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OVERCOMING DESIGN AND LICENSING CHALLENGES -THE B(U) FLASK TGC27

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ABSTRACT

For the return shipment of intermediate-level compacted metallic waste (CSD-C - Colis Standard de Déchets Compactés) resulting from the reprocessing of German spent fuel assemblies at the La Hague reprocessing plant, France, to Germany, the TGC27 transport and storage flask has been developed. It is a Type B(U) package design for fissile material suitable for transport and long-term interim storage of CSD-Cs. The flask is developed by the AGC consortium, a private partnership of TN International (France) and GNS Gesellschaft für Nuklear-Service mbH (Germany). The consortium has applied for approval of a Type B(U) package design for fissile material in Germany. The strategy of structural safety demonstration is based on a penalizing full-scale mock-up with a thick forged body. Specific expertise has been developed to select materials and tolerances representative of the serial flask in service conditions. For the forging of the body, a low alloy carbon steel grade with an optimized chemical composition has been used. The tensile properties at room temperature are representative of the serial flask at maximum service temperature. The bottom-to-shell welding was performed in order to have mechanical properties corresponding to the minimum properties of the serial production weld, causing maximized deformation in the punch bar tests. The shock absorbers have been produced with hard and soft properties: hard properties to maximize the stress and to be representative of the behavior at -40 °C and soft properties to control the ability of the parts for absorption of the impact energy at the maximum service temperature. For the closing system, i. e. the lids and bolts, the requirements were set with minimum mechanical properties at maximum service temperature. Dummy canisters have also been produced to represent the CSD-Cs. A total of 8 drops will be performed to demonstrate the safety robustness of the TGC27 design: one axial drop, one lateral drop, two angle drops, and four punch bar drops.

INTRODUCTION

The new TGC27 flask (Figure 1) has been developed by the AGC consortium, a private partnership of TN International (France) and GNS Gesellschaft für Nuklear-Service mbH (Germany). This flask based on a thick forging design, is intended to be used for the transport and storage of intermediate-level compacted metallic waste (CSD-C - Colis Standard de Déchets Compactés). This waste is coming from the reprocessing of spent Light Water Reactor fuel assemblies at the La Hague plant in France. The TGC27 flask is designed for transport by road and rail. The capacity is 27 CSD-Cs placed in a specially designed basket in the cavity of the flask. The total mass of the package is less than 120 000 kg in transport configuration.
The design of flask body consists mainly of a thick cylindrical forged cryogenic steel shell with a narrow gap welded to a thick forged steel bottom in the same material. The upper third of the flask is covered with a thermal protection, composed of a layer of 40 mm thick Vyal B resin blocks for thermal insulation in the lids area.

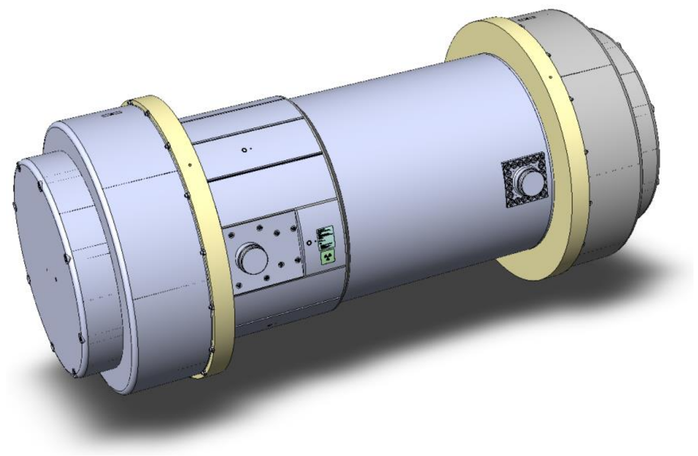

Figure 1. TGC27 flask (3D illustration)

The TGC27 flask has two leak-tightness barriers:

> The primary one: the flask body, the primary lid and its orifice cover, the metallic gasket of the primary lid and the metallic gasket of the primary lid orifice cover, the screws of the primary lid and the screws of the primary lid orifice cover,
> The secondary one: the flask body, the secondary lid and its orifice covers, the metallic gasket of the secondary lid and the metallic gasket of each orifice cover of the secondary lid, the screws of the secondary lid and the screws of the orifice covers of the secondary lid.

