SAFETY EVALUATION REPORT

Docket No. 71-9319
Model Nos. MAP-12 and MAP-13 Packages
Certificate of Compliance No. 9319
Revision 0

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SUMMARY

By application dated March 13, 2007, as supplemented October 24, December 6 and 14, 2007, AREVA NP, Inc. (AREVA or the applicant), requested the U.S. Nuclear Regulatory Commission (NRC) to approve the Model Nos. MAP-12 and MAP-13 packages (MAP package). The MAP package is designed to transport two unirradiated uranium fuel assemblies with enrichment up to 5.0 weight percent (wt%). The MAP package consists of two essentially identical versions, the Model Nos. MAP-12 and MAP-13. The primary difference is in the length of the packages. The package consists of two basic components: a base and a lid, which includes a strong-back and impact limiters, respectively.

The package was evaluated against the regulatory standards in Title 10 of the Code of Federal Regulations (10 CFR) Part 71, including the general standards for all packages, standards for fissile material packages, and performance standards under normal conditions of transport (NCT) and hypothetical accident conditions (HAC). Staff reviewed the application using the guidance in NUREG-1609, "Standard Review Plan for Transportation Packages for Radioactive Material."

Based on the statements and representations in the application, as supplemented, and the conditions listed in the Certificate of Compliance (CoC), the staff concludes that the design has been adequately described and evaluated and meets the requirements of 10 CFR Part 71.

REFERENCES

Letter to Director, Spent Fuel Project Office, from Richard D. Montgomery, AREVA, NP Inc., application dated March 13, 2007.

Letter to Jessica M. Glenny, Division of Spent Fuel Storage and Transportation, from Richard D. Montgomery, supplements dated October 24, December 6 and 14, 2007.

1.0 GENERAL INFORMATION

1.1 Package Description

The MAP package is designed to transport two unirradiated uranium fuel assemblies with enrichment up to 5.0 wt%. The MAP package consists of two versions: Model Nos. MAP-12 and MAP-13. The primary difference between the two versions is the active fuel length of the payload assembly: the MAP-12 ships nominal active fuel length 144 inches long and the MAP-13 ships nominal active fuel length 150 inches long. The packaging for the two versions is essentially identical with the exception of the package length. The Model No. MAP-12 is 208 inches in length, 45 inches in width, and 31 inches in height. The Model No. MAP-13 is 221 inches in length, 45 inches in width, and 31 inches in height. The maximum gross weight for both versions of the MAP package is 8,630 lbs. Each package can hold up to two PWR fuel assemblies with square lattices of 14 x 14, 15 x 15, 16 x 16, or 17 x 17. The criticality safety index (CSI) is 2.8.

The MAP package consists of two basic components: a base and a lid. The base consists of a fixed stainless steel strong-back which supports the fuel assembly. The lid includes independent impact limiters, constructed from rigid polyurethane foam, at opposite ends of the package. Both the base and the lid include end plates with interfacing, interlocking angles upon assembly.

The containment system for the MAP package is the fuel rod cladding.

Both Type A and Type B materials in the form of unirradiated fuel assemblies will be shipped in the MAP package. The chemical and physical form of the Type A and Type B contents are the same, with the exception of the Type B contents having elevated concentrations of ^{234}U.

The MAP package is primarily constructed from stainless steel, aluminum, and rigid polyurethane foam. Other materials used are fiberglass reinforced resin, refractory insulation, Nylon 6,6, and borated metal matrix composite.

1.2 Contents

The Model Nos. MAP-12 and MAP-13 are designed to transport Type A and Type B materials meeting the limits specified in Table 1-2 of the application. Type A contents of the packaging is fresh unirradiated low enriched uranium pressurized water reactor (PWR) nuclear fuel assemblies. A maximum of two fuel assemblies are placed in each packaging. The fuel pellets, loaded in rods and contained in the packaging, are uranium oxides primarily as ceramic UO_2 and U_3O_8. The fuel assembly maximum enrichment is less than or equal to 5.0 wt% ^{235}U. Loose fuel rods or partial fuel assemblies are not permitted in the MAP package.

The Type B content of the packaging is unirradiated low enriched uranium PWR nuclear fuel assemblies derived from off-specification high enriched uranium or reprocessed uranium. The increase in ^{236}U causes the contents to fall under the Type B requirements. A maximum of two fuel assemblies are placed in each packaging. The fuel pellets, loaded in rods and contained in the packaging, are uranium oxides primarily as UO_2 and U_3O_8. The fuel assembly maximum enrichment is less than or equal to 5.0 wt% ^{235}U.

