The NCS 45 Cask Family: an Updated Design Replaces an Old Design Lessons Learned during Design, Testing and Licensing

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1. Introduction

The NCS 45 cask family is intended to replace the cask types R52, TN6/1 and TN6/3. These packagings – country of origin France – were in operation worldwide since mid 1970. In the late nineties prolongations of the certificates of package approval became more and more difficult and time consuming. Finally only special arrangements for restricted contents were issued by the competent French authority which caused considerable problems when validations in other countries were applied for. To guarantee the availability of such a cask in the future for its customers NCS decided to replace the old casks by an updated design, the NCS 45 cask family.

2. Design

The NCS 45 cask family has following general design features:

- Outer and inner shell made of stainless steel
- Lead shielding and thermal insulation
- Double O-rings in all lids
- Rotary lock at the lid side
- Removable plug at the bottom side
- 4 trunnions for vertical and horizontal handling qualified according to KTA
- Openings at the lid and bottom side for venting and draining
- Shock absorbers at both ends

The design is shown in Fig. 1 and basic data for the largest and smallest member of the family are given in Tab. 1.

Characteristic	unit	NCS 45	NCS 15
Total length with shock absorbers	mm	6 207	3 207
Total width with shock absorbers	mm	1 630	1 630
Length without shock absorbers	mm	5 307	2 307
Width over trunnions	mm	1 038	1 038
Cask body diameter	mm	730	730
Usable length max.	mm	4 625	1 535
Usable diameter	mm	220	220
Empty mass	kg	21 800	11 040
Payload	kg	700	250
Max. total mass	kg	22 500	11 290

