January 12, 2010

Mr. Richard Boyle, Chief
Radioactive Materials Branch
Office of Hazardous Materials
Technology
U.S. Department of Transportation
400 Seventh Street, S.W.
Washington, DC 20590

SUBJECT: REVALIDATION OF THE MODEL NO. NCS-45 PACKAGE, GERMAN PACKAGE DESIGN CERTIFICATE NO. D/4347/B(U)F-96, REV. 0

Dear Mr. Boyle:

This refers to your request dated January 22, 2009, for a recommendation concerning the revalidation of the Model No. NCS 45 package, German Certificate of Approval No. D/4347/B(U)F-96, Revision 0.

Based on our review, the statements and representations contained in the application, as supplemented, and for the reasons stated in the enclosed Safety Evaluation Report, we recommend revalidation of German Package Design Certificate No. D/4347/B(U)F-96, Rev. 0, dated December 4, 2008, with the following conditions:

(1) irradiated intact PWR rods, full length fuel rods with cladding failures (damaged fuel rods) provided that the damaged rods are enclosed in sealed cans, or solid irradiated structural materials (for example top nozzles, fuel rod tubes, contaminated parts from hot cells, etc…). In all cases, the combined payload shall not exceed 75 Kg per package;

(2) the allowable burnup and enrichment combination shall satisfy the limits as specified in Table 1;

(3) the allowable burnup and cooling times shall satisfy the limits specified in Table 2;

(4) each fuel rod with an average burnup greater than 45 GWd/MTU must be placed in a sealed can (fuel above 45 GWd/MTU should be treated as damaged fuel due to the unknown property of high burnup fuel);

(5) graphite and beryllium in any form are prohibited in the package;

(6) the package shall not be used for air transport;

(7) each package must be pressurized with pure Helium 4.6 (purity 99.996 or better) to mitigate the potential for cladding oxidation;

(8) content 1 is limited to a maximum number of fuel rods of 29, fuel rod diameters must be within the range of 0.6 to 1.2 cm, and maximum active fuel rod length is limited to a maximum of 390 cm; and

(9) contents 1.2 and1.3 are limited to a maximum fissile material distribution of 17.0 g/cm.

Table 1 – Allowable enrichment/burnup combination for contents of NCS 45 irradiated fuel package

| Enrichment (wt.% U-235) | Average Burnup (GWd/MgU) |
|---|---|
| 1.0 | 10 |
| 1.7 | 20 |
| 2.4 | 30 |
| 3.1 | 40 |
| 3.7 | 50 |
| 4.5 | 60 |
| 5.3 | 80 |
| 5.3 | 100 |
| 5.3 | 120 |

Table 2 – Allowable contents of NCS 45 irradiated fuel package (kg)

| | Minimum Cooling time (days) | | | | | |
|---|---|---|---|---|---|---|
| Maximum Burn-up GWd/MgU | 120 | 180 | 365 | 730 | 1825 | 3650 |
| 10 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 |
| 20 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 |
| 30 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 |
| 40 | 64.0 | 70.0 | 75.0 | 75.0 | 75.0 | 75.0 |
| 50 | 40.0 | 46.0 | 53.0 | 63.0 | 75.0 | 75.0 |
| 60 | 30.0 | 32.0 | 37.5 | 44.0 | 53.0 | 65.0 |
| 80 | 15.3 | 16.3 | 17.7 | 19.8 | 23.4 | 28.5 |
| 100 | 6.7 | 6.9 | 7.5 | 8.3 | 10.2 | 13.2 |
| 120 | 2.7 | 2.8 | 3.1 | 3.5 | 4.9 | 6.9 |

If you have any questions regarding this matter, I may be contacted at (301) 492-3394 or you may contact Chris Staab at (301) 492-3321.

Sincerely,

**/RA/**

Eric Benner, Chief
Licensing Branch
Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-3084
TAC No. L24301
Enclosure: 1. Safety Evaluation Report
2. Table of TS-R-1 2005 General Requirements for Packages
cc: J. Shuler, Department of Energy

January 12, 2010

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Radioactive Materials Branch
Office of Hazardous Materials
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(1) irradiated intact PWR rods, full length fuel rods with cladding failures (damaged fuel rods) provided that the damaged rods are enclosed in sealed cans, or solid irradiated structural materials (for example top nozzles, fuel rod tubes, contaminated parts from hot cells, etc…). In all cases, the combined payload shall not exceed 75 Kg per package;

(2) the allowable burnup and enrichment combination shall satisfy the limits as specified in Table 1;

(3) the allowable burnup and cooling times shall satisfy the limits specified in Table 2;

(4) each fuel rod with an average burnup greater than 45 GWd/MTU must be placed in a sealed can (fuel above 45 GWd/MTU should be treated as damaged fuel due to the unknown property of high burnup fuel);

(5) graphite and beryllium in any form are prohibited in the package;

(6) the package shall not be used for air transport;

(7) each package must be pressurized with pure Helium 4.6 (purity 99.996 or better) to mitigate the potential for cladding oxidation.

(8) content 1 is limited to a maximum number of fuel rods of 29, fuel rod diameters must be within the range of 0.6 to 1.2 cm, and maximum active fuel rod length is limited to a maximum of 390 cm; and

(9) contents 1.2 and1.3 are limited to a maximum fissile material distribution of 17.0 g/cm.

