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# Brazed and welded cans for transport and storage of damaged fuel rods

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## Abstract

For the type B(U)F package NCS 45 leak tight cans are stipulated in the certificate of package approval to provide a barrier for the radioactive material under routine and normal conditions of transport for fuel rods with a burn-up of more than 62 GWd/MgHM. For damaged fuel rods a significantly higher mass of heavy metal is permissible when using such cans.

DAHER NUCLEAR TECHNOLOGIES GmbH (DAHER NT) is using two different technologies for producing leak tight cans. Brazed cans are produced under water in NPP pools and welded cans are produced under dry conditions in a Hot Cell.

For the production of brazed cans as well as for the production of welded cans prequalification documents for brazing/welding have been set up by DAHER NT and released by the competent authority. The prequalification documents reflect the different production processes but are identical with respect to Quality Assurance (QA) requirements.

Brazed cans are produced by using the Underwater Brazing Equipment (UBE), a patented technology. The qualification of the UBE was presented at PATRAM 2013 [2]. Welded cans are produced by orbital fusion and spot welding. With both technologies high quality stainless steel cans are produced which can be used for transport and storage.

## Introduction

The type B(U)F-96 package NCS 45 is licensed for the transport of fuel rods with a burn-up of up to 120 GWd/MgHM. Fuel rods with a burn-up of more than 62 GWd/MgHM must be encapsulated. The cans must not contain free water and must be sealed by welding or an adequate method.

DAHER NT can provide two types of cans complying with the requirements of the German competent authority specified in the certificate of package approval:

- Brazed cans produced under water in the UBE
- Welded cans produced in a Hot Cell.

For the production of brazed cans as well as for the production of welded cans rather high QA requirements apply. Prequalification documents for brazing/welding are described in detail in the first part of the paper.

In the second part of the paper the production process for brazed cans using the UBE and the production process for welded cans by using orbital fusion and spot welding are described.

## Quality Assurance Requirements

In Germany, the Federal Institute for Materials Research and Testing (BAM) is the competent authority for approval and supervision of quality assurance measures for packages for radioactive material. For both types of cans BAM guideline BAM-GGR 011 [1] must be fulfilled. This guideline classifies the different parts of packagings for radioactive material in three grades, with grade 1 having the highest requirements. According to the PDSR the cans are classified as grade 1 parts.

The guideline BAM-GGR 011 requires that in Germany the owner of the certificate of package approval is responsible for all quality assurance measures during design, manufacturing and operation of the packaging. Hence for both types of cans DAHER NT set up the prequalification documents consisting of manufacturing specification, drawings, material list, manufacturing and test sequence plans (MTSP) and brazing/welding plan and had these documents released by BAM before start of production.

### Drawings and Material List

The safety analysis for the both types of cans is carried out in the PDSR based on template drawings of the cans. In these template drawings all safety relevant design details are specified and the certificate of package approval references these template drawings. Variations of the cans based on the template drawings are possible and have to be released by BAM and approved by the German competent authority, the Federal Office for the Regulation of Nuclear Waste Management (BfE). These variations could include e. g. a different length or a different design of the handling pin.

The released drawings are then used as basis for the material list. The material list contains for all individual parts of the cans a column block “material prequalification” and a column block “material documentation”.

The column block “material prequalification” consists of the columns

- no. and designation of the part (e. g. tube),
- dimensions,
- material,
- belonging material test sheet and revision index.

The column block “material documentation” consists of the columns

- manufacturer of semi-finished product,
- heat no.,
- sample no.,
- pipe no.,
- certificate filing no.,
- the columns for the marks of certificate approval checks by the manufacturer, the purchaser and the independent expert.

The column block “material prequalification” is filled in before start of manufacturing by the manufacturer, checked by DAHER NT and released by BAM. The column block “material documentation” is filled in by the manufacturer during manufacturing and finally checked by DAHER NT and BAM after manufacturing is completed.

## Manufacturing and Test Sequence Plan (MTSP)

The manufacturing specification of both cans is part of the PDSR and describes the requirements towards manufacturer’s responsibilities, fabrication, controls and checks. The MTSP dissects these requirements in manufacturing and test/check steps. Like the material list the MTSP is subdivided in a column block “prequalification” and a column block “documentation”.