1.3 Criticality Safety Index

The CSI for the Model Nos. MAP-12 and MAP-13 is 2.8.

1.4 Drawings

The Model Nos. MAP-12 and MAP-13 are fabricated and assembled in accordance with AREVA NP, Inc., Drawing Nos.: 9045393, Sheets 1 & 2, Rev. 0; 9045397, Rev. 0; 9045399, Rev. 0; 9045401, Rev. 0; 9045402, Rev. 0; 9045403, Sheets 1 & 2, Rev. 0; 9045404, Rev. 0; 9045405, Rev. 0.

2.0 STRUCTURAL

2.1 Structural Design

The package consists of two basic components: a base, and a lid. The base consists of a fixed stainless steel strong-back that supports the fuel assembly. The lid includes independent impact limiters at opposite ends of the package. The MAP package is primarily constructed from stainless steel, aluminum, and rigid polyurethane foam. The Model Nos. MAP-12 and MAP-13 are similar in design with the exception of the length of the package. The Model No. MAP-12 is designed to transport fuel 144 inches long and the Model No. MAP-13 is designed to transport fuel 150 inches long. The maximum payload weight, 3,400 lbs, and the gross weight, 8,630 lbs, is the same for both models.

2.2 Materials

A commercial metal-matrix-composite material is to be used as the neutron absorber plate material in MAP packages. AREVA originally termed this material as “borated aluminum,” but replaced this with the term “Boral.” This change was made in a supplement to the application, so as to make the supplement technically correct and to be consistent throughout the Safety Analysis Report (SAR).

The MAP packages use a Nylon 6,6 material. This material has high durability and is sufficient for this application, including its resistance to thermal influences under HAC. Variations in the thickness and density of the Nylon 6,6, material are regarded by staff to be negligible for this application. The use of the nylon material has been modeled in a manner that is regarded as conservative for this application.

2.2.1 Mechanical Properties and Specifications

The material used in the fabrication of the certified test units (CTUs) meets the requirements of 10 CFR Part 71. The neutron absorber plates for the CTUs were fabricated from 1100 aluminum, due to its ability to simulate the mechanical and thermal properties of the Boral material used in neutron absorber plates of the production units. Hence, material properties of the production units compare favorably with properties of the material used in the CTU packages. Other materials in the package are aluminum and rigid polyurethane foam and boron containing absorber material.

2.2.2 Chemical, Galvanic, or Other Reactions

Chemical, galvanic, or other reactions have been considered and the materials of concern are regarded as essentially non-reactive for the environmental conditions expected for this application. Should corrosion or deterioration occur to the stainless steel components of the package, it can be readily detected. The staff finds that no deleterious corrosion or other reactions are anticipated during normal use. The staff finds that the requirements of 10 CFR 71.43(d) are satisfied.

2.2.3 Effects of Radiation on Materials

Since the payload of the MAP package is fresh unirradiated fuel assemblies, radiation from the payload is negligible.

2.3 Fabrication and Examination

Fabrication is conducted using conventional metal forming and welding techniques, with welder qualification and the inspection requirements of AWS D1.2, D1.6, or ASME Section IX being followed for all welding procedure.

Fabrication of the components of the Model Nos. MAP-12 and MAP-13 are specified in AREVA Drawing Nos. 9045393, Sheets 1 & 2, Rev. 0; 9045397, Rev. 0; 9045399, Rev. 0; 9045401, Rev. 0; 9045402, Rev. 0; 9045403, Sheets 1 & 2, Rev. 0; 9045404, Rev. 0; 9045405, Rev. 0;

2.4 General Requirements for All Packages

The staff reviewed the design of the Model No. MAP-12 and MAP-13 for compliance with the general requirements for all packages including (a) minimum size of 4 inches; (b) tamper indicating features; and (c) positive closure. The staff concludes that the Model Nos. MAP-12 and MAP-13 meets the requirements of 10 CFR 71.43.