Table 1 – Allowable enrichment/burnup combination for contents of NCS 45 irradiated fuel package

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| 5.3 | 100 |
| 5.3 | 120 |

Table 2 – Allowable contents of NCS 45 irradiated fuel package (kg)

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| 20 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 |
| 30 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 |
| 40 | 64.0 | 70.0 | 75.0 | 75.0 | 75.0 | 75.0 |
| 50 | 40.0 | 46.0 | 53.0 | 63.0 | 75.0 | 75.0 |
| 60 | 30.0 | 32.0 | 37.5 | 44.0 | 53.0 | 65.0 |
| 80 | 15.3 | 16.3 | 17.7 | 19.8 | 23.4 | 28.5 |
| 100 | 6.7 | 6.9 | 7.5 | 8.3 | 10.2 | 13.2 |
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Docket No. 71-3084
TAC No. L24301
Enclosure: 1. Safety Evaluation Report
2. Table of TS-R-1 2005 General Requirements for Packages

cc: J. Shuler, Department of Energy

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| **NAME:** | CStaab | | JPiotter | | NJordan | | ZLi | | CBajwa | | MGordon |
| **DATE:** | 1/4/2010 | | 1/6/2010 | | 1/12/2010 | | 1/4/2010 | | 1/5/2010 | | 1/6/2010 |
| **OFC:** | SFST | | SFST | | SFST | | SFST | | SFST | | SFST |
| **NAME:** | MWaters | | CCook | | LCampbell | | MDeBose | | EBenner | | |
| **DATE:** | 1/8/2010 | | 1/12/2010 | | 1/12/2010 | | 1/12/2010 | | 1/12/2010 | | |

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SAFETY EVALUATION REPORT
Docket No. 71-3084
Model No. NCS 45 Package
German Package Design Certificate No. D/4347/B(U)F-96
Revision 0


**Summary**

The Department of Transportation (DOT) requested NRC's recommendation concerning the revalidation of the Model No. NCS 45 package, German Package Design Certificate No. D/4347/B(U)F-96, Rev. 0. The package is currently licensed under TS-R-1 Rev 2005 by the German Competent authority. The package is designed to transport a variety of spent fuel rods, components, and fuel debris. The rods can have a burnup up to 120 GWd/MTU. Fuel containing gadolinium is allowed but beryllium and graphite is recommended to be prohibited from the package. The package will be used for sea, road, rail, and inland waterway transport, but is recommend not to be permitted for air transport

Based on the statements and representations in the application, as supplemented, the NRC recommends revalidation of the German Package Design Certificate No. D/4347/B(U)F-96, Rev. 0, for use in the United States, with the following conditions:

(1) irradiated intact PWR rods, full length fuel rods with cladding failures (damaged fuel rods) provided that the damaged rods are enclosed in sealed cans, or solid irradiated structural materials (for example top nozzles, fuel rod tubes, contaminated parts from hot cells, etc…). In all cases, the combined payload shall not exceed 75 Kg per package;

(2) the allowable burnup and enrichment combination shall satisfy the limits as specified in Table 1;

(3) the allowable burnup and cooling times shall satisfy the limits specified in Table 2;

(4) each fuel rod with an average burnup greater than 45 GWd/MTU must be placed in a sealed can (fuel above 45 GWd/MTU should be treated as damaged fuel due to the unknown property of high burnup fuel);

(5) graphite and beryllium in any form are prohibited in the package;

(6) the package shall not be used for air transport;

(7) each package must be pressurized with pure Helium 4.6 (purity 99.996 or better) to mitigate the potential for cladding oxidation.

(8) content 1 is limited to a maximum number of fuel rods of 29, fuel rod diameters must be within the range of 0.6 to 1.2 cm, and maximum active fuel rod length is limited to a maximum of 390 cm; and

(9) contents 1.2 and1.3 are limited to a maximum fissile material distribution of 17.0 g/cm.

Table 1 – Allowable enrichment/burnup combination for contents of NCS 45 irradiated fuel package

| Enrichment (wt.% U-235) | Average Burnup (GWd/MgU) |
|---|---|
| 1.0 | 10 |
| 1.7 | 20 |
| 2.4 | 30 |
| 3.1 | 40 |
| 3.7 | 50 |
| 4.5 | 60 |
| 5.3 | 80 |
| 5.3 | 100 |
| 5.3 | 120 |

Table 2 – Allowable payload of NCS 45 irradiated intact PWR fuel rod package (kg)

| | Minimum Cooling time (days) | | | | | |
|---|---|---|---|---|---|---|
| Maximum Burn-up GWd/MgU | 120 | 180 | 365 | 730 | 1825 | 3650 |
| 10 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 |
| 20 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 |
| 30 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 |
| 40 | 64.0 | 70.0 | 75.0 | 75.0 | 75.0 | 75.0 |
| 50 | 40.0 | 46.0 | 53.0 | 63.0 | 75.0 | 75.0 |
| 60 | 30.0 | 32.0 | 37.5 | 44.0 | 53.0 | 65.0 |
| 80 | 15.3 | 16.3 | 17.7 | 19.8 | 23.4 | 28.5 |
| 100 | 6.7 | 6.9 | 7.5 | 8.3 | 10.2 | 13.2 |
| 120 | 2.7 | 2.8 | 3.1 | 3.5 | 4.9 | 6.9 |

**1.0 General Information**

The TS-R-1 regulations with issues relevant to this cask with respect to general information are listed in the table in the appendix.

