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Transport cycle for hotlabs: R72 and TNB170 packagings

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Abstract

Research labs worldwide investigate radioactive materials that come from and go to nuclear power plants or research reactors. This can be nuclear fuel, irradiated material samples, instrumentation… all materials with different composition, dimension, weight, residual heat, fissile material. The transport of these radioactive materials often requires the use of a Type B transport packaging according to the IAEA SSR-6 [1] recommendations. To be able to fulfill this specific transport service, Transnubel has, amongst others, two different types of packaging at its disposal: R72 and TNB170.

Since 2009, the packaging R72 has been in operation for the transport of irradiated fuel rods. This packaging was developed with the experience gained during the transports of the BG18 and R62 packagings. The R72 packaging is a type B(M)F packaging, designed for the transport of fresh or irradiated fuel rods UO_2 or MOX, as well as non-fissile irradiated material. Studies are ongoing to be able to transport leaking fuel. The difficulty for obtaining an approval for this will be explained.

The loading and unloading operation can be vertical or horizontal either in a dry manner against a hot cell or submersed in a spent fuel pool. Specific tools and baskets were designed and fabricated for executing the loading/unloading and transport operations in a safe way. The limiting constraints of the different loading and unloading areas have been a major challenge.

To transport small materials up to 20 cm’s in length, the packaging TNB170 is available. It is a type B(U) packaging designed and to be approved in Belgium in 2016 for the transport of radioactive material, in various physical and chemical forms, allowing shipment by all different modes. The packaging can be loaded/unloaded in a dry manner docked against a hot cell or in vertical position.

The packaging can safely transport solid or powder materials: metallic uranium, UOX, MOX, different kind of sources (isotope and neutron sources). Specific tools have been developed such as absorbing material, tilting chair, pallet for transport and handling, internal fittings and baskets.

Introduction

The purpose of this paper is to share the information regarding the transport of irradiated fuel rods, segments of irradiated fuel rods and the difficulties of leaking fuel rods and higher burnup rates in fuel rods.

Until 2011, the transport of full length fuel rods or fuel segments, leaking or not, could be performed using the BG18 transport cask (see Figure 1). Due to the ever increasing demands for packagings to demonstrate compliance with the safety regulations, the older design of the BG18 could no longer guarantee this compliance. The BG18 cask has over 10 years of experience and performed about 40 transport campaigns.

Since 2011, the new R72 transport cask (see Figure 2) is being used as a replacement of the BG18 cask. The R72 packaging is designed for the transport of fuel rods or fuel segments. In this new packaging design the amount of fuel rods transported has been decreased from 30 rods, as for the BG18, to 10 rods. The R72 packaging is owned, designed and constructed by Robatel Industries and managed, operated and maintained by Transnubel. The R72 packaging is also designed but not yet approved for the transport of leaking fuel rods.

Figure 1 – BG18 cask

Figure 2 – R72 cask

Return of experience, transport of irradiated fuel rods

Over the years, Transnubel has performed many transports of irradiated fuel rods between research facilities and nuclear power plants in Belgium, Germany, France, Spain, Sweden, Switzerland, etc. For each research facility or power plant, specific constraints, both for the installation itself as for the operational procedures, needed to be taken into account.

Due to the transports performed in the past, Transnubel has acquired a significant experience and knowledge of these facilities. By this way, many particularities could be treated. For instance, the lifting crane may vary which calls for an adapted lifting beam to lift the packaging used for the transport of the fuel rods. Also the loading / unloading zone can have different dimensions which could make it more difficult to load / unload the packaging and ask for specific hoisting equipment or a different size of trailer.

Specific equipment has also been designed for operating the cask, for instance equipment to remove the plug or the basket both in horizontal and vertical positions. A guillotine system has been designed to secure safe working conditions to remove the plug and to guarantee the safe docking of the cask against the hot cell (see Figure 3 and Figure 4).