Tab. 1. Basic data of the NCS 45 and the NCS 15

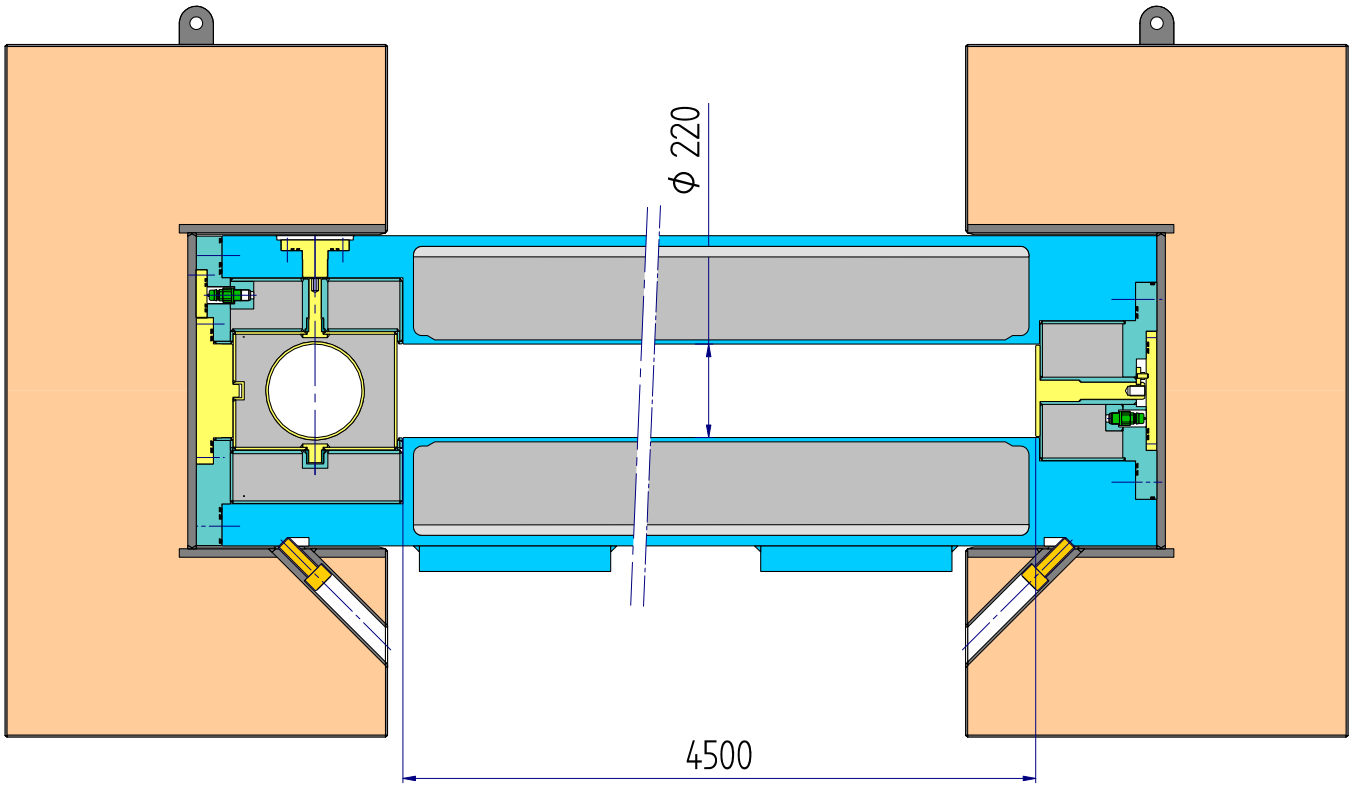

Fig. 1. Design of the NCS 45 cask family

During the design phase it became apparent that only very few design details of the old design could be used for the new design. The most important design changes were:

- increase of the thickness of inner and outer shell to provide enhanced safety during accidental conditions
- use of forged parts for the lid and bottom part of the packaging to enhance the rigidity of these parts
- use of double O-rings in all lids to provide a testable containment
- increase of the size of the shock absorber to provide sufficient crushable volume and reduce the accelerations during accidental conditions
- use of certified trunnions for handling in order to comply with the requirements of the customers
- reduction of the size of the packaging feet to avoid negative effects during accidental conditions

3. Radioactive Content

For the NCS 45 cask family a wide range of contents is foreseen. In general, there are no restrictions on the physical form of the material, whether it consists of fuel assemblies or rods, parts of fuel rods, pellets or powder. However, for broken rods, pellets and powder provisions for particle retention should be applied to avoid excessive inner contamination of the packaging. Tab. 2 contains the most important specification details of the contents of the NCS 45 and the NCS 15.

To provide maximum flexibility, several content descriptions with respect to criticality are foreseen:

- **limit 1** defines a permissible total mass of fissile material per package: for this content there are no requirements towards a supporting structure for the fissile material,
- **limit 2** defines a permissible mass per unit length of the fissile material: for this content the fissile material must be supported by appropriate installations to guarantee the specified limit,
- **limit 3** defines a permissible enrichment for the fissile material if it is of a specified form (e.g. rods) and positioned in a standardized rack.

Characteristic	unit	NCS 45	NCS 15
Burn-up max.	MWD/tHM	120 000	120 000
Cooling time min.	d	10	10
Total HM mass max.	kg	200	50
U-235 mass max.	kg	24	6
Enrichment in U-235 max.	%	100	100
Pu_{fiss} mass max.	kg	3,4	1,2
Pu_{fiss} / Pu max.	%	100	100

Tab. 2. Radioactive contents of the NCS 45

4. Licensing

The certificate of package approval for the NCS 45 has been applied for in July 2002, the application for the NCS 15 was filed in July 2003. For both members of the NCS 45 cask family a completely new safety analysis report was prepared.

The structural analysis was based for loading/unloading and normal conditions of transport on calculations according approved standards. For the structural analysis with respect to accidental conditions pre-calculations using proven methods as well as DYNA3D [1] analyses were carried out. For the proof that the requirements of the Regulations concerning accidental conditions of transport are fulfilled drop tests with a 1:3 scale drop test models were foreseen.