Engineering drawings are provided in the Safety Analysis Report (SAR).

A description of the contents is provided in the SAR and coincides with the contents approved on the German Package Design Certificate No. D/4347/B(U)F-96, Rev. 0. Contents as allowed by the German certificate is natural or enriched uranium oxide in the form of fuel rods, fuel rod sections, pellets, pellet scraps, and powders limited to uranium oxide and Gadolinium in the form of $Gd_2O_3$, for contents 1.1, 1.2, 1.3, 1.4, and 1.5. Activated structural materials, cladding tubes, and surface contaminated parts from hot cells make up Contents 5.1.

A description of the packaging is provided and consists of a main body, trunnions, lid and bottom plug, shock absorber, seals, and containment system.

1.1 Findings

Based on review of the statements and representations in the application, the staff concludes the design has been adequately described and evaluated to meet the IAEA requirements of TS-R-1 Rev. 2005.

**2.0 Structural Evaluation**

The package has a double walled austenitic stainless steel body. Between the walls are lead shielding and a cement thermal insulator. The cement layer also serves as a neutron shielding. Four stainless steel trunnions are bolted to the body. The top and bottom have stainless steel bolted closures using double EPDM polymer o-rings. The lid includes a tungsten shield. The package contains no neutron absorbers for criticality control. There is a variety of baskets (centering frames) that can be used with the package. The design of the basket, constructed from austenitic stainless steel, is dependent on the contents of the package.

The impact limiters (shock absorbers) are constructed of balsa and spruce wood contained in a stainless steel shell. There is an aluminum plate at the ends of the impact limiters to protect the limiters from damage due to direct loads. The shock absorbers are attached to the package with six clamp bolts.

The TS-R-1 regulations with structural issues relevant to this package are listed in the table in the appendix. The ability of this package to meet these regulations is also in the table in noted the table.

2.1 Structural Findings

Staff reviewed the findings of the German competent authority as well as the Safety Analysis Report prepared by the applicant and compared the conclusions drawn with the applicable regulations provided in TS-R-1, 2005. Staff verified that appropriate calculations or analyses were performed and verified that the margins of safety provided reasonable assurance that the package would perform as intended.

Based on review of the statements and representations in the application, the staff concludes that the structural design has been adequately described and evaluated and that the package has adequate structural integrity to meet the IAEA requirements of TS-R-1 Rev. 2005.

2.2 Materials Evaluation

The applicant states in the SAR that the packaging materials will be able to withstand the tests under Normal Conditions of Transport and Hypothetical Accident Condition as specified in TS-R-1. The applicant demonstrated via tests that the, stainless steel, lead, cement, and tungsten layers will not change significantly their geometric shapes. The applicant however assumes that the concrete layer will be lost under Hypothetical Accident Conditions in terms of shielding analysis, i.e., the applicant takes no credit for the cement layer for neutron shielding for package under Hypothetical Accident Conditions.

The applicant states that the cement layer will retain its capability for thermal insulation because fire test result has shown that the cement layer is capable of surviving the fire test as prescribed in TS-R-1, paragraph 728, though the cement may lose some materials due to spalling.

The TS-R-1 regulations with materials issues relevant to this package are listed in the table in the appendix. The ability of this package to meet these regulations is also noted in the table.

2.3 Materials Findings

Based on review of the statements and representations in the application, the staff concludes that the materials aspects of the design have been adequately described and evaluated and the package meets the IAEA requirements of TS-R-1 Rev. 2005.

## 3.0 Thermal Evaluation

The purpose of the thermal review is to verify that the package design satisfies the thermal safety requirements of the IAEA Regulations for the Safe Transport of Radioactive Material, TS-R-1. The staff review included the evaluation of the materials, drawings, assumptions, and calculations listed in the thermal safety analysis portions of the revalidation request.

The package has a double walled austenitic stainless steel body. The walls encase lead shielding and a cement thermal insulator. Four stainless steel trunnions are bolted to the body. The top and bottom have stainless steel bolted closures using double EPDM polymer o-rings. The lid includes a tungsten shield. The package contains no neutron absorbers for criticality control. There is a variety of baskets (centering frames) that can be used with the package. The design of the basket, constructed from austenitic stainless steel, is dependent on the contents of the package.

3.1. Thermal Design

The NCS 45 is designed to meet the IAEA requirements for both normal conditions of transport (NCT), both hot and cold, and hypothetical accident conditions (HAC), as described in paragraphs 651, 654, and 655 of TS-R-1. The design of the package is described in the NCS report, NCS0017, Parts 0-11.

The decay heat load proposed by the applicant ranges from 7 W to 3 kW, depending on whether the package is shipped within an ISO container, and what cavity fill gas is employed. The maximum decay heat allowed with air in the cavity is 750 W, while the maximum allowed with helium in the cavity is 3 kW. The applicant has evaluated the package while exposed to solar insolation by applying an insolation load per IAEA TS-R-1, paragraph 654.