The top and bottom shock absorbers protect the flask in the event of accident during transport. The top and bottom shock absorbers are each composed of an aluminum ring to absorb the energy in case of a lateral drop and axial elements in wood encased in a stainless-steel housing to absorb the energy in the event of an axial or oblique drop.

PRINCIPLES OF THE MOCK-UP DESIGN

The mock-up (Figure 2) is of scale 1:1 compared to the serial flask. In order to ensure less favourable behaviour in terms of leak-tightness compared to the worst behaviour of the TGC27 serial flask during the drop tests, a similarity principle is applied to ensure that specific design features differ between the mock-up and the serial flask:

- Material properties of the main components constituting the leak-tightness barriers of the mock-up are lower than the minimal material properties of the serial flask in the most unfavourable temperature conditions (explained in detail below).
- Shock absorbing materials (aluminium rings and the wood blocks) of the mock-up have been selected to be representative of the most unfavourable behaviour of the materials used for the serial flask;
- Specific dimensions of the mock-up have been defined in order to ensure penalizing behaviour during the drop regarding the leak-tightness of the lids compared to the serial flask.

Figure 2. TGC27 Mock-up (without shock absorbers)

CONTAINMENT MATERIAL

In order to ensure less favourable behaviour of the mock-up regarding the leak-tightness in comparison with the serial flask in accident conditions, the supply range for the yield strength of the components of the mock-up leak-tightness barriers are below the minimal specifications required for the components of the serial flask. This applies for the following components: the shell, the bottom, the butt-weld bottom to shell, the secondary lid, the secondary lid screws.
Although no similarity on the primary lid and its screws is required, their material properties have been downgraded to ensure the penalizing behavior of the mock-up.

MOCK-UP SHOCK ABSORBER

The mock-up shock absorbing aluminium rings are made of the same material as for the serial flask, but the supply range for yield strength, tensile strength and elongation at fracture have been defined differently, as described below.
Hardness of the aluminium ring has been defined by its rational tensile strength. For the lateral drop (#2.1), the aluminium rings of the mock-up have been selected to be harder, or at least as hard as, the hardest aluminium ring of the serial flask. For the lateral drop (#3.1), the aluminium rings have been selected to be softer than, or at least as soft as, the softest aluminium ring of the serial flask.
The same arrangement and types of wood have been used for the mock-up and the serial flask. Each type of wood is characterized by a specified range for its crushing stress. Wood of high crushing stress is called “hard”, whereas the wood of low crushing stress is called “soft”. The

woods of the shock absorber of the serial flask have been selected considering the average admissible crushing stress defined as a target for the overall crushing stress of the shock absorber.
The hard wood has been selected for the axial drop #1.1 to maximize accelerations and cause the maximum stress, strain and accelerations in the containment barrier. Moreover, the hard wood of the shock absorber will be cooled down to -40 °C maximum during the drop. In that way, the wood properties of the mock-up are ensured to be penalizing compared to the serial flask regarding the aim of the drop (#1.1).
The soft wood has been selected to assess the resistance of the shock absorber during the corner drop (#3.1) and oblique drop (#4.1) against the risk of compaction. Moreover, the top shock absorber will be heated up so that the temperature of the wood will be at least +70 °C. In this way, the wood properties of the mock-up are ensured to be penalizing compared to the serial flask regarding the aim of the drops (#3.1) and (#4.1).

MOCK-UP BASKET AND DUMMY CANISTERS

The mechanical characteristics of the aluminium alloys of the basket of the mock-up are representative of the serial flask. The dummy canisters are representative of that produced for the La Hague reprocessing plant. The Compacted Waste is to be replaced by a ballast mass in steel representative of the maximum waste mass (Figure 3).