2.5 Lifting and Tie-Down Standards for All Packages

The MAP package is handled using a forklift truck, interfacing with the integral fork accommodations in the base. The lifting devices are as described in Section 2.5.1 of the application. Adequate safety margins were provided for both shear stress and bending stress in the lifting devices. The MAP-12 and MAP-13 packages are normally transported by flatbed trailer and are to be tied down using passive-contact devices such as load-restraint bars, cargo netting, or over the-top strapping which does not rely on any feature of the MAP package for a tie-down attachment point. Failure of these restraint devices will not impair or reduce the packages ability to perform as required to protect the payload. The staff concludes that the requirements of 10 CFR 71.45(a) and (b)(2) are satisfied.

2.6 Normal Conditions of Transport

2.6.1 Heat

The design of the MAP package does not have any features that could be affected by differential thermal expansion of the package components. The package has negligible internal decay heat, and any temperature differences will arise only from the solar loading, which are relatively small. The staff finds that the requirements of 10 CFR 71.43(g) and 71.71(c)(1) are met.

2.6.2 Cold

The minimum design temperature the package is assumed to encounter under NCT is -40°F. None of the material used for construction of the Model Nos. MAP-12 and MAP-13 packages (i.e., austenitic steel, polyethylene foam, or fiberglass) will undergo ductile-to-brittle transition at temperatures higher than or equal to -40°F. The staff finds that the requirements of 10 CFR 71.71(c)(2) are satisfied.

2.6.3 Reduced External Pressure

The MAP package is not capable of retaining pressure. Therefore the effect of the reduced pressure required by 10 CFR 71.71(c)(3) is negligible. Additionally, the reduced external pressure has no impact on the fuel rod cladding. The staff finds the requirements of 10 CFR 71.71(c)(3) are satisfied.

2.6.4 Increased External Pressure

The material between the lid and base is not capable of sustaining pressure. An increase in external pressure of 20 psia would not affect the MAP package. Therefore, the effect of the increased pressure required by 10 CFR 71.71(c)(4) is satisfied.

2.6.5 Vibrations

The design of the MAP package avoids the use of components sensitive to low vibration frequency. As a result of materials used for the construction of the MAP package, the package is heavily vibrationally damped. The staff finds that the requirements of 10 CFR 71.71(c)(5) have been met.

2.6.6 Water Spray

The exterior of the MAP package is made of ASTM Type 304 stainless steel. The joint between the lid and base has a small, downward facing skirt, which does not allow for the collection of water or admittance of it in the fuel cavity. Any openings into the polyurethane foam are closed with plastic plugs. Thus, the staff finds that the requirements of 10 CFR 71.71(c)(6) are satisfied.

2.6.7 Free Drop

Since the package gross weight is less than 11,000 lbs the applicable free drop is 4 ft. The two orientations tested were the horizontal flat drop on the lid and the 10° slap-down on the base. The damage in each case was modest, and there was no loss or dispersal of the package contents, and no substantial reduction in the effectiveness of the packaging. The staff finds that the requirements of 10 CFR 71.55(d)(4) and 71.71(c)(7) are satisfied.

2.6.8 Corner Drop

The corner drop test as required by 10 CFR Part 71.71(c)(8) does not apply, as the package is not made of fiberboard, and weighs more than 220 lbs.

2.6.9 Compression

As required by 10 CFR 71.71(c)(9), the package must be able to support five times its loaded weight without damage. The sides of the base and lid must withstand 43,150 lbs. The CTU was subjected to the compressive load specified. The staff concludes that the Model Nos. MAP-12 and MAP-13 adequately satisfy the stacking test requirements of 10 CFR 71.71(c)(9).

2.6.10 Penetration

The MAP package was subjected to a penetration test (CTU2) by dropping a bar measured with a diameter of 1.25 inches and 39 inches long with a hemispherical end, weighing at least 13.22 lbs on to the weakest part of the specimen. The package was not damaged by the penetrant test, thus the requirements of 10 CFR 71.71(c)(10) were met.

2.7 Hypothetical Accident Conditions

The package was evaluated, as required by 10 CFR 71.55, for criticality with the inclusion of any damage resulting from the NCT tests, previously mentioned, plus the damage from the HAC tests specified in 10 CFR 71.73. The regulation in 10 CFR 71.73(c)(1) requires the drop of the package onto essentially unyielding surface from a height of 30 ft in the orientation for which maximum damage is expected. A total of three, full scale, prototypic test units (CTU1, CTU2, and CTU3) were used in certification testing. Test units, numbers, orientations and purpose of the test are listed in the Table 2.12.1-3 of the application. The following tests were conducted:

- 30° slap-down on forward end base,
- 20° oblique puncture on lid through center of gravity (c.g.),
- puncture on the side closure joint through c.g.,
- vertical forward bottom end drop, and
- horizontal lid down drop.