The applicant has demonstrated, by analysis of the package design, that the decay heat of the contents will not have any impact on the required performance of the containment and shielding systems of the package if the package were to remain unattended for one week, in accordance with IAEA TS-R-1, paragraph 651.

In accordance with IAEA TS-R-1, paragraph 653, the temperature of any accessible surfaces of the package (during transport) does not exceed 85°C.

For HAC conditions, described in IAEA TS-R-1, paragraph 728, the performance of the containment and the shielding remain unchanged, according to the applicant’s analysis.

3.2. Package Analysis

The applicant conducted an analysis of the NCS 45 using a 2 dimensional model in the HEATING7 thermal code. This code was developed by Oak Ridge National Laboratory as part of the SCALE suite of analysis codes for radioactive material package designs.

The applicant's model was reviewed by the German competent authority (BAM) and the results were verified by a BAM confirmatory thermal model using the ANSYS FEA code (v11).

A number of simplifications were made by the applicant in the thermal model, including a simplification of the contents for the NCS 45. The basket and fuel contents were modeled as a series of ring shaped heat sources as well as a one central heat source.

Heat transfer from the package surface was modeled as radiation and convection, with the values for convection being calculated in accordance with IAEA TS-R-1 paragraph 728.

The maximum temperatures for NCT and HAC conditions reported by the applicant are summarized in Table 3 below. The containment gaskets and lead shielding remain below its limits. All other component temperatures are below their specified limits as well, with the exception of the thermal insulation (cement) during the HAC condition. The thermal insulation serves a sacrificial purpose of protecting the package during the fire. Shielding considerations have been taken into account as well and the performance of this thermal shield has been evaluated as part of the shielding review offered in Section 5.0.

Table 3

**NCS 45 Package Analysis Temperature Results (Reported for Centrally Located Heat Source)**

| **Component/ Position** | | **NCT (°C)** | | **Maximum HAC (°C)** | | **Limit (°C)** | |
|---|---|---|---|---|---|---|---|
| | | 3000 W[1] (Helium fill) | 750 W (Air fill) | 3000 W (Helium fill) | 750 W (Air fill) | NCT | HAC |
| Package Surface (middle) | | 88 | 47 | 671 | 665 | 100 | |
| Impact Limiter (lid side) | | 57 | 39 | 793 | 793 | 100 | n/a[2] |
| Lid Gasket (top side) | | 86 | 48 | 145 | 128 | 150 | 204 |
| Lid Gasket (bottom side) | | 96 | 50 | 145 | 126 | | |
| Lead | Inside | 101 | 50 | 221 | 198 | 164 | 327 |
| | Outside | 98 | 49 | 219 | 198 | | |
| Thermal Insulation – Cement (outside) | | 88 | 47 | 641 | 634 | 100 | 573 |
| Contents (center) | | 364 | 220 | 411 | 277 | 400 | 570 |

[1] with solar insolation
[2] Impact limiter material (wood) is assumed to be consumed in the HAC fire.

The applicant also addressed inhomogeneous or "short" heat sources to account for variations in spent PWR and BWR burn-up profiles or fuel rods from fast breeder reactors. These analyses provided the highest temperatures for the contents (387°C for helium backfill at 3000 W and 397°C for air backfill at 750 W heat load). While this is still within the limits prescribed by the applicant, it is generally recommended by the staff that spent fuel assemblies be shipped in a pure helium environment to mitigate the potential for cladding oxidation.

### 3.3. Conclusions

The staff finds that the NCS 45 generally meets the requirements for thermal performance outlined in IAEA TS-R-1 for the transportation of radioactive materials, and the staff has reasonable assurance that the package will perform as designed for shipments made in accordance with the applicable Certificate of Compliance.

A summary of the TS-R-1 requirements related to the thermal performance of the NCS 45 package, along with the staff's findings, is provided in the table in the appendix.

## 4.0 Containment Evaluation

The purpose of the containment review is to verify that the package design satisfies the containment safety requirements of the IAEA Regulations for the Safe Transport of Radioactive Material, TS-R-1. The staff review included the evaluation of the materials, drawings, assumptions, and calculations listed in the containment safety analysis portions of the revalidation request.

This is a DOT revalidation of a German type B(U)f package licensed under TS-R-1, Rev. 2005, by the German Competent authority. The package is designed to transport a variety of spent fuel rods, components, and fuel debris. The rods can be damaged or undamaged, and can have a burnup up to 120 GWd/MTU. Fuel above 45 GWd/MTU and damaged fuel must be placed in a sealed can. Fuel containing gadolinium is allowed but beryllium and graphite is specifically prohibited. The package will be used for sea, road, rail, and inland waterway transport, but not for air transport.

The package has a double walled austenitic stainless steel body. Between the walls are lead shielding and a cement thermal insulator. Four stainless steel trunnions are bolted to the body. The top and bottom have stainless steel bolted closures using double EPDM polymer o-rings. The lid includes a tungsten shield and the flange of the top lid is closed with 18 bolts at a torque of 50 Nm (36 ft-lbs). The package contains no neutron absorbers for criticality control. There is a variety of baskets (centering frames) that can be used with the package. The design of the basket, constructed from austenitic stainless steel, is dependent on the contents of the package.