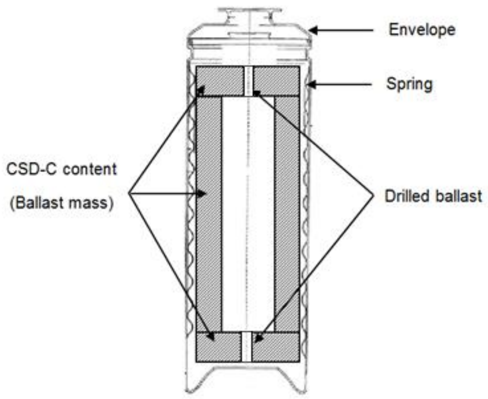

Figure 3. TGC27 Dummy CSD-C

GEOMETRIC DIMENSIONS

Some dimensions have been adapted in order be penalizing either in the full behaviour of the flask such as the gaps around primary and secondary lids or in a local behaviour of a part such as the protection against punch bar plate.
Indeed, during the 9.3 m lateral drop (#2.1), the lids will slide to close the gaps with the shell. The influence of these gaps on leak-tightness behaviour during the drops has been taken into account as the gaskets sliding can be detrimental to tightness. The radial gaps of the mock-up have been maximized, to cover the maximum radial gaps of the serial flask.
Axial gaps in the cavity are relevant parameters regarding the delayed impact of the content on the primary lid. Thus, the axial gaps in the cavity of the mock-up have been adjusted to be representative of the maximum gaps of the serial flask. Adjustments are foreseen for the axial gaps between the CSD-C stacks and the internal dampers and for the axial gap between the primary lid and the basket.

In order to prove the non-fracture of several protection plates in the top shock absorber, the thickness of these parts has been reduced to ensure a penalizing behaviour of the part even if mechanical properties of the parts are not downgraded.

TEST PROGRAM

A total of 8 drop tests will be conducted to demonstrate the safety robustness of the TGC27 design (Figure 4): one axial drop, one lateral drop, two angle drops, and four punch bar drops. The drop tests are ordered in four drop sequences, each with two drops - one drop representing the 9 m drop and one drop representing the punch bar drop in accordance with IAEA transport regulations. The drop sequences have been selected to cause maximized potential damage on the mock-up. All drop sequences will be performed with the same mock-up flask body and the same lids, but the sealing gaskets, lid screws, the basket and dummy CSD-Cs and the shock absorbers will be changed between all drop sequences.

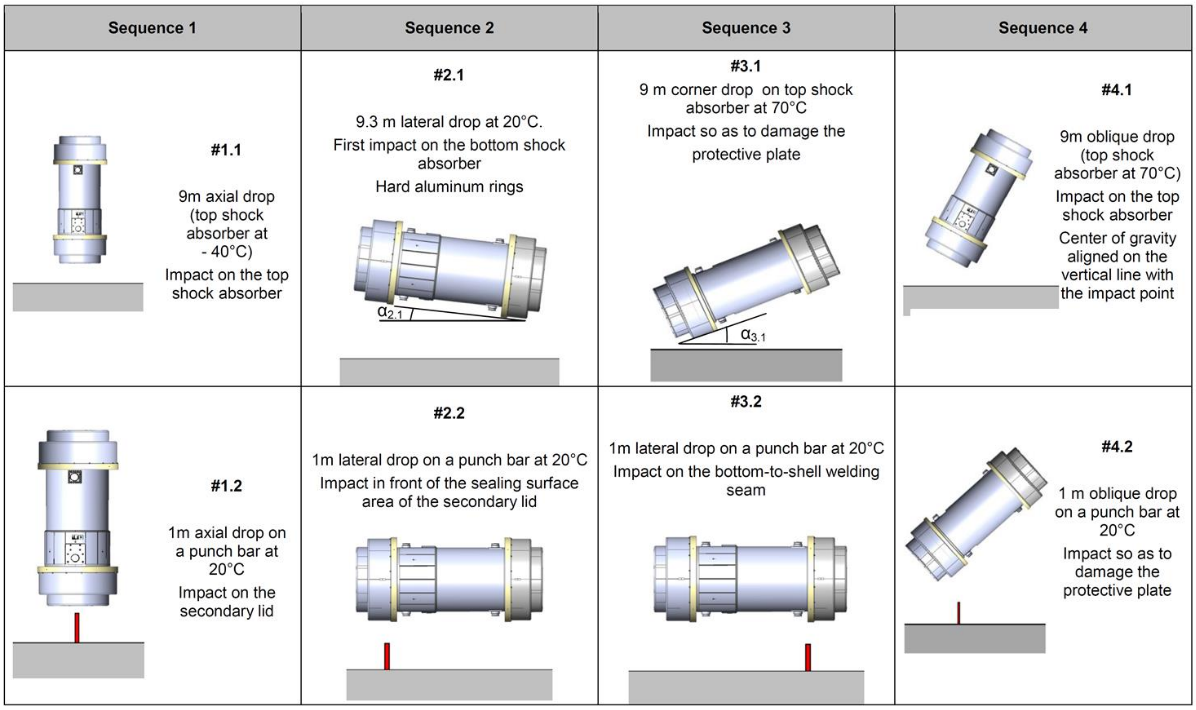

Figure 4. TGC27 drop test program

The main objectives of the drop test program are to:

- Demonstrate the leak-tightness of the containment barrier after transport accidents via leak-tightness testing and metrological determination of both the stresses in the secondary lid screws and the accelerations of the forged shell,
- Provide experimental data for the demonstration of the non-impact of the trunnion on the ground during transport accidents,
- Demonstrate the mechanical behaviour of the shock absorbers and their fixations on the shell, e. g. via determination of the crushing behaviour of the wood and the top aluminium ring,
- Provide experimental data for the demonstration of the brittle fracture safety.

To achieve these objectives, measurements are to be taken with electrical sensors, such as 1D and 3D accelerometers, linear strain gauges, strain gauge rosettes and thermocouples. The sensors will be placed on the inner and outer surfaces of the mock-up at different positions. Regions of particular interest, such as the zone of the welding seam between the flask shell and bottom, the secondary lid screws, the secondary lid, the top end of the flask shell and the top shock absorber will be equipped with multiple sensors. Their data will be stored in the drop test sequences and used for verification of the expected results of the drop test program as well as for verification of the hypotheses on the general kinetic behavior of the mock-up which were used for determination of the comprehensive drop test program.
To ensure that the sensor data can be stored, the mock-up has been reworked to provide guidance and breakthroughs for sensor cables (Figure 5).

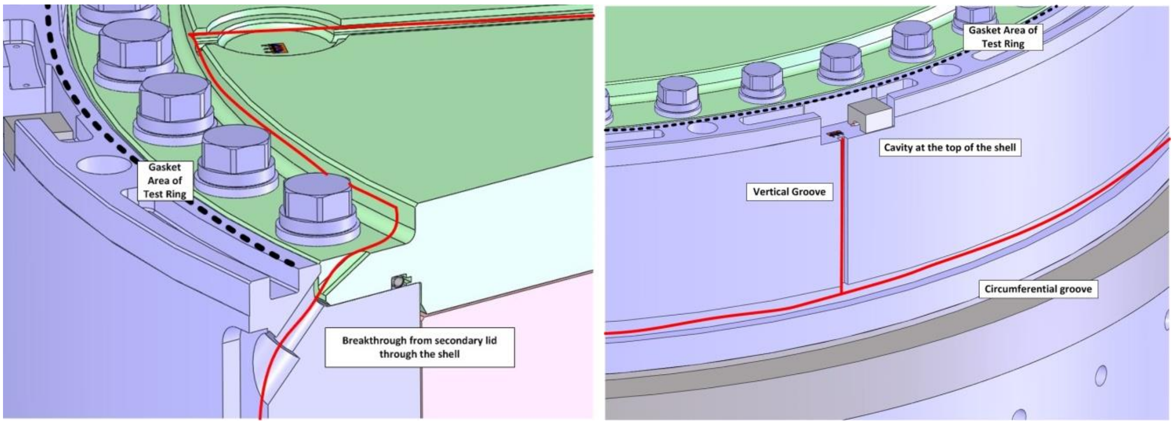

Figure 5. Reworks for cable guidance

Further, there are several measurements which will be taken with other means including:

- 3D deformation measurements of the shock absorbers, the gasket planes of both the mock-up shell and the secondary lid in impact zones, and of the punch bar,
- Photogrammetric recording of the position of the primary lid and secondary lid for exclusion of lid sliding during the drops,
- Visual inspections and photo documentations of various components to record the apparent drop impact,
- Metrological determination of mounting and unmounting torques and forces,
- Video documentation of the drops (including high-speed video), and
- Leak-tightness tests.

CONCLUSIONS

In application of the similarity principle, the mechanical behaviour of the mock-up regarding the leak-tightness after the drop tests is penalizing compared with that of the serial flask and the behaviour of each key component is penalizing for the mock-up compared with the serial flask. The similarity principle ensures the representability of the serial flask as well. In this way, drops selected as worst case scenarios for leak tightness or characteristic parameters in the drop test program validated by the authorities will demonstrate the robustness of the TGC27 flask design.

ACKNOWLEDGMENTS
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