2.7.1 Free Drop

The free drop height of 30 ft and the orientations of the tests conducted (e.g., on the end, 30° slap down on base and horizontal lid down, etc.) satisfied the regulatory requirements. The package and impact limiter was crushed by total 5.88 inches (14.25 – 8.37 inches). The test results also indicated that the 20° oblique puncture on the lid through c.g. for CTU1 went through the outer shell into the lid foam. The puncture was 6 inches in diameter, with a depth of 7 inches measured from the flat surface of the lid. As a result of this puncture, two 12-gauge plates were welded to CTU3 to increase the thickness of the outer shell. The CTU3 was retested with the thicker outer shell. The cumulative internal damage from these tests was minor and acceptable. The staff concludes that the requirements of 10 CFR 71.73(c)(1) are satisfied.

2.7.2 Crush

The crush test required per 10 CFR 71.73(c)(2) was not applicable as the maximum weight of the MAP package 8,630 lbs is greater than 1,100 lbs, and the package density of 68 lbs/ft^3 is greater than 62.4 lbs/ft^3.

2.7.3 Puncture

A puncture test was performed by dropping the package onto a 6 inch diameter steel bar from a height of 40 inches. The 20° oblique puncture drop test through c.g. on the lid was performed. The puncture was 6 inches in diameter over 180° with tears extending outward on both sides of the 18°, exposing the polyurethane foam. The puncture slightly exposed some of the moderator. Due to the more severe foam compression experienced with CTU3 in the 30 ft drop test, two 12-gauge plates were welded to the CTU to increase the thickness of the outer shell. The c.g. over side closure joint puncture test was performed after the oblique puncture test. The CTU showed a maximum puncture depth of 3.5 inches as a result of this puncture test. The puncture test requirements of 10 CFR 71.73(c)(3) were met.

2.7.4 Thermal

A full scale CTU package was tested in a fully engulfing hydrocarbon fuel fire as required by 10 CFR 71.73(c)(4). The results of the thermal test are described in Section 3.0 of this Safety Evaluation Report (SER).

2.7.5 Immersion - Fissile Material

The requirements of 10 CFR 71.73(c)(5) related to the immersion test for packages containing fissile material are discussed in Section 6.0 of this SER.

2.7.6 Immersion - All Packages

The immersion test requirements per 10 CFR 71.73(c)(6), defined to be equivalent to a uniform external pressure of 21.7 psig was not required as the mechanical and thermal tests were more limiting. The deep water immersion test was not required as the MAP package does not contain more than $10^5 A_2$.

2.8 Evaluation Findings

The fuel rod cladding is considered to provide containment of radioactive material under both normal and accident test conditions. Therefore demonstration of cladding's ability to maintain sufficient mechanical and structural integrity during the transportation HAC is essential. Upon the staff's request AREVA furnished a discussion of the structural integrity of the cladding. The staff found that the visual inspections of the fuel rods in each CTU did not identify any bent or damaged rods. The test assemblies were removed from each CTU and further inspected, and no cracked or breached rods were identified visually. A random sample of rods were removed from the most damaged assembly and checked for pressurization. All were found to be pressurized. Therefore, no leakage or breach of the rods occurred as a result of the performance tests. The interior of the CTU3 was coated with tar as a result of the condensation of foam off-gas; however the fuel rods, being covered by a thin sheet of polypropylene, remained in their as-fabricated condition. The HAC fire test had no further effect on the cladding.

The discussion provided in Section 2.12.1 of the application, adequately demonstrated the structural integrity of the cladding during transportation HAC. Table 2.12.1-3 of the application included a summary description and results of all tests conducted for each CTU. The overall requirements of 10 CFR 71.73 were met.

The test for the accident conditions for air transport of plutonium and fissile material packages as required by 10 CFR 71.74 are not applicable as the MAP package is not transported by air.

Since special form is not claimed for the MAP package, the requirements of 10 CFR 71.75 are not applicable.

In summary, the structural evaluation presented in the application is in compliance with the structural performance requirements of 10 CFR Part 71.

3.0 THERMAL

3.1 Description of Thermal Design

The applicant provided the design features, content's decay heat, temperature summaries, and a summary of the maximum pressures. In addition the material properties and component specifications were addressed.