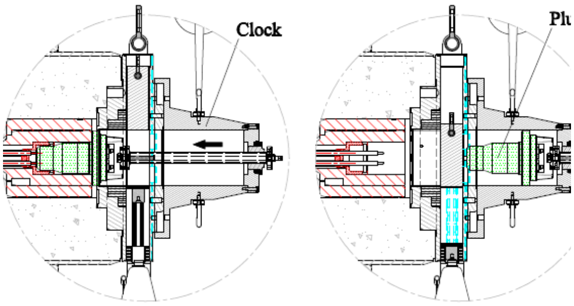

Figure 3 – Principle of guillotine system and clock for plug removal

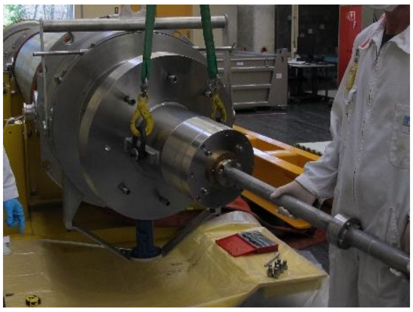

Figure 4 – Guillotine system and clock for plug removal

A blank test or cold handling is performed by Transnubel at the loading / unloading site when "new" situations occur (other packaging, new site, etc.) to verify and adjust the equipment to perform the loading and unloading operations of the packaging. If necessary, new tools are created and tested.

The R72 packaging is designed to transport the commonly used dimensions of fuel rods. Since the fuel rods that will be transported can also differ in size depending on the loading site, different baskets are designed to allow these other dimensions. Specific spacers are used to accommodate for different lengths.

For specific loading operations with major dimensional constraints, a Transnubel packaging has been used to act as a lead castle (see Figure 5) to transfer the fuel rods between the loading pool and the transport packaging. For this specific operation, a docking equipment (see Figure 6) was designed to facilitate the transfer of the fuel rods between the lead castle and the transport packaging.

Figure 5 - Packaging serving as lead caste

Figure 6 – Docking of lead castle onto transport packaging

Return of experience, transport of irradiated fuel rod segments

Despite the reduced dimensions, the packagings used for the transport of fuel rod segments are subjected to the same issues as those for the transport of irradiated fuel rods. The packaging can be selected depending on the properties of the segments.

For the loading / unloading operations of segments of fuel rods, specific requirements are needed depending on the packaging and the installation. For instance, the docking against the hot cell, the specific basket needed in the packaging or the need to encapsulate the segments which may be required by the safety analysis report of the packaging.

Figure 7 - TNB170

The R72 packaging, as described in the paragraph above, could be used for longer segments of fuel rods if these segments are loaded against a hot cell. A specific spacer has to be foreseen in order to avoid movements of the content during the transport.

For short segments of fuel rods, the TNB170 (see Figure 7) is a promising alternative. The packaging is currently under approval by the authorities and will be available soon. Specific equipment has been designed to facilitate the loading and unloading of segments (or other sources) when docked against a hot cell.

A tilting device (see Figure 8) is foreseen to bring the packaging from the vertical to the horizontal position. The docking equipment (see Figure 10) will allow a smooth gliding of the plug when pulled into the hot cell. In order to have an easy access from inside the hot cell, an extension tool (see Figure 9) is mounted on the plug.

Figure 8 - Tilting device

Figure 9 – Extension tool

Figure 10 - Docking part

Difficulty regarding the transport of leaking fuel rods

Most nuclear power plants over the world have been or will be concerned by the presence of leaking irradiated fuel rods in their pool. It is important to understand the reasons of the ruptures or damage in order to be able to take actions and avoid as much as possible the leaking fuel rods in the future. This requires a transport of these leaking fuel rods to specific laboratories for research.

The BG18 packaging was authorized in the past to transport leaking fuel rods but its approval has expired in 2011. The R72 packaging has taken over the transports performed with the BG18. The studies presented in its safety analysis report show that the packaging is able to transport leaking fuel rods, but the certificate of approval does not allow it. At the moment there is no possibility to transport leaking fuel rods as such.

