatory measures approved by the competent authority in Belgium, provided that conformity with the SSR-6 regulations is impracticable and standards of safety are established and demonstrated.

The competent authority may approve special arrangement transport operations for a single consignment or a planned series of multiple consignments. The overall level of safety in transport shall be at least equivalent to that which would be provided if all the applicable requirements in these safety regulations have been met. Some of the transports executed by the shielded ISO 20ft container are routine transports and cannot be transported under special arrangement and for other drums the activity or dose rate exceeds the allowed content of the system.

To be in compliance with the SSR-6, a new system is necessary for the transport of these drums. The new system should be capable of handling an extended range of 400l drums with different dose rates, activities and configurations in different existing loading and unloading locations.

Materials and Methods

The new system designed for the transport of 400l drums consists out of two type B packagings and an autonomous system for the loading and unloading of 400l drums. Figure 2 displays the concept drawing. The two type B packagings are named CAROLINE-R80. The packaging CAROLINE-R80 is a result of the collaboration between Transnubel and Robatel Industries for the design, safety report, and construction of the type B packaging. The certification of the type B packaging is done by the competent authority in Belgium.

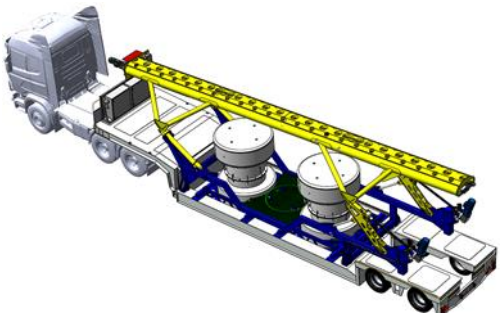

Figure 2. Concept of two CAROLINE-R80 packagings and autonomous loading/unloading system

Description of the CAROLINE-R80

CAROLINE-R80 is a package design of type B(U) in accordance with the IAEA SSR-6, 2012 edition, and will be available in two versions. The standard version, or CAROLINE-R80/ST, is designed for the transport of 400l drums or baskets. The extra shielded version, or CAROLINE-R80/ES, is designed for higher activity material placed in 200l drums or baskets. Each version can be supplied with the optional bottom located draining orifice for underwater loading. The initial concept was developed as a packaging for high active waste but the possible applications are highly versatile due to its design. The two lid sealing system makes for a secure deduplication of shielding and leak tightness.

Transportation of the packaging is possible by road, rail, maritime, inland waterways and air. The safety is in accordance with the corresponding regulations: ADR, RID, IMDG, AND and ICAO respectively. Without the shock absorbers, the CAROLINE-R80/ST and CAROLINE-R80/ES can both be used as type IP-2 or type A packaging.

The CAROLINE-R80 package model is of cylindrical shape. It is used, operated and transported vertically. The main components of the packaging are listed below:

- Lower and an upper shock absorbers, both constituted by a stainless steel casing filled with FENOSOL™ foams. These impact limiters aim to protect the packaging body in case of a hypothetical accident during transport and thus provide both mechanical and thermal protection to the body and its safety components. In addition, the upper shock absorber is equipped to tie down the package on its conveyance.
- Body, composed of a cylindrical inner enclosure made of stainless steel, a shielding protection made of lead, a thermal protection and an outer stainless steel enclosure.
- Shielding plug made of stainless steel which is put in place on the flange.
- Closure lid made of stainless steel, fixed on the body with stainless steel bolts and equipped with two O-rings.
- Control plug and sampling plug.
- Radial drain (optional).

