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SAFETY EVALUATION REPORT

Model No. ANF-50 Package
German Certificate of Approval No. D/4365/AF-96
Revision 2
Docket No. 71-3080

Enclosure

Table of Contents

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SUMMARY

By letter dated May 7, 2015, the U.S. Department of Transportation (DOT) requested that the U.S. Nuclear Regulatory Commission (NRC) staff review the Model No. ANF-50, Type A fissile package, as authorized by the German Certificate of Approval No. D/4365/AF-96, Revision 2. DOT requested that the staff provide a recommendation concerning the revalidation of the certificate for import and export use as well as changing the criticality safety index (CSI) from 0.6 to 0.4. The DOT provided supplemental information on July 10, 2015.

The German Competent Authority renewed the Model No. ANF-50 certificate until January 31, 2020, and approved a CSI of 0.4. In 2013, the NRC staff's previous revalidation included a condition that the minimum CSI is 0.6 and that there would be no hydrogenous plastic material wrapping the package during air transport. The applicant submitted information supporting the decrease in CSI but not the inclusion of hydrogenous material during air transport, therefore the exclusion of hydrogenous material is still recommended as a condition of the revalidation.

The staff evaluated the design of the packaging Model No. ANF-50 against the standards in the International Atomic Energy Agency (IAEA) Safety Standards Series No. TS-R-1, "Regulations for the Safe Transport of Radioactive Material," 2009 Edition, in 2013. The staff also used TS-R-1, 2009 Edition, for the revalidation review of Revision 2 of the Model No ANF-50.

Based upon the statements and representations contained in the SAR and supplemental information, and for the reasons stated below, the staff recommends that DOT revalidate the German Certificate of Approval No. D/4365/AF-96, Revision 2, with the condition limiting hydrogenous material during air transport.

1.0 GENERAL INFORMATION

The ANF-50 packaging consists of a shipping frame, receptacle box, pellet box, supporting frame, pellet trays, clamping device, container lid, box lid, and protective lid. The main dimensions of the package are approximately 712 millimeters (mm) in length, 712 mm in width, and 756 mm in height. The total mass of the ANF-50 shipping container is about 248 kilograms (kg).

The packaging Model No. ANF-50 is designed for transporting a maximum of 51.29 kg uranium oxide, containing a maximum of 45.27 kg of uranium with a maximum 5 weight percent (wt.%) enrichment of uranium-235 (^{235}U) in the form of sintered pellets. The Model No. ANF-50 packaging is also designed for transporting a maximum of 14.5 kg uranium oxide, containing a maximum of 12.8 kg of uranium with a maximum 5 wt.% enriched ^{235}U in the form of pellets, pellet fragments, abraded pellet material, or uranium oxide powder. The staff did not perform a shielding evaluation given the contents of the package. The package can be transported by road, rail, sea, and air.

Table 1.1. General Requirements for all Packaging and Packages

TS-R-1 Regulation Number	TS-R-1 Regulation Summary	Evaluation
807	An application for approval shall include: (a) a detailed description of the proposed *radioactive contents* ...; (b) a detailed statement of the *design*, including complete engineering drawings …; (c) a statement of the tests which have been done and their results, or evidence …; and (d) the proposed operating and maintenance instructions for the use of the *packaging*…	Requirement met. This information was included in the safety analysis report (SAR) and SAR files submitted with the application.
813	An application for approval shall include all information necessary to satisfy the competent authority that the design meets the requirements of paragraph 671, and a specification of the applicable quality assurance program as required in paragraph 310.	Requirement met.

2.0 STRUCTURAL EVALUATION

The staff reviewed the ANF-50 application package for structural adequacy with respect to the standards in the IAEA Safety Standards Series No. TS-R-1, "Regulations for the Safe Transport of Radioactive Material," 2009 Edition. A summary of the staff's structural evaluation is provided below.

Table 2.1. Structural Evaluation Considering General Requirements for Packaging and Packages

TS-R-1 Regulation Number	TS-R-1 Regulation Summary	Structural Evaluation
606	*Package* mass, volume, and shape shall be such that it can be easily and safely transported. In addition, the *package* needs to be properly secured in or on the *conveyance* during transport.	Requirement met.
607	Any lifting attachments on the *package* will not fail when used in the intended manner and that, if failure of the attachments should occur, the ability of the *package* to meet other requirements of these regulations would not be impaired. Take account of appropriate safety factors to cover snatch lifting.	Requirement met per ANFG-11.118 (01E), Rev. 3, "Statics calculations for shipping container."