During the preparation of the loaded packaging for transport, the cavity needs to be dried to limit the amount of hydrogen in it. This is done by creating a vacuum to extract the water from the cavity. With leaking fuel rods it could not be fully guaranteed that all water is removed from the fuel rod.

The following two phenomena could occur with leaking fuel rods and explain why the removal of water is not certain:

- Due to the effect of radiation, the pellets inside the fuel rods deform which may result in water trapped inside the fuel rod. One or more pellets deform and could act as a barrier between the hole in the cladding and the remaining water in the rod.
- When a fuel rod cools down after use, an existing hole in the cladding may close during this process. This results also in water trapped inside the fuel rods.

For the approval of leaking fuel rods, a radiolysis analysis is required. This analysis has to demonstrate that the amount of hydrogen remains under 4% (lower explosion limit). The determination of the leak is very difficult and the analysis is practically impossible to carry out because of the deformation of the pellets and the closure of existing holes, especially at nuclear power plants. For these reasons, the amount of hydrogen in the fuel rod could not be shown.

The concern of the authorities deals with the possible presence of water in the packaging during transport. They consider the release of the water out of the fuel rod as possible which could lead to radiolysis and risk of explosion.

Transport of high burnup fuel rods

Nuclear power plants ask for higher burnup rates to be able to get more power out of the fuel rods before having to replace them. This demand requires that laboratories need to receive high burnup fuel rods to validate calculation codes. The transport of this high burnup fuel rods however cannot be validated without these calculations.

The currently used calculation codes are validated to a certain limit of burnup for low enriched fuel rods. With these codes it is possible to determine the different characteristics of the irradiated fuel rods such as the thermal power and the isotopic composition. Depending on these characteristics, the operating parameters of the packaging can be determined. These parameters of the packaging are the radiation protection, the thermal analysis and the leak tightness.

With high burnup fuel, more actinides are present in the fuel. This results in lower A_2-values for the content. The leak tightness of the packaging is also more difficult to show because the limit is more restrictive. Both points reduce the total amount or the total activity to be shipped.

The current calculation codes are valid till a certain limit of burnup. To validate calculation codes for higher burnup of low enriched fuel rods, the laboratories need to receive fuel rods with higher burnup. Before a transport of high burnup fuel may be performed however, it needs validation first.

The evolution of the burnup rates in nuclear power plants leads to a need for transport of fuel rods with higher burnup. The European laboratories need to receive such high burnup fuel rods to evaluate the low enriched fuel's behavior at high burnup and to collect radiological data in order to obtain a sufficient benchmark for the qualification of calculation codes.

To perform the safety studies on packagings intended for the transport of high burnup low enriched irradiated fuel, designers need to describe the content from the radiological point of view, to be loaded in the packaging; calculation codes need to be used out of the range of their validation.

However, the competent authorities in charge of the approval of packagings request the content to be precisely known; the usual way is to make calculations of the isotopes and activities based on calculation codes, but these codes need to be validated by the authorities. As the validation is not granted for high burnups, long, hard and expensive discussions start about the way used for the characterization of the content and about the justification of safety margins, without possibility of demonstration.

Conclusion

The transports of irradiated fuel rods require in most of the situations a case by case analysis of the loading and unloading possibilities, leading to adapted procedures or specific tooling. These kind of transport campaigns remain in any case punctual operations. Due to the important experience gained by Transnubel over the years, different kinds of solutions have been successfully implemented.

For the transport of irradiated fuel rods or segments of irradiated fuel rods, a specific packaging could be used. For full length fuel rods, the cask R72 is most suited. For segments of irradiated fuel rods, the packaging TNB170 is a promising option.

The transport of leaking fuel rods and high burnup fuel remains a challenge regarding the demonstration to the competent authorities, due to the ever increasing demands for packagings to demonstrate compliance with the safety regulations.

References

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