The source terms for thermal, containment and shielding analysis were calculated by using the SAS2 calculation sequence of the SCALE [2] package. The thermal analysis was carried out by using HEATING and the shielding analysis with the SAS4 calculation sequence, both part of the SCALE package. For the containment analysis all relevant release paths including permeation through the elastomer gaskets were taken into account.

With respect to the flexible definition of the fissile material extensive analyses were carried out to prove the criticality safety of the specified contents. For the contents defined through limit 1 and limit 2 given in chapter 3 heterogeneous and homogeneous material distributions were taken into account. By variation of the height and diameter of the moderated zone containing fissile material the peak of reactivity was determined for the different fuel compositions defined through limit 1. For the contents defined through limit 2 an axially infinite fissile zone was assumed and the peak of reactivity by variation of the diameter calculated.

5. Drop Tests

As none of the tests carried out with the old cask design was documented according to the current standards, a complete test programme was established. The final drop test program accepted by both the German and the French competent authorities comprises 7 drop test sequences with 7 drop tests from 9 m height and 6 drop tests from 1 m onto the bar. Two of the type A drop tests from 0.3 m height simulating normal conditions of transport to be carried out before the tests simulating accidental conditions are performed as first drop of a drop test sequence. In the other cases the 0.3 m and 9 m drop tests were combined to a single 9.3 m drop test. In sequence 6, drop test 1-6, an unrealistically long bar of 6 m length is used to test if the rear shock absorber could be stripped off. In sequence no. 7 the behaviour of the lead under drop test conditions – lead slump – is investigated. Therefore only one 9.3 m drop is carried out. Tab. 3. summarizes the drop test sequences.

At the time of PATRAM 2004 the first two drop test sequences are completed. The overall performance of the packaging was excellent. The deformation behaviour of the shock absorbers was within the pre-calculated limits. Dimensional checks after the tests showed no global deformation of the packaging. Only the oblique puncture test onto the lid resulted in a small deformation of the impacted area. Helium leak tightness tests before and after each drop test sequence showed that the containment function was not impaired. Fig. 2 shows the drop test model after the 0.3 m and 9 m drop tests of the first drop test sequence.

Sequence no.	drop test no.	drop height (m)	orientation	puncture test
1	0-1	0.3	lid	no
	9-1	9.0	lid	no
	1-1	1.0	lid, 4° oblique onto rotary lock lid	yes
2	9-2	9.3	bottom	no
	1-2	1.0	bottom, center push plug lid	yes
3	9-3	9.3	lid corner	no
	1-3	1.0	lid corner, 10° oblique	yes
4	9-4	9.3	bottom corner	no
	1-4	1.0	bottom corner, 6° oblique	yes
5	0-2	0.3	horizontal	no
	9-5	9.0	horizontal	no
	1-5	1.0	30° oblique onto side	yes
6	9-6	9.3	slap-down, drop angle 20°	no
	1-6	1.0	onto rear shock absorber	yes
7	9-7	9.3	lid, operating temperature	no

Tab. 3. Drop test sequences

In the framework of the drop tests a comprehensive investigation of the wood used in the shock absorbers was carried out. In total approx. 90 static and 80 dynamic compression tests were carried out. With this investigation the influence of following parameters on the properties of the crushable material were clarified:

- Material: balsa, pine, spruce, combinations
- Fibre orientation: longitudinal, transversal
- Casing: no casing, outer casing, compartments
- Temperature: room temperature, -40°C
- Humidity: 10% to 20%
- Crushing velocity: near static to several m/s

The results of these investigations are used to enhance the calculation models and to understand the behaviour of the shock absorbers during the drop tests.

6. Manufacturing

For manufacturing none of the existing documents for the old designs could be used. A complete set of new documents based on the valid international and national standards was prepared:

- Drawings
- Manufacturing specification
- Procedure for visual inspection, dimension and thread checks
- Procedure for overload test of handling devices
- Procedure for leak tightness check
- Procedure for pressure test
- Procedure for thermal test at maximum normal operating temperature

All these documents are part of the application for the certificate of package approval and will be released together with the expert opinion of BAM.