3.1.1 Design Features

The MAP has an internal strong-back structure providing support for the fuel assemblies. Impact limiters (on each end of the package body) are used for impact energy absorption as well as for thermal protection. A loaded MAP will be transported in a horizontal position on its transportation trailer. The MAP package is designed to allow multiple packages to be stacked upon one another during transportation.

3.1.2 Content's Decay Heat

The decay heat loading associated with the fresh, unirradiated low enriched PWR fuel assemblies or loose rods to be carried in the MAP is negligible.

3.1.3 Summary of Temperatures

The table below provides summaries of component temperatures for both the normal conditions of transport (NCT) and hypothetical accident conditions (HAC) analyses conducted by the applicant.

Table 3.1 - Component Temperatures

Location / Component		Temperature (°F)		
		NCT	HAC	Maximum Allowable
Fuel Assembly		131	< 300[1]	752 / 1058
Polypropylene Wrap (on Fuel Assembly)		131	< 300[1]	225 / 300
Neoprene Rubber (Fuel Cavity)		130	< 300[1]	225 / 500
Fuel Cavity Doors		130	< 300[1]	400 / 1100
Borated Aluminum Neutron Absorber		133	< 300[1]	850 / 1000
Thermoplastic Neutron Moderator		135	< 500[1]	500
Polyurethane Foam, Body	Maximum	201	n/a[2]	500
	Average	148	n/a[2]	150
Polyurethane Foam, Impact Limiter	Maximum	206	n/a[2]	500
	Average	141	n/a[2]	150
Fiberglass Thermal Breaks		138	< 500[1]	250 / 2900
Exterior Shell		210	2192	800 / 2700

[1]Temperatures reported were determined based on a post-test examination of the package condition, and were not directly measured by the applicant.
[2]Foam was considered consumed during the fire test and therefore no temperature is reported for the foam following the HAC test.

3.2 Thermal Evaluation under Normal Conditions of Transport

The applicant considers an isolated horizontal package in order to analyze the thermal performance of the MAP package design under NCT.

The applicant provides temperature-dependent material properties for all major components of the MAP package as well as acceptable temperature ranges of operation (minimum and maximum allowable values) in Section 3.2 of the application. In response to a nonconformance in the polyurethane foam, the thermal conductivity has been updated to 0.025 Btu/hr-ft-°F in Table 3.3. The applicant evaluated the nonconformance and found that the slightly higher thermal conductivity would not impact the performance of the package. Anisotropic thermal conductivities (radial & axial) for the fuel region are separately derived using a “k effective” approach, described in Section 3.5.2.1 of the application. The approach is based on a detailed model of the individual fuel pins within the strong-back walls and allows a simplification of the loaded MAP package to be used, where the fuel region is treated as a homogeneous material with an effective conductivity.

Using the Thermal Desktop and SINDA/FLUINT computer programs, the applicant constructed a 1/2 symmetry model of a loaded MAP package, using appropriate detail to represent the strongback structure with the borated aluminum neutron absorber sheets, thermoplastic neutron absorbers, polyurethane foam insulation, and the exterior shell. The attached impact limiters were modeled separately. The model simulates one-half of the package, assuming symmetry about the package’s vertical plane, and extends about 7.8 inches along the axial direction, from one stiffener to the midpoint between stiffeners. Inside the MAP package, both conduction and radiation are allowable means of heat transfer. The MAP package exchanges heat with the surrounding environment through convection and radiation. As the decay heat of the payload is negligible, the only heat input to the package under NCT is solar insolation, which the applicant modeled using a diurnal cycle described in Section 3.5.2.1 of the application.

The applicant modeled only the NCT hot case, with insolation. The case without insolation was deemed trivial, as there is no heat input to the package. Similarly, the NCT cold case with an ambient temperature of -40°F was also considered trivial. In both cases, all parts of the package could be assumed to reach the ambient temperature with no adverse effects.

The applicant predicts all components temperatures well within operational limits, even when insolation is accounted for. The applicant also demonstrates that the accessible external surface temperature remains below the regulatory limit in 10 CFR 71.43(g) of 122°F without insolation, required for packages under nonexclusive use.