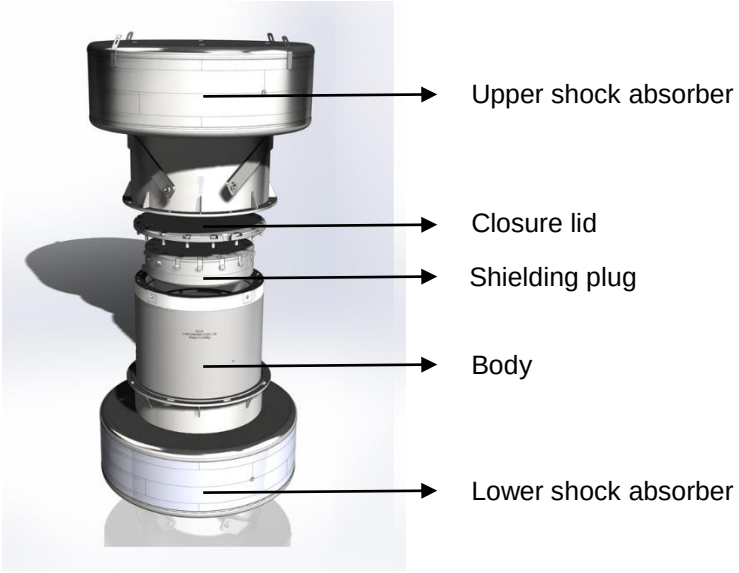

Figure 3. Main components of the CAROLINE-R80

The table 1 and 2 below show the various dimensions and weights of CAROLINE-R80/ST and CAROLINE-R80/ES.

Nominal dimensions	***CAROLINE-R80/ST***	***CAROLINE-R80/ES***
Overall height	2.111 mm	2.111 mm
Overall external diameter	1.700 mm	1.700 mm
Body height	1.485 mm	1.485 mm
External diameter of the body	1.060 mm	1.060 mm
Internal height of the cavity	1.163 mm	1.008 mm
Internal diameter of the cavity	775 mm	670 mm
Volume of the cavity	560 l	355 l

Table 1. Dimensions of the CAROLINE-R80

Nominal masses	***CAROLINE-R80/ST***	***CAROLINE-R80/ES***
Mass of the empty body	4.780 kg	6.900 kg
Mass of the upper shock absorber	1.030 kg	1.030 kg
Mass of the lower shock absorber	790 kg	790 kg
Mass of the equipped lid	370 kg	270 kg
Mass of the plug	735 kg	695 kg
Maximal mass packaging	7.700 kg	9.700 kg

Table 2. Weights of the CAROLINE-R80

This packaging CAROLINE-R80 is designed with numerous loading and unloading capabilities: dry vertical/horizontal loading, docking against a hot cell and underwater loading. It is also possible to use CAROLINE-R80/ST and CAROLINE-R80/ES as an interim storage packaging with or without shock absorbers while providing thermal and mechanical protection as well as leak tightness control.

Two packages are allowed to be transported simultaneously with their shock absorbers installed as a type B(U) package on a trailer or in a ISO container. For the transport of low-active radioactive material this package solution can be used as a type IP-2 or type A without the shock absorbers. This way three packages are allowed to be transported together.

Description of the autonomous system

The autonomous system exists of 4 main components: truck, trailer, 2x CAROLINE-R80 and mechanical and electrical system for loading/unloading the 400l drums. Different tools are also designed and constructed to manipulate the components of the CAROLINE-R80 (upper shock absorber, closure lid and closure plug). These tools are necessary for the opening and closing of the packaging. For manipulation of the 400l drum, a specific compact gripper is designed by Transnubel to fit inside the CAROLINE-R80. This is important because it allows easy loading/unloading of the 400l drums in/out the two packagings.

The truck that can be used in combination with the low loader trailer is a 6x2/2. The weight of the front of the low loader trailer will be supported by the axes and wheels of the truck. The truck is only equipped with a day cabinet, to keep the weight as low as possible. One of the criteria during the design of the system was to keep the total weight bellow 44 ton. No special transport permits are necessary in Belgium if the total weight remains below this limit.

A hydraulic low loader trailer has been selected to keep the height of the system during transport and during loading/unloading activities as low as possible. The low loader trailer is displayed in figure 4. The floor can be placed on the ground hydraulically during loading/unloading operations and can be adjusted up to 0,5 m height to overcome obstacles during transport.

Figure 4. Hydraulic low loader trailer

The mechnical and the electrical system has two functions. The first function is the lashing of the packaging on the trailer during transport and the second function is the autonomous loading and unloading of 400l drums. In figure 5, the lashing structure is shown. Fixation of the upper shock absorber to the metal structure is done with tensioners; the metal structure is fixed to the trailer with bolts.