### 4.1. Containment Design

The containment system of the NCS 45 is described in Section 3.10 of report NCS 0017, Rev. 3, and is made up of the components listed below, which are numbered to correspond to the locations in Figure 1.

- The inner tube (vessel), including the head piece and foot piece of the packaging main body and the connecting welds (1)
- The flange of the top lid plug with associated inner seal and bolts (2)
- The rotary lock lid with associated inner seal and bolts (3)

- 
- The coupling lid with associated inner seal and bolts (4)
- The rotary lock driving lid with associated inner seal and bolts (5)
- The flange of the bottom lid with associated inner seal and bolts (6)
- The discharge lid plug with associated inner seal and bolts (7)

Note that item 5 above is not explicitly shown in Figure 1 (but can be viewed in Drawing # 0-150-151-03-00), so the approximate location of this component is provided:

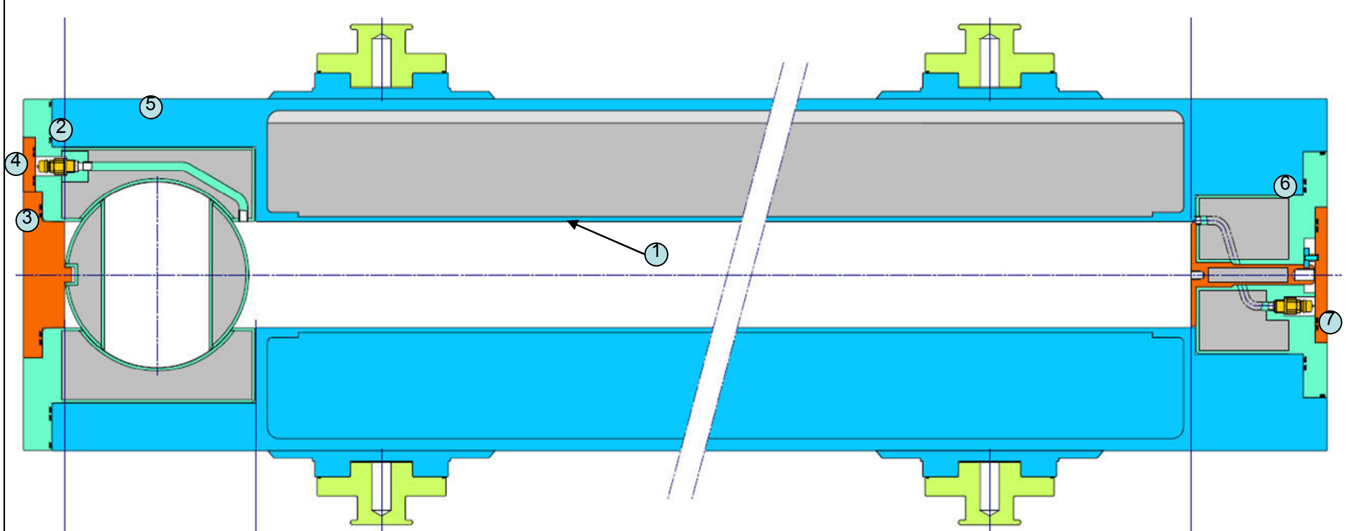


Figure 1 – Containment Boundary for NCS 45

4.2 Seal Performance

Maximum seal temperatures were evaluated and reported by the applicant in Table 5-18 of report NCS 0017, Rev. 3. All seal temperatures for NCT (hot and cold) and HAC exposures were within limits. The applicant states that the EPDM gasket material will perform as needed to a temperature of -40°C, as required by IAEA TS-R-1, paragraph 637. Based on this, the staff has reasonable assurance that the seals will perform as designed for all transport conditions described in IAEA TS-R-1.

The results of the HAC mechanical tests described in Chapter 4 of report NCS 0017, Rev. 4, were reviewed by the staff, and it was determined that the package would remain leak-tight under those conditions. The applicant reported the results of leak tests following the drop tests in Section 4.5.3.6 (Table 4-47) in NCS 0017, Rev. 4.

The staff also reviewed the leak testing procedure (PA-02-06) for the NCS 45. Tests are carried out for fabrication (final inspection), periodic inspections, and after loading of the package. Tests can be helium leakage tests, pressure drop tests, and pressure rise/soap bubble tests. The applicant specifies which tests are applicable and how the results of each test should be evaluated in the procedure.

The leak tightness requirement (described in Section 6.9 of the procedure) is specified as the following:

For the packaging: <1.0 x $10E^{-5}$ Pa $m^3$ $s^{-1}$
For the fabrication of the canister: <1.0 x $10E^{-8}$ Pa $m^3$ $s^{-1}$
For the lid plug and bottom plug: <5.0 x $10E^{-6}$ Pa $m^3$ $s^{-1}$

The acceptance criteria are in accordance with the requirements of IAEA TS-R-1, paragraph 502. The staff recommends these leak testing limits and leak testing procedure (PA-02-06) be required for shipments in the U.S.

The staff found that the procedure provided a reasonable summary of the tests to be conducted in order to ensure that the package containment envelope will be meet the requirements of IAEA TS-R-1, paragraphs 501 and 502.