The column block “prequalification” consists of the columns

- step no.,
- description of the manufacturing/test step
- the indication of who is responsible for each step (manufacturer, purchaser and independent expert) and if a record of the tests is required.

For steps like machining of a part the responsible is the manufacturer alone, for steps like dimension check after final machining the manufacturer, the purchaser and the independent expert are responsible and a record is required.

The column block “documentation” consists of the columns

- for confirmation that the step has been performed,
- remarks
- reference to the record.

The column block “prequalification” has to be filled in before start of manufacturing by the manufacturer, checked by DAHER NT and released by BAM. The column block “documentation” is filled in during manufacturing by the manufacturer and finally checked by DAHER NT and BAM after manufacturing is completed.

## Brazing/welding plan

The brazing/welding plan is based on the brazed connections or welding seams defined in the drawings and specifies the brazing/welding procedures in detail.

For brazing the brazing plan defines the process (like inductive brazing), the brazing equipment, the kind of brazing connection, the dimensions of the brazing connections, base materials and brazing materials, atmosphere, cleaning before and after brazing, heat treatment, etc.

For welding the welding plan defines the welding process, the kind of welding seam, the dimension of the welding seam, polarity, current, voltage, pre-heating requirements, heat treatment, etc.

The brazing/welding plan has to be filled in before start of manufacturing by the manufacturer, checked by DAHER NT and released by BAM.

## Deviations during manufacturing

Deviations during manufacturing are treated formally in the manufacturer's deviation management system. In case a deviation from the specification, drawings, material list, MTSP or brazing/welding plan is recorded a deviation report is issued which contains the reference to the deviation, the description of the deviation and a first assessment on measures to deal with the deviation. The deviation report is submitted to the QM staff unit and the design/licensing department of DAHER NT for further analysis. Depending on the results of the analysis the deviation may lead to a rejection, repair or acceptance of the respective part. For parts classified in grade 1 according to BAM-GGR 011 in any case acceptance of the measures by BAM is required.

## Process Qualification:

For the qualification of the manufacturing process of brazed and welded cans prototype cans with dummy fuel rods were produced. These prototype cans were examined with non-destructive and destructive testing.

The qualification comprised the entire manufacturing process from manufacturing of semi-finished parts to loading, draining, drying and brazing/welding to the helium leakage test.

The following non-destructive and destructive tests were carried out:

- visual check of brazing/welding seams
- helium leakage test
- surface crack test of welding seams
- pressure test

- tensile test of welding seam (for welded cans)
- metallographic analysis of heat influenced zones

Results of the non-destructive and destructive tests are documented in a report.

### Brazed cans

Design of the brazed cans

The design of the brazed cans is shown in Figure 1. The main body is a tube (1) made of stainless steel. On the top side the tube has two guide slits (10) which allow safe handling of the empty tube under water. On the bottom side the tube has two slits (5) through which the water is drained after the fuel rod was loaded. The tube is closed on both sides with two plugs which are connected to the tube by brazing. The bottom plug (3) is preassembled with the tube. In the “loading” position the bottom plug allows draining of the water through holes (4) in the plug and the corresponding slits in the bottom part of the tube. In order to reach the “brazing” position the bottom plug is pushed axially into the tube and comes to rest above the slits. The top plug (2) is inserted after loading of the fuel rod into the can and is positioned by a circular stop (6). The outer shape (7) of the top plug can be adapted to the requirements of the NPP to allow handling with existing tools. Both plugs are made of stainless steel. The brazing solder is fixed to the plugs in a deposit (8) which is applied by using the “cold gas spray” technology.