Table 2.1. Structural Evaluation Considering General Requirements for Packaging and Packages (Continued)

TS-R-1 Regulation Number	TS-R-1 Regulation Summary	Structural Evaluation
608	Attachments and any other features on the outer surface of the *package* which could be used to lift it shall be designed either to support its mass in accordance with the requirements of paragraph 607 or shall be removable or otherwise rendered incapable of being used during transport.	Requirement met per ANFG-11.118 (01E), Rev. 3, "Statics calculations for shipping container."
612	In particular, nuts, bolts, and other securing devices shall be so designed as to prevent them from becoming loose or being released unintentionally, even after repeated use.	Requirement met per ANFG-11.118 (01E), Revision 3, "Statics calculations for shipping container."
615	The design of the *package* shall take into account ambient temperatures and pressures that are likely to be encountered in routine conditions of transport.	Requirement met.
617	For *packages* to be transported by air, the temperature of the accessible surfaces shall not exceed 50°C at an ambient temperature of 38°C, with no account taken for insolation.	Requirement met.
618	*Packages* to be transported by air shall be so designed that, if they were exposed to ambient temperatures ranging from -40°C to 55°C, the integrity of containment would not be impaired.	Requirement met.

Table 2.2. Structural Evaluation Considering Requirements for Type A Packages

TS-R-1 Regulation Number	TS-R-1 Regulation Summary	Structural Evaluation
636	Any tie-down attachments on the *package* shall be so designed that, under normal and accident conditions of transport, the forces in those attachments shall not impair the ability of the *package* to meet the requirements of these regulations.	Requirement met per ANFG-11.118 (01E), Revision 3, "Statics calculations for shipping container." The analyzed stress remains below material specifications.
637	The *design* of the *package* shall take into account temperatures ranging from -40°C to 70°C for the components of the *packaging*.	Requirement met.

Table 2.2. Structural Evaluation Considering Requirements for Type A Packages (Continued)

TS-R-1 Regulation Number	TS-R-1 Regulation Summary	Structural Evaluation
641	If the *containment system* forms a separate unit of the *package*, it shall be capable of being securely closed by a positive fastening device which is independent of any other part of the *packaging*.	Requirement met.

Table 2.3. Structural Evaluation Considering Requirements for Packages Containing Fissile Material

TS-R-1 Regulation Number	TS-R-1 Regulation Summary	Structural Evaluation
676	The *package* shall be designed for an ambient temperature range of -40°C to 38°C unless the *competent authority* specifies otherwise in the certificate of approval for the *package design*.	Requirement met.

Table 2.4. Structural Evaluation for Test Procedures

TS-R-1 Regulation Number	TS-R-1 Regulation Summary	Structural Evaluation
723	*Stacking test* - See TS-R-1 paragraph 723 for details.	Requirement met per ANFG-11.118 (01E), Revision 3, "Statics calculations for shipping container."

Table 2.5. Structural Evaluation for Approval and Administrative Requirements

TS-R-1 Regulation Number	TS-R-1 Regulation Summary	Structural Evaluation
813	An application for approval shall include all information necessary to satisfy the *competent authority* that the *design* meets the requirements of paragraph 671, and a specification of the applicable *quality assurance* program as required in paragraph 310.	Requirement met.

2.1 Additional Information Related to the Structural Evaluation

The applicant performed the following analyses to demonstrate the adequacy of the structural design for the ANF-50 shipping container:

1. Stress conditions of the ANF-50 shipping container when handling it with a fork lift truck;
2. Stress conditions of the ANF-50 shipping container when handling it with a crane;
3. Stress conditions of the ANF-50 shipping container during load securing; and
4. Stress conditions of the pellet box when removing it from the shipping frame.

For each analysis, the applicant calculated the induced maximum bending stress, shear stress and axial stress due to applied loading conditions. The staff compared the calculated stresses with the material allowable stresses, and found that all calculated stresses are smaller than the allowable stresses indicating that the design of the ANF-50 shipping should also withstand normal conditions of transport.