4.3 Conclusions

The staff's review of the NCS 45 package has determined that there is reasonable assurance that the package, if assembled, loaded, sealed, and tested in accordance with the applicable Certificate of Compliance, will meet the containment requirements outlined in IAEA TS-R-1.

A summary of the TS-R-1 requirements related to the containment performance of the NCS 45 package, along with the staff's findings, is provided in the table in the appendix.

## 5.0 Shielding Evaluation

The purpose of the shielding review is to ensure that the package design meets the radiation limits set forth in the IAEA's regulations for radioactive materials transportation, TS-R-1. The review includes evaluation and verification of the applications shielding calculations contained in the section of the Safety Analysis Report (SAR) titled "Dose Rate Calculation" as well as descriptions of the design and technical drawings contained in the SAR.

The D/4347/B(U)F-96 is designed for the transportation of irradiated uranium oxide in the form of fuel rods, fuel rod sections, pellets, as well as pellet scraps. For the use of this package in the U. S., the allowable contents are limited to PWR fuel rods only as evaluated. Graphite or Beryllium is not allowed in the package. The maximum burnup is 120 GWd/MTU for enrichment greater than 5.3% and 10 GWd/MTU for enrichment not less than 1.0%.

The package shielding design consists of concentric cylindrical stainless steel, lead, cement, and stainless steel shells in the radial direction. Stainless steel, lead, and tungsten are used to provide shielding at the top (lid) and the bottom of the package. The packaging is open at both ends. Open ends of the body are closed by lid and bottom plugs using screwed flanges. Impact limiters are constructed of balsa and spruce wood in a stainless steel shell and fastened to the ends of the package main body by 6 cylinder head screws. The package has four trunnions to accommodate handling of the package; two are attached at each end of the package.

The package consists of a payload cavity of maximum length of 462.5 cm and diameter of 22 cm, with either guide tubes to support fuel rods and/or a center axial cavity to axially align materials welded in cans. PWR fuel rods with maximum burnup of 120 GWd/MTU and a minimum 120 day cooling time are admissible contents. The maximum payload is 75kg, which may have heavy metal or combination of heavy metal and fuel assembly structural materials. The contents with burnup less than 45 GWd/MTU are not required to be placed in welded cans unless other condition(s) requires doing so.

The TS-R-1 regulations related to radiation shielding of this package design are listed in the table below as well as the ability of this package to meet these regulations. The applicant used CE16x16 PWR fuel assembly configuration for source term calculations. This is inconsistent with the intended contents, i.e., V C Summer or Vogtle fuel assemblies; both use Westinghouse 17x17 fuel assembly. This practice is in general considered not acceptable.

In addition, since the applicant used the SAS2H code way beyond its validated range, i.e., 45 GWd/MTU for PWR fuel assembly depletion analysis, additional quantified uncertainties may have been included in the source term calculation. As such, the results may be highly unreliable. Hence, use of the SAS2H code beyond its validated range is general not acceptable.

However, since the content is further reduced by 25% (comparing with original 100 Kg payload), the staff considers this limit on content will compensate the errors in source term calculations that were introduced by using incorrect fuel assembly design and code beyond its validated range. As such, the staff considers the shielding evaluation acceptable. However, more detailed review would have been performed without this significant reduction of payload.

5.1 Shielding Findings

The staff reviewed the information presented in the SAR on the package design. The maximum dose rate under Normal Conditions of Transport is 1810 μSv at the surface of the package and 89.1 μSv at 2 meters from the surface of the package. The maximum dose rate under Hypothetical Accident Conditions is 790 μSv at 1 meter from the surface of the package. Based on the information and presentation provided in the SAR and responses to the RAI, the staff finds that the package designs meets the shielding safety requirements of TS-R-1 and recommends the Department of Transportation approve the NCS 45 package design.

In addition, the staff recommends that any fuel with burnup greater than 45 GWd/MTU should be sealed in welded cans and treated as damaged fuels because of the unknown property of the high burnup fuels.

A summary of the TS-R-1 requirements related to the shielding performance of the NCS 45 package, along with the staff's findings, is provided in the table in the appendix.

**6.0 Criticality Evaluation**

The purpose of the criticality review is to verify that the package design satisfies the criticality safety requirements of the IAEA Regulations for the Safe Transport of Radioactive Material, TS-R-1. The staff review included the evaluation of the materials, drawings, assumptions, and calculations listed in the criticality safety analysis portion of the Safety Analysis Report (SAR).

The NCS 45 type B(U) cask is designed for the transportation of uranium oxide material. The cask consists of cylindrical main body with a lid plug and shield plug. The cask also has two impact limiters for shock absorption and four trunnions for handling operations. The cask is credited with remaining leaktight during normal and accident conditions specified in the SAR.

The allowable content is natural or enriched uranium oxide in the form of fuel rods as specified in the SAR. The allowable contents are limited to uranium oxide and Gadolinium in the form of $Gd_2O_3$, for contents 1.1, 1.2, 1.3, 1.4, and 1.5.