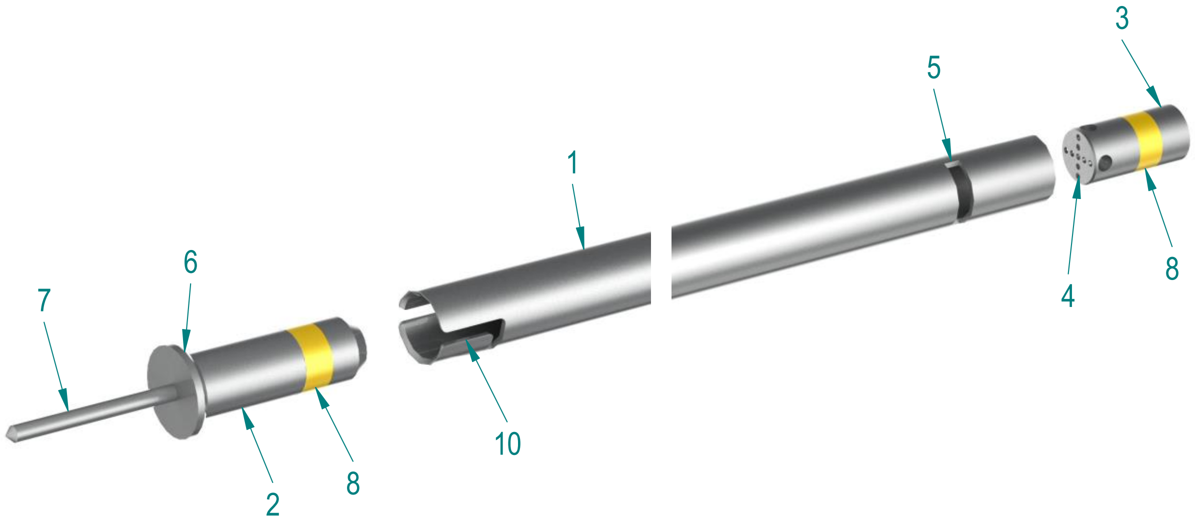


**Figure 1: Brazed can**

During the brazing operation the brazing solder becomes liquid and flows into the narrow gap (9) between the tube and the plugs and seals this connection, see Figure 2.

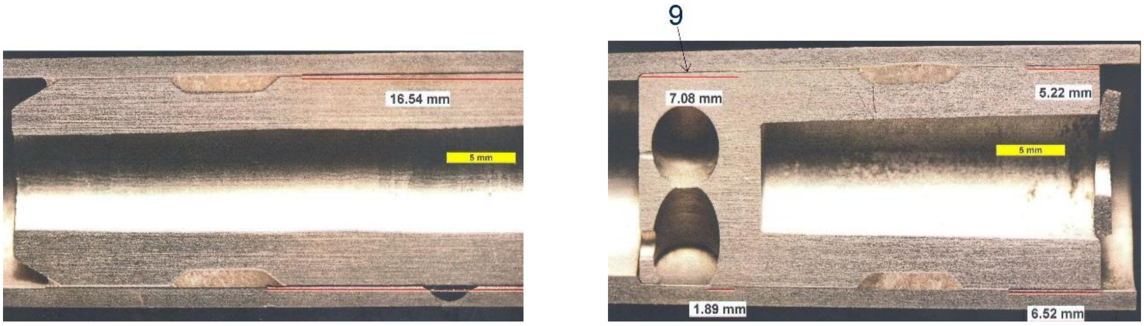


**Figure 2: Cross section of brazed plugs**

## Manufacturing

The brazed cans are manufactured in 6 steps:

- The tube is manufactured with final dimensions
- Upper and lower plug are prefabricated with final dimensions of the groove for the brazing material and excess material elsewhere
- The brazing material is applied by “cold gas spray” technology
- Upper and lower plug are machined to final dimensions
- The lower plug is inserted into the lower part of the tube and secured
- In the pool loading area the tube is lowered into the UBE, loaded with a fuel rod and closed by brazing as described below

## Production of brazed cans with the UBE

For encapsulation of fuel rods with the UBE it must be operated in a pool which provides a sufficient head of water during all handling steps. For standard length fuel rods a water depth of 12-14 m is sufficient to meet this requirement. The UBE is shown in Figure 3.