2.2 Conclusion

The staff determines that the ANF-50 package meets the structural requirements of the IAEA TS-R-1 regulations.

5.0 CRITICALITY SAFETY EVALUATION

The applicant requested to decrease the criticality safety index (CSI) from 0.6 to 0.4. The CSI of 0.4 was requested in the previous revalidation of the CoC dated December 17, 2013 (ADAMS Accession No. ML13353A620). The original certificate had a CSI of 0.4, however; in response to staff inquiries in 2013, the applicant increased the CSI to 0.6. The staff questioned some results from Appendix 4.3-9 of BAM Test Report No. III.3/10830/ANF-50, which showed that there was some damage to the outer pellets after the crush test. The hypothetical accident conditions (HAC) in the criticality model for Content No. 1 (intact pellets) did not assume damage to any of the pellets. To address the staff's concern, the applicant submitted a HAC criticality evaluation on December 5, 2013 (ADAMS Accession No. ML13347B366) assuming damage to some of the outer rows of pellets and pellet fragments within the clamping space and the interstitial space between the peripheral pellets. To meet the upper subcriticality limit for this evaluation, the applicant reduced the array size from 6 x 6 x 8 to 5 x 6 x 6.

The staff reviewed the current application to determine if the package design met the subcriticality limits set forth in the IAEA's regulations for radioactive materials transportation, TS-R-1, 2009 edition given the requested change in CSI back to 0.4. The review included NRC staff's evaluation and verification of the applicant's HAC criticality calculations of Content No. 1 (uranium oxide in the form of sintered pellets) contained in the "Criticality Safety Analysis for the Transport Approval of ANF-50 Shipping Containers," Number ANFG-5.061 (11), Revision 6, issued in July 2014 as well as descriptions of the design contained in the "Safety Report for the Shipping Container ANF-50 as Type A-package," English translation.

In Section 7 of the report ANFG-5.061 (11), Revision 6, there is an updated HAC analyses for Content No. 1. The discussion states that this analysis was performed with the 6 x 6 x 8 array and includes some damaged fuel on the periphery with some pellet chips entering the clamping space. The results of these calculations were included in Table 17 of the application with the

highest k_{eff} of 0.8964 ± 0.00083. In the 2013 calculation for the damaged periphery pellets with the smaller 5 x 6 x 6 array, the highest k_{eff} was 0.9326 ± 0.0008.

In a letter to the applicant dated June 10, 2015, the staff requested additional information about the differences in the current versus the 2013 analyses that would produce the different k_{eff} results and to justify that the changes appropriately represent the package under HAC. The applicant provided supplemental information on July 10, 2015.

The applicant stated in its response that it increased the spacing in the package to make it more realistic, yet still conservative. The previous analysis (i.e., 2013 evaluation) had no space between the packages in the array evaluation, and therefore neglected the presence of the shipping rack and protective cover. Although these components experience damage as shown in test report ANFG-11.119 (003E), Revision 0, these are still present.

In the current criticality analysis supporting the decrease in CSI, the applicant assumed more realistic, yet still conservative, spacing of the packages within the criticality array evaluation under HAC. As discussed in Enclosure 1 to E-42425 (dated July 10, 2015), the applicant increased the width on each side by half of the rack tube diameter, and the height by the tube diameter. ANFG-11.119 (003E), Revision 0, shows evidence that the shipping rack and protective cover would remain present after the HAC tests, however the selection of the diameter and half diameter of the tube to credit appears arbitrary as the staff did not find any data showing what this deformation could be. Figure 2 from Enclosure 1 to E-42425 and the figures in ANFG-11.119 (003E), Revision 0, that show that there are dents and deformation in the shipping cage but not uniformly across any surface. Staff believes crediting some of this space is reasonable since it would be unlikely for the package to deform uniformly across an entire surface to less than the assumed spacing during HAC, and the distance is still less than that of an undamaged package. The staff also finds that it is reasonable to credit the entire tube diameter in the top and bottom as the bottom part of the rack has two tube thicknesses in that direction considering the cross bars that the package sits on and the top includes the pellet box protective cover. Therefore the staff finds the change in package spacing for the current evaluation reasonable and acceptable.

A summary of the applicable TS-R-1 requirements related to the criticality safety of the package, and the ability of the package design to meet such requirements, is provided below.