Activated structural materials, cladding tubes, and surface contaminated parts from hot cells that make up contents 5.1 are also allowable content. Mixed loading of Content 1 among each other as well as with Content 5 is not admissible. In addition, graphite or beryllium is not allowed in the inner cask volume.

For the Content 1 and Content 5 material, the following applies Table 4:

Table 4

| | wt.% U-235 | Mass of fissile Material | Max. Burnup GWd/MgU |
|---|---|---|---|
| Content 1.1 | 5.3 | 16.4 g U-235/cm<br>max. 4.0 kg U-235 | 120 |
| Content 1.2 | 5.3 | max. 4.0 kg U-235 | 120 |
| Content 1.3 | 5.3 | max. 1380 g U-235 | 120 |
| Content 1.4 | 3.4 | max. 6.5 kg U-235 | 62 |
| Content 1.5 | 7.0 | max. 5.25 kg U-235 | 120 |
| Content 5.1[a] | 7.0 | max. 3000 $A_2$ | 120 |

[a]Consist of structural materials, cladding tubes of fuel assemblies, and surface contaminated parts from hot cells.

The following assumptions were applied in the criticality safety analysis:

- Water in-leakage was assumed for accident conditions
- Fuel rods were modeled without cladding material which allows more water to be modeled between fuel
- Trunnions and shock absorbers were disregarded in the criticality safety analysis models which would allow more water to be included.
- In some cases, an axial infinite cylinder was assumed.
- The models were based on the pre-irradiated content specifications

The TS-R-1 regulations relevant to the criticality safety aspects of the NCS 45 cask are listed in the table in the appendix as well as the ability of this cask to meet these regulations.

6.1 Criticality Findings

With the exception of the conservative assumptions used by the applicant, NRC staff does not agree the methodology used in the criticality analyses portion of the SAR. The criticality analysis performed as part of this package included the use of an earlier version of SCALE. The applicant did state that they successfully verified the results using SCALE 5 on their system with the results of the referenced output files. However in comparing the results from Section 8 of NCS 0017, Rev. 3 with confirmatory calculations performed by NRC staff using the most currently issued version of the SCALE code (SCALE 6), it was determined that the results obtained by NRC staff were higher in most cases involving variations in array pitch for approved contents 1.2 and 1.3. It is stated in the SAR that the applicant used inhommedium in the HET cases. However, the system that was modeled involves smaller diameter cylindrical rods in a hexagonal configuration. It is the view of NRC staff that a lattice cell structure would have yielded more accurate results. In addition, the applicant stated in Section 8.5.3.1 of NCS 0017, Rev. 3 that Dancoff factors were used from previous CSASN calculations. The reviewer was not able to verify that the Dancoff factors used were appropriate for this set of analyses. However, confirmatory calculations were performed that show that fissile material, in the configurations discussed in Section 8 of the SAR, were subcritical.

In addition, NRC staff found that in some cases where fissile material distribution was optimized that the most reactive case was that involving the maximum cylindrical diameter (e.g. 18 cm). Plots supplied showing the results (e.g. Figure 1 from the RAI Responses) did not adequately show that the system was undermoderated. NRC staff generated additional calculations which yielded only minor increases in the reactivity for the scenario in question.

The conservative assumptions used in the criticality analyses are described in more detail in Section 8 of the SAR. NRC staff performed a number of additional cases as part of the review. Confirmatory analyses performed by NRC staff were performed using the Latticecell cell data option in SCALE 6.0 to compare results generated in Inhommedium. Although the reactivity for some cases involving Content 1 material exceeded 0.94, the applicant considered a number of conservative assumptions in their criticality analysis. As stated in telephone discussions with the applicant, the cask is credited with remaining leaktight during normal and accident conditions as described in the SAR. As part of the criticality analysis the applicant used assumptions such as excluding the cladding material in the analysis, assuming flooding conditions within the cask cavity, and considering fissile material distribution in excess of that limited in the content specification portion of the SAR. However, in some cases corresponding to Content 1.2, 1.3, and 1.4 the highest reactivity occurred for fissile material distributions between 26 $g/cm^3$ and 28.2 $g/cm^3$. Furthermore, analyzing these models in a newer version of SCALE with the appropriate Dancoff factors may yield higher results than those submitted in the SAR. During further discussion, the applicant stated that fissile material proposed in the revalidation will be transported with the following specifications in Table 5:

Table 5

| | |
|---|---|
| Maximum number of rods | 29 |
| Fuel pellet diameter range (cm) | 0.6 to 1.2 |
| Nominal Fuel Height (cm) | 390 |

Using the above parameters, additional analysis was performed to evaluate the reactivity effects as a result of having the 29 rods in the cask cavity. In the analysis 61 rods were used, more than twice the allowable amount, and each rod was modeled at a height of 390 cm. The analysis covered diameters 0.6, 0.8, 1.0, and 1.2 cm. The rods were modeled in a hexagonal close-packed array with infinite reflection in the axial direction. The analysis involved adjusting the pitch between fuel rods until the point of optimum moderation could be determined. The most reactive case was identified for a rod diameter of 1.2 cm. The bounding reactivity for this case was 0.9348, which was consistent with the trend developed in earlier results.