Fig. 2. NCS 45 drop test model after the 0.3 m and 9 m drop test of sequence 1

7. Operation

The NCS 45 cask family is suitable for dry and wet loading and unloading.

In case of dry loading and unloading the packaging can be in a vertical or horizontal orientation. Depending on the radioactive material the rotary lock lid can be removed before or after the head of the packaging is attached to a hot cell. In any case the rotary lock would only be opened after attaching the package to the hot cell. The loading and unloading operation itself can be carried out by using equipment of the hot cell to handle the content through the rotary lock or by using the push plug at the bottom of the packaging.

In case of wet loading and unloading the packaging would be submerged under water in vertical orientation and loaded through the opened rotary lock. The rotary lock can be operated for this purpose under water. The openings in the lid and bottom plug are used for draining and drying of the package.

For horizontal and vertical lifting operations the packages are equipped with two trunnions at each side. These trunnions are designed and certified according to KTA for the use in nuclear facilities. For support and tie-down foot plates are welded to the lower part of the packaging.

For the preparation of the operating procedures the knowledge gained from the long experience with the old cask designs was a valuable asset. The handling procedures are based on the handling procedures proven to be adequate for the old cask designs. For the procedures for periodical tests the records of the long term behaviour of the old designs was of great importance.

8. Maintenance and Periodic Retesting

Maintenance and periodic retesting was defined for the old designs in a rather general manner in the certificates of package approval. Based on the requirements specified in the certificate NCS developed therefore instructions for maintenance and inspection easy to handle for the personnel and complying with the QA requirements in Germany. All work was then carried out according to these instructions.

For the NCS 45 cask family new procedures for maintenance and periodic retesting were established based on the experience gained with the instructions for the old designs. These new instructions will be specified in the certificates of package approval for the individual package designs. They reflect the state of the art concerning Quality Assurance currently required for packages for the transport of radioactive material.

Maintenance and periodic retesting is documented in the packaging test book which contains at least:

- Valid certificate of package approval
- Handling and maintenance instructions
- Instructions for periodic retesting
- Final acceptance certificate issued after manufacture
- Records of periodic inspections
- Records of use
- Records of repairs and replacement of parts
- Complete set of drawings

The German competent authority must be kept informed about putting into operation, periodic inspections, and major repairs of each individual packaging.

9. Conclusion

The NCS 45 cask family is intended to replace the cask types R52, TN6/1 and TN6/3 which were in operation since approx. 30 years. Only the general designs of the old and new cask types are similar. Important design changes were required for the new casks. Some of the design changes were required in order to fulfil new or increased requirements of the Regulations. Other design changes were made because of requirements of customers. Finally, some of the design changes reflect the experience gained with the old designs.

A wide range of contents is foreseen for the NCS 45 cask family. All these contents are specified in a rather detailed form to allow a high payload of the casks. A more general specification, as used in the former certificates, is not likely to be accepted by the competent authorities today.

For licensing a completely new safety analysis report was prepared. A test program consisting of 7 drop test sequences was established for the assessment of the mechanical behaviour under accidental conditions of transport. Additionally, a comprehensive study concerning the properties of wood with respect to its use as shock absorber material was carried out. For manufacturing, operation, maintenance and periodic retesting a new set of specifications and instructions was established. The experience gained through operation of the old cask designs was a valuable asset for this task.

The licensing procedure and the assessment of the safety analysis by the competent authority do not show any significant difference to a licensing procedure for a completely new design.

10. Literature

[1] Whirley, R.G., and Engelmann, B.E., DYNA3D: A Nonlinear, Explicit, Three-Dimensional Finite Element Code for Solid and Structural Mechanics – User Manual, University of California, Lawrence Livermore National Laboratory, UCID Report, UCRL-MA-107254 Rev. 1, 1993

[2] SCALE4.4A, A Modular Code System for Performing Standardized Computer Analysis for Licensing Evaluation, NUREG/CR-0200, Rev. 6, ORNL/NUREG/CSD-2/R6