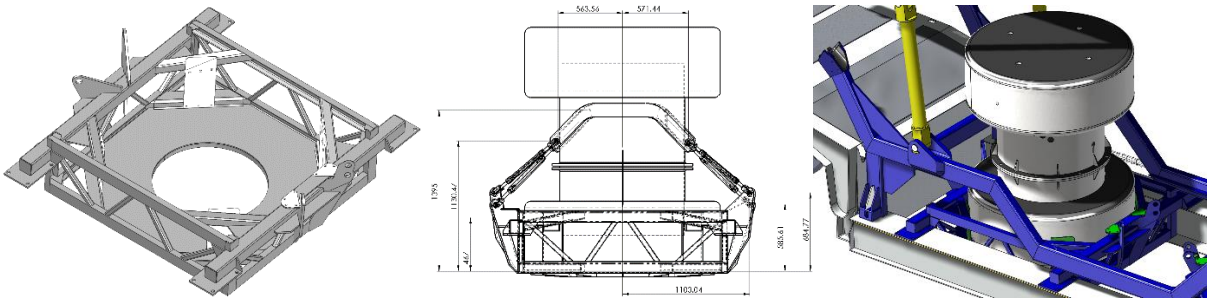

Figure 5. Lashing structure

The second function, autonomous unloading and loading of 400l drums, is done by a hoist bridge. This bridge is fixed to a metal frame. Standard twist locks are used to connect the metal structure to the trailer (item 6, figure 6).

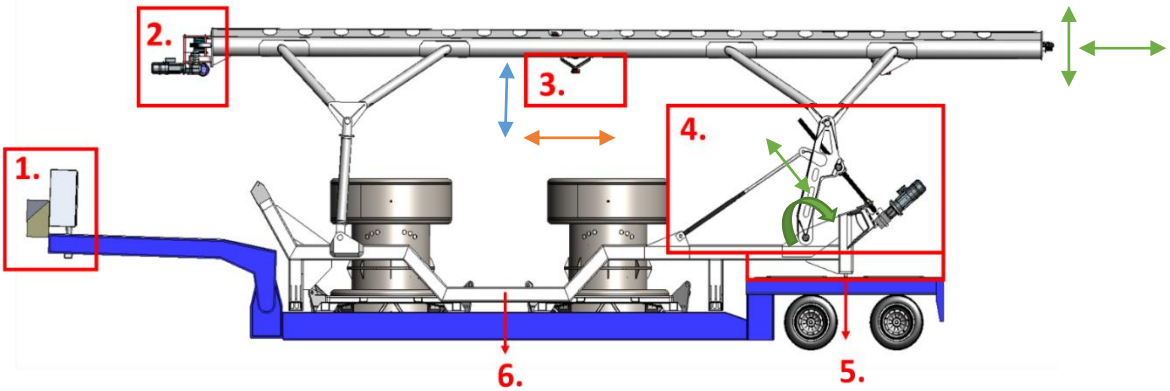

Figure 6. Components of the autonomous system

On the top of the trailer an electrical cabinet is installed (item 1, figure 6). Motors are installed (item 2, figure 6) for the two dimensional movement of the cat (item 3, figure 6), cameras are mounted to give the operator a clear view as the handling is remote controlled. Motors are installed on each side to create a swivel movement (item 4, figure 6). This movement allows the system to higher/lower the upper beam to respect transport and operational criteria. In the same time an overhang could be created, depending on the swivel position. An extra support is provided to support the weight of the swivel system (item 5, figure 6).

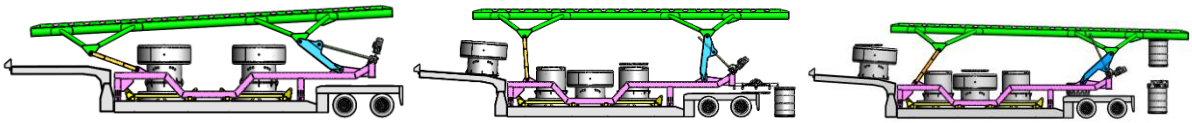

Figure 7. Transport configuration (left), operational configuration (middle), extra overhang (right)

In figure 7, the different configurations of the swivel system are shown. In the transport configuration, all transport conditions are respected and no extra permits are necessary during the transport. In the operational configuration we have two options: the middle position with extra height or the right configuration with extra overhang. Extra overhang can be necessary, when the vehicle cannot enter the load area because of contamination. In this case the 400l drums can still be loaded/unloaded by the autonomous system.