The encapsulation process is carried out in following steps:

1. **Loading of a tube into the UBE, loading of the fuel rod into the tube and closing of the UBE**

   Prior to loading, the lid of the UBE is opened. The tube with preassembled bottom plug is attached to the handling tool and lowered into the device. Then the fuel rod is inserted into the tube by using the fuel rod handling tool of the NPP. Next the upper plug is inserted into the UBE and the UBE is closed.

2. **Draining and drying of the UBE, filling of the UBE with Helium**

   The water in the UBE is drained into the pool by applying overpressure. The water inside the tube drains off through the holes in the bottom plug and the slits in the tube. Then, the cavity of the UBE, the cavity of the tube and the fuel rod are dried by vacuum drying. Finally, the cavity of the UBE and the cavity of the tube are filled with Helium.

3. **Brazing**

   Before brazing starts both plugs are lifted into the brazing position by using a remote controlled mechanical system. Additionally the correct position is checked by underwater cameras through windows in the UBE. The tube around the plugs and the plugs are heated up by inductive heating until the brazing material becomes fluid and flows into the gaps between tube and plugs.

4. **Flooding of the UBE and unloading of the brazed can of the UBE**

   The UBE is flooded with water, opened and the brazed can is removed with the handling tool and transferred into the leakage test station.

5. **Helium leakage test**

   The brazed can is loaded into the leakage test station. The leakage test station is closed, drained and dried. Then the leakage test is carried out by the Helium leakage test method.