As part of the review, it was also determined that using the 1.2 cm pellet diameter with the 5.3 wt.% enrichment yields 0.58 g/cm U-235 axially. A total fissile material distribution of 17 g/cm corresponds to approximately the maximum number of rods proposed in the package (29 rods).

Therefore NRC staff recommends revalidation of the package under the following conditions for Content 1 of the SAR:

| | |
|---|---|
| Max number of fuel rods | 29 |
| Fuel rod diameters from | 0.6 to 1.2 cm |
| Max active fuel rod length | 390 cm |
| Max. fissile material distribution for Content 1.2 and 1.3 | 17.0 g/cm |

Based on review of the statements and representations in the application, and the responses to the RAIs, the staff concludes that the design has been adequately described and evaluated and that the package meets the IAEA requirements of TS-R-1 Revision 2005.

## 7.0 Operating Procedures and Maintenance

The TS-R-1 regulations with issues relevant to this cask with respect to package operations, acceptance tests, and maintenance program are listed in the table in the appendix.

Operating Procedures are provided as Handling Instruction No. HA-02-06 of the SAR. Loading and unloading instructions are provided. Torque instructions, thread inspection requirements, drying test instructions, contamination and dose rate measurement requirements, and temperature measurement requirements are provided.

Leak testing of the containment boundary is required prior to shipment. After loading, the package must be leak tested according to procedure HA-02-06 specified in the German certificate of package approval additional clause No. 4 to have a leakage rate of less than 10E-5 Pa $m^3$/s.

The Trunnion screws and threads are checked completely after manufacture and periodically in accordance with Test Procedure No. WP-02-02 of the SAR. Load testing is required per Test Procedure No. PA-02-04 of the SAR. The load test includes an inspection of the three highest stressed screws in addition to two randomly chosen screws before and after the load test according to Test Instruction No. PA-02-05 Revision 2, Chapter 9.3, of the SAR.

Quality assurance measures for manufacturing of the packaging are regulated in specification No. SB-02-01 of the SAR.

7.1 Findings

Based on review of the statements and representations in the application, the staff concludes the design has been adequately described and evaluated to meet the IAEA requirements of TS-R-1 Rev. 2005.

**Conditions**

The NRC recommends revalidation of the German Package Design Certificate No. D/4347/B(U)F-96, Rev. 0, for use in the United States, with the following conditions:

(1) irradiated intact PWR rods, full length fuel rods with cladding failures (damaged fuel rods) provided that the damaged rods are enclosed in sealed cans, or solid irradiated structural materials (for example top nozzles, fuel rod tubes, contaminated parts from hot cells, etc…). In all cases, the combined payload shall not exceed 75 Kg per package;

(2) the allowable burnup and enrichment combination shall satisfy the limits as specified in Table 1;

(3) the allowable burnup and cooling times shall satisfy the limits specified in Table 2;

(4) each fuel rod with an average burnup greater than 45 GWd/MTU must be placed in a sealed can (fuel above 45 GWd/MTU should be treated as damaged fuel due to the unknown property of high burnup fuel);

(5) graphite and beryllium in any form are prohibited in the package;

(6) the package shall not be used for air transport;

(7) each package must be pressurized with pure Helium 4.6 (purity 99.996 or better) to mitigate the potential for cladding oxidation.

(8) content 1 is limited to a maximum number of fuel rods of 29, fuel rod diameters must be within the range of 0.6 to 1.2 cm, and maximum active fuel rod length is limited to a maximum of 390 cm; and

(9) contents 1.2 and1.3 are limited to a maximum fissile material distribution of 17.0 g/cm.

Table 1 – Allowable enrichment/burnup combination for contents of NCS 45 irradiated fuel package

| Enrichment (wt.% U-235) | Average Burnup (GWd/MgU) |
|---|---|
| 1.0 | 10 |
| 1.7 | 20 |
| 2.4 | 30 |
| 3.1 | 40 |
| 3.7 | 50 |
| 4.5 | 60 |
| 5.3 | 80 |
| 5.3 | 100 |
| 5.3 | 120 |

Table 2 – Allowable payload of NCS 45 irradiated intact PWR fuel rod package (kg)

| | Minimum Cooling time (days) | | | | | |
|---|---|---|---|---|---|---|
| Maximum Burn-up GWd/MgU | 120 | 180 | 365 | 730 | 1825 | 3650 |
| 10 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 |
| 20 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 |
| 30 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 | 75.0 |
| 40 | 64.0 | 70.0 | 75.0 | 75.0 | 75.0 | 75.0 |
| 50 | 40.0 | 46.0 | 53.0 | 63.0 | 75.0 | 75.0 |
| 60 | 30.0 | 32.0 | 37.5 | 44.0 | 53.0 | 65.0 |
| 80 | 15.3 | 16.3 | 17.7 | 19.8 | 23.4 | 28.5 |
| 100 | 6.7 | 6.9 | 7.5 | 8.3 | 10.2 | 13.2 |
| 120 | 2.7 | 2.8 | 3.1 | 3.5 | 4.9 | 6.9 |

**Conclusion**

Based on the statements and representations contained in the application, the staff concludes the Model No. NCS 45 package design, with the above stated conditions meets the IAEA requirements of TS-R-1 Rev. 2005.

Issued with letter to R. Boyle, Department of Transportation,
on January 12, 2010.