The electrical cabinet needs to be connected with three-phase electric power to be operational. For manipulating the system, the cabinet can be connected with a tablet and external screens. The external screens will display the cameras and the tablet can be used for the autonomous manipulation of the system.

In case of power failure or failure of one of the motors, manual systems are installed on the system to allow the safe loading and unloading of the 400l drum.

Tools to manipulate the packaging and 400l drum

Specially designed tools are needed to open and close the CAROLINE-R80 packaging and for the loading/unloading of the 400l drum.

To open the CAROLINE-R80 packaging the upper shock absorber needs to be removed first. After this operation, the closure lid of the packaging needs to be removed. For these two operations one lifting tool can be used. The operations and tool is shown in figure 8. To make the autonomous system as compact as possible, this lifting tool has been designed to limit the height as much as possible.

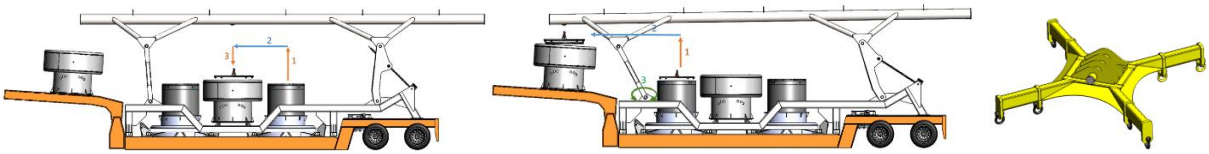

Figure 8. Lifting the upper shock absorber and closure lid

After the upper shock absorber and the lid have been removed, the tools need to be switched. The lifting tool needs to be changed for the gripper. The gripper allows us to manipulate the tool for lifting the closure plug of the CAROLINE-R80. The lifting operations and gripper are shown in figure 9. The gripper is specially designed to fit inside the CAROLINE-R80. After the removal of the shielding plug, access to the cavity has been granted.

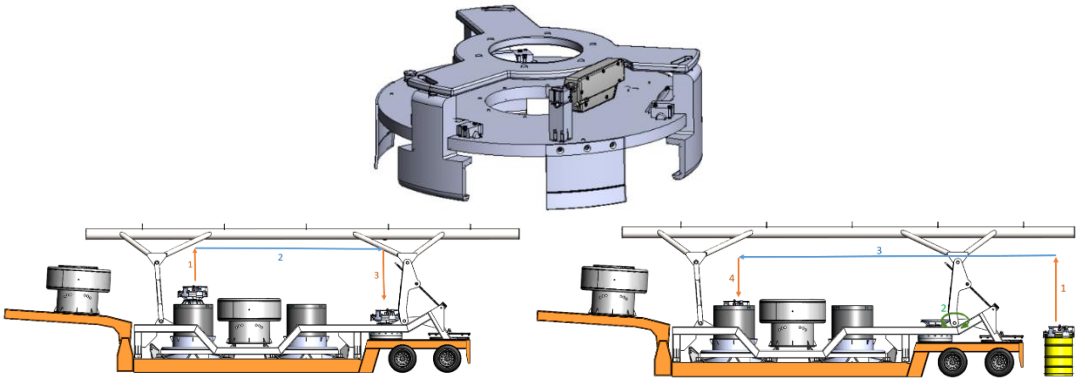

Figure 9. Lifting the shielding plug of the CAROLINE-R80 and loading/unloading 400l drums

The closure plug acts as biological shielding against radiation. Loading/unloading of the 400l drums are done remote controlled, because of the elevated dose rates during the operation. The advantage of manipulating the closure lifting tool with the gripper is that no change of tool is needed during this operation, this limits the exposure to radiation. After the closure plug is installed, operators can have access to the loading area to switch tools, install the closure lid, perform leak tightness tests on the type B packaging and make it ready for transport.

Results

The design and construction of the autonomous system was a complex challenge, but we succeeded to respect the design, regulatory and operational limitations regarding waste types, weight and dimensions. With this autonomous system we provided a solution for the Belgium market to allow safe transport of 400l drums in a type B packaging, including a system for loading and unloading to prevent adaptations by the facilities as much as possible.

In the future the autonomous system can also be used to load inside a medical facility. This is useful because most medical facilities in Belgium are not equipped with overhead cranes that allow the manipulation of a type B packaging.