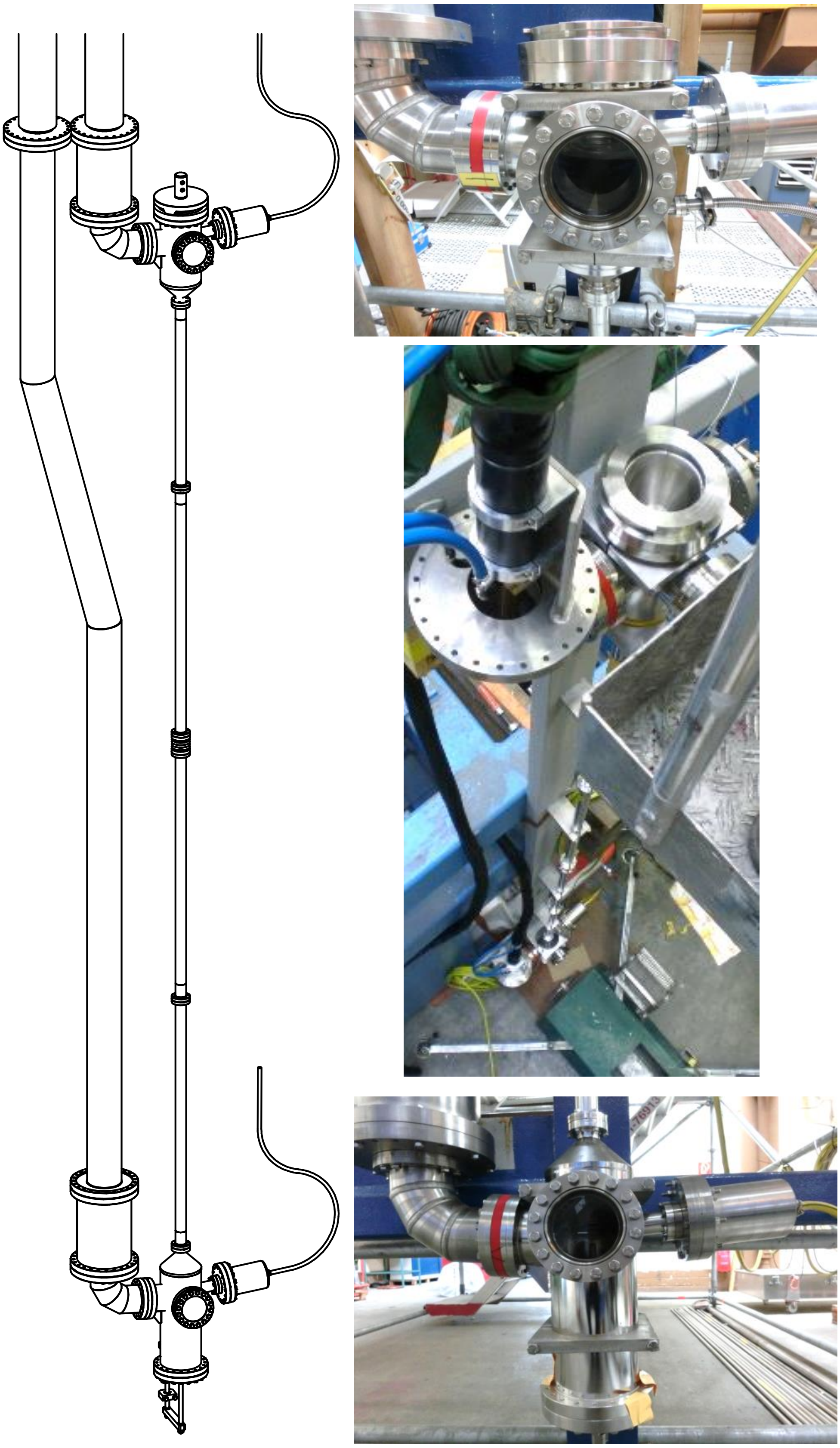

**Figure 3: Sketch and pictures of the UBE**

## Welded cans

Design of the welded cans

The main body is a tube (1) made of stainless steel. As general rule the lower plug (2) is welded to the tube before one or more segments of fuel rods are loaded into the can. Eventually the upper plug (3) is inserted into the can and is first welded on its circumference before its extremity will be closed. The opening (4) at the extremity of the top plug allows the heat evacuation when performing the orbital welding and the filling of the can with helium. The outer shape (5) of the top plug can be adapted to the requirements of the nuclear site to allow handling with existing tools.

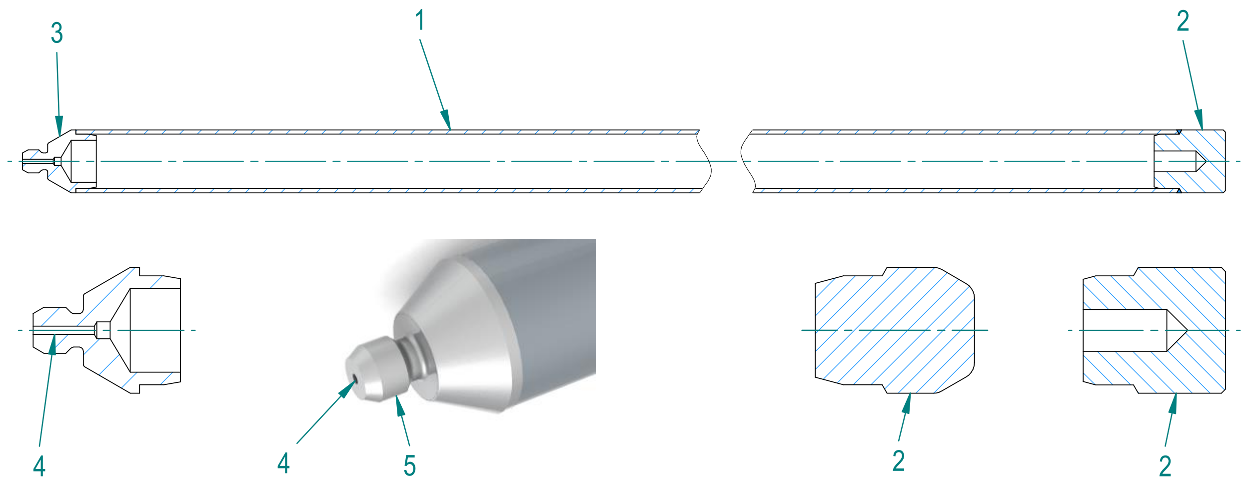


**Figure 4: Welded can**

Manufacturing

The welded cans are manufactured in 4 steps:

- The tube, upper and lower plug are machined with final dimensions
- The lower plug is welded to the tube. Then the welding seam leak tightness is controlled by helium leakage test.
- In the Hot Cell the tube is loaded with the fuel rod/parts of fuel rod and the upper plug is welded to the tube
- The can is filled with inert gas through the opening at the extremity of the upper plug and this hole is closed by a spot weld

Production of welded cans

Welded cans are produced in a Hot Cell by remote operation. The encapsulation process is carried out in following steps:

1. **Loading of the tube with the fuel rod/parts of fuel rods**

   The tube with already attached lower plug is fully or partially inserted into the Hot Cell and filled with the fuel rod or parts of fuel rods.