Table 5.1. Requirements for the Criticality Safety Review of the DOT Revalidation

TS-R-1 Regulation Number	TS-R-1 Regulation Summary	Criticality Safety Evaluation
528	The CSI for packages containing fissile material shall be obtained by dividing the number 50 by the smaller of the two values of N derived in paragraphs 681 and 682. The value of the CSI may be zero, provided that an unlimited number of packages are subcritical.	Requirement met. The derived CSI value is 0.4. This is consistent with the value of N equal to 125 used for the array of packages calculations for NCT and HAC of transport.

Table 5.1. Requirements for the Criticality Safety Review of the DOT Revalidation (Continued)

TS-R-1 Regulation Number	TS-R-1 Regulation Summary	Criticality Safety Evaluation
529	The CSI for each consignment shall be determined as the sum of the CSIs of all the packages contained in that consignment.	CSI for a given consignment is determined at time of shipment. The minimum criticality safety index for the Model No. ANF-50 package is 0.4.
530	The transport index of any package or overpack shall not exceed 10, nor shall the CSI of any package or overpack exceed 50 except for consignments under exclusive use.	Requirement met. The CSI does not exceed 50.
671(a)	Maintain subcriticality during normal and accident conditions of transport, in particular, the following contingencies shall be considered, water leaking into or out of packages, the loss of efficiency of built-in neutron absorbers or moderators, rearrangement of the contents either within the package or as a result of loss from the package, reduction of spaces within or between packages, packages becoming immersed in water or buried in snow, and temperature changes, and	(i) Applicant evaluated full water in-leakage to the most reactive extent. (ii) There are no neutron absorbers required for the ANF-50. (iii) Applicant analyzed at the most reactive geometry for the contents considering (1) damage to the pellets as a result of accident conditions for Content No. 1 and (2) a bounding geometry for Content No. 2. (iv) Accident condition modeling assumes damaged condition packages maintain conservative spacing. (v) Analyses assume full water in-leakage and reflected packages by 30 cm water. (vi) Temperature changes would not have an adverse effect with respect to criticality.

Table 5.1. Requirements for the Criticality Safety Review of the DOT Revalidation (Continued)

TS-R-1 Regulation Number	TS-R-1 Regulation Summary	Criticality Safety Evaluation
677(a)	Multiple high standard water barriers, each of which would remain watertight if the package were subject to the tests prescribed in paragraph 682(b), a high degree of quality control in the manufacture, maintenance, and repair of packagings and tests to demonstrate the closure of each package before each shipment.	Requirement met. The package nuclear safety assumes full in-leakage of water.
678	It shall be assumed that the confinement system shall be closely reflected by at least 20 cm of water or such greater reflection as may additionally be provided by the surrounding material of the packaging. However, when it can be demonstrated that the confinement system remains within the packaging following the tests prescribed in paragraph 682(b), close reflection of the package by at least 20 cm of water may be assumed in paragraph 679(c).	Requirement met. The applicant assumed 30 cm water reflection in the criticality safety analyses.
679	The package shall be subcritical under the conditions of paragraphs 677 and 678 with the package conditions that result in the maximum neutron multiplication consistent with: (a) routine conditions of transport (incident free), (b) the tests specified in paragraph 681(b), and (c) the test specified in paragraph 682(b).	The criticality safety evaluation uses nominal dimensions for the package. The safety analysis report states that there was only insignificant damage to the shipping frame under normal conditions; therefore, the dimensions were not recorded. The accident condition analyses were performed assuming a conservative amount of space occupied by the shipping cage consistent with the accident tests within the safety analysis report. Also, the applicant considered measurement tolerances for the fissile material.