2. **Loading of can and welding of top plug**

   The welding device is attached to the top of the tube. Then the upper plug is inserted into the tube. The upper plug is positioned and welded first on its circumference by orbital fusion welding technique (see Figure 5).

3. **Filling with helium and spot welding of hole in top plug**

   The can is evacuated and filled with Helium through the hole in the top plug. Then this hole is closed by a spot weld (see Figure 5).

4. **Helium leakage test**

   The leakage test is carried out by using the Helium leakage test method in a specific area inside the Hot Cell.

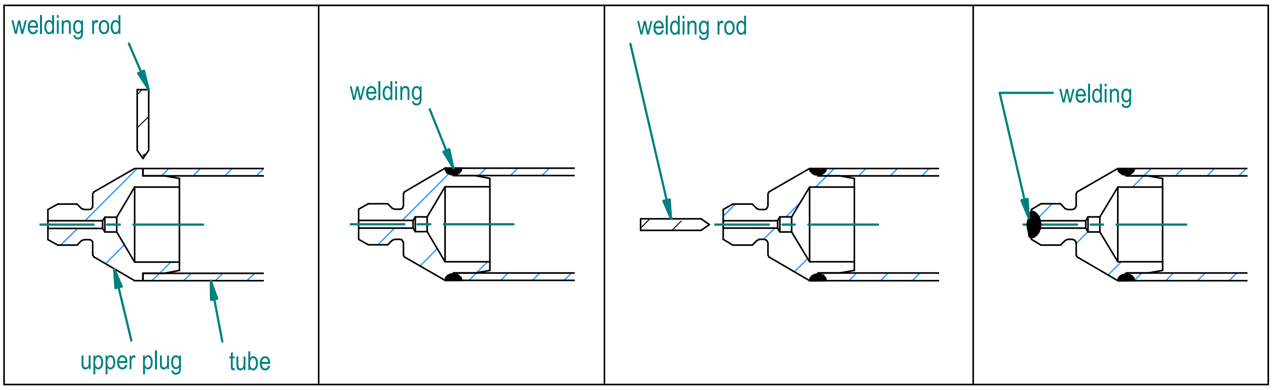


**Figure 5: Circumferential and spot welding**

### Site specific requirements

The adaptation of the brazing and welding technology to different sites is easily feasible.

For the brazing technology the rather compact UBE can be fixed to a rack positioned at the bottom of the pool or to a frame attached to the pool side. The solution based on a rack was realized for the application of the brazing technology in a German NPP (see Figure 6).

For the welding technology only limited space is required in the Hot Cell in order to weld the upper plug and perform a helium leakage test on the welding seam. Adaption to any kind of Hot Cell should be easily feasible even for rather small cells.

**Figure 6: Earthquake safe rack for UBE**

## Conclusions

DAHER NUCLEAR TECHNOLOGIES GmbH can provide two mature technologies for the production of gas tight cans for damaged fuel rods and/or fuel rods with very high burn-ups: brazed cans produced under water by using the UBE or welded cans by using proved welding technology. For both types of cans the highest QA requirements specified in BAM GGR 011 are met. Both technologies are specified in the certificate of package approval of the type B(U)F-96 package NCS 45. Both types of cans can be used for transport and storage of fuel rods requiring encapsulation. Last but not least, both technologies can be easily adapted to any NPP and any Hot Cell.

## References

[1] BAM-GGR 011, Quality Assurance Measures of Packagings for Competent Authority Approved Package Designs for the Transport of Radioactive Material

[2] Th. Breuer, F. Hilbert: Qualification of the DAHER-NCS Fuel Rod Encapsulation Process for Transport and Storage, PATRAM 2013