Table 5.1. Requirements for the Criticality Safety Review of the DOT Revalidation (Continued)

TS-R-1 Regulation Number	TS-R-1 Regulation Summary	Criticality Safety Evaluation
681	A number “N” shall be derived, such that five times “N” shall be subcritical for the arrangement and package conditions that provide the maximum neutron multiplication consistent with the following:	Requirement met. N is equal to 125. The applicant performed criticality array calculations assuming a 9×9×9 array (i.e., 729), which exceeds the 5×N (i.e., 625) array requirements.
681(a)	There shall not be anything between the packages, and the package arrangement shall be reflected on all sides by at least 20 cm of water, and…	Requirement met. The applicant modeled packages with no interspersed moderation and with 30 cm water reflector on all sides.
681(b)	The state of the packages shall be their assessed or demonstrated condition if they had been subjected to the test specified in paragraphs 719 to 724.	The criticality evaluation uses nominal dimensions for the package, the safety analysis report states that there was only insignificant damage to the shipping frame and was so minor that the dimensions were not recorded; accident condition analyses were performed assuming a conservative amount of space occupied by the shipping cage consistent with the accident tests in the safety analysis report and damage to the outer layer of pellets. The applicant considered measurement of tolerances for the fissile material.
682	A number "N" shall be derived, such that two times "N" shall be subcritical for the arrangement and package conditions that provide the maximum neutron multiplication consistent with the following:	Requirement met. N is equal to 125. The applicant performed criticality calculations for accident conditions with a 6x6x8 (i.e., 288) packages which exceeds the 2×N requirement (i.e., 250).

Table 5.1. Requirements for the Criticality Safety Review of the DOT Revalidation (Continued)

TS-R-1 Regulation Number	TS-R-1 Regulation Summary	Criticality Safety Evaluation
682(a)	Hydrogenous moderation between packages, and the package arrangement reflected on all sides by at least 20 cm of water.	Requirement met. The applicant assumed no hydrogenous moderation between packages. This was found to be the most conservative. The staff found this acceptable.
682(b)	The tests specified in paragraphs 719 to 724 followed by any of the following, if the more limiting: the tests specified in paragraph 727(b) and, either paragraph 727(c) for packages having a mass not greater than 500 kg and an overall density not greater than 1,000 kg/m³ based on the external dimensions, or paragraph 727(a) for all other packages, followed by the test specified in paragraph 728 and completed by the tests specified in paragraphs 731 to 733, or the test specified in paragraph 729,	Requirement met. The applicant performed nuclear safety analyses for the package under hypothetical accident conditions assuming conservative package spacing consistent with the results of the accident testing in the safety analysis report.
682(c)	Where any part of the fissile material escapes from the containment system following the tests specified in paragraph 682(b), it shall be assumed that fissile material escapes from each package in the array and all of the fissile material shall be arranged in the configuration and moderation that results in the maximum neutron multiplication with close reflection by at least 20 cm of water.	Requirement met. The pellet box and receptacle remain intact as a result of accident condition tests; however the applicant performed a calculation assuming the pellets escape the box and performed array calculations with this configuration.
731	Packages for which water in-leakage or out-leakage to the extent which results in greatest reactivity has been assumed for purposes of assessment under paragraphs 677 to 682 shall be excepted from the test.	Requirement met. Water in-leakage was assumed to the most reactive extent for all evaluations.
733	The specimen shall be immersed under a head of water of a least 0.9 m for a period of not less than eight hours and in the attitude for which maximum leakage is expected.	Requirement met. Water in-leakage was assumed to the most reactive extent for all evaluations.

Table 5.1. Requirements for the Criticality Safety Review of the DOT Revalidation (Continued)

TS-R-1 Regulation Number	TS-R-1 Regulation Summary	Criticality Safety Evaluation
807 (a)	An application for approval shall include: A detailed description of the proposed radioactive contents with reference to their physical and chemical states and the nature of the radiation emitted.	Requirement met. The applicant adequately describes the contents to the extent necessary to evaluate its criticality safety.
807 (b)	An application for approval shall include: A detailed statement of the design, including complete engineering drawings and schedules of materials and methods of manufacture.	Requirement met. Engineering drawings are included. Materials used that are important to criticality safety are specified.
807 (c)	An application for approval shall include: A statement of the tests which have been done and their results, or evidence based on calculative methods or other evidence that the design is adequate to meet the applicable requirements.	Requirement met. The criticality evaluations were based on calculative methods, which are clearly stated in the application.

Conclusion

Based on the review of the statements and representations contained in the application, as supplemented, the staff agrees that the Model No. ANF-50 package meets the standards in IAEA Safety Standards Series No. TS-R-1, 2009 Edition. The staff recommends that DOT revalidate the German Certificate of Approval No. D/4365/AF-96, Revision 2.

Issued with letter to Richard W. Boyle, U.S. Department of Transportation,
on August 3, 2015.