3.3 Thermal Evaluation Under Accident Conditions

The thermal performance of the MAP package under HAC was assessed by conducting a fire test and exposing the package to a 30 minute fully-engulfing fire, as required in 10 CFR 71.73. The test was performed using one of the fire test pools at the South Carolina Fire Academy (SCFA) in Columbia, SC. Prior to the fire test, the MAP test unit was also subjected to the free and puncture drop tests. The package was placed on a simple, water-cooled, insulated steel support stand one meter above the surface of the pool, and oriented as to maximize heat input into the puncture damaged area. Eight Inconel sheathed type K thermocouples were placed around the package to measure fire temperatures, while an additional eight were placed on the package surface to measure the temperature of the exterior shell.

The fire was considered to be fully-engulfing for 38 minutes. Temperature data from the thermocouples showed that the average temperature of the fire, 1,746 °F, was above the 1,475 °F regulatory requirement. The temperatures experienced by components inside the package were to be measured by examining temperature indicating strips which had been placed on the flame side of the neutron moderator blocks. However, these strips were rendered unreadable by condensation of gasses released by the decomposition of polyurethane foam. Temperatures were instead estimated by examining the physical condition of the interior components. The interior components were found by the applicant to be under their maximum allowable temperature limits. While the thermoplastic moderator did experience a small degree of melting, it was not enough to impact its function, as outlined in the criticality evaluation in Section 6 of the application. The applicant concluded that all thermal requirements for HAC were successfully met.

3.4 Internal Pressure

The Maximum Normal Operating Pressure (MNOP) for the package is 0 psig. The containment boundary for the package is defined as the fuel rod cladding. The peak fuel rod cladding temperature of 131°F is reached under extended operations in the NCT hot environment. The peak pressure within the fuel rod under this condition is 254 psig.

The MAP package does not contain any sealed enclosures other than the fuel rods contained in the payload. As such, the maximum package pressure developed during the HAC fire event remained near atmospheric conditions at all times. Outgassing caused by the decomposing polyurethane foam can be expected to produce slightly elevated pressures within various package enclosures containing the foam material, but each of these enclosures contain a plastic blow-out plug designed to fail under either the heat or pressures generated during the fire event. The estimated peak fuel rod temperatures reached under HAC is 225°F, resulting in a pressure of 297 psig within the fuel rod.

3.5 Conclusion

Based on the documentation and information supplied by the applicant, and the review performed by staff, there is reasonable assurance that the package design, as amended to include additional contents discussed above, meets the requirements of 10 CFR Part 71 for thermal performance.

4.0 CONTAINMENT

4.1 Description of the Containment System

The containment system of the MAP package is the fuel rod cladding.

4.2 General Considerations

The Type A package containment system contains unirradiated ^{235}U and ^{238}U which both have 10 CFR Part 71 A_2 values designated as ‘unlimited’ under HAC.

However, the fuel rod's post fabrication testing to the leak-tight criteria of ANSI14.5-1997 and their structural integrity ensure that there is no release of radioactive material under NCT or HAC.

The Type B package containment system contains unirradiated low enriched uranium fuel derived from off-specification high enriched uranium or reprocessed uranium (i.e., Blended Low Enriched Uranium, BLEU). The presence of ^{234}U and ^{236}U in quantities exceeding their associated A_2 values causes the content to fall under the Type B requirements. The radiative material may not exceed any of the following limits:

^{232}U	0.002 microgram per gram of uranium
^{234}U	0.002 gram per gram of uranium
^{236}U	0.025 gram per gram of uranium
Fission Products	6.4×10^5 MeV-Becquerel per kilogram of uranium
Np and Pu	115 Becquerels per gram of uranium

4.3 Normal Conditions of Transport

Under NCT the structural integrity of the cladding ensures that there is no loss or dispersal of radioactive material. The fuel rods are leak tested after fabrication to ensure that the leakage rate is less than 1E-07 ref cc/sec.

4.4 Hypothetical Accident Conditions

To demonstrate compliance with the HAC, three CTUs were subjected to the HAC testing (i.e., drop, puncture, and fire) using a dummy fuel assembly containing tungsten carbide pellets with dimensions and density similar to the current uranium oxide fabricated pellets. The weight of each CTU fuel assembly was increased by loading of lead in the guide and instrument tubes. After the HAC testing the cladding was found to be undamaged, rods were still pressurized and their surface appeared to be pristine. As a result of the staff's request a description of the cladding post-HAC testing was added to the application in Sections 2.12.1.5 and 3.4.3.1 and affirmation was provided that the dummy fuel rods were pressurized to 225 psig (same as maximum design pressure for current assembly designs). In the initial application submittal no discussion was provided to explain why the CTU only contained a fuel assembly and not individual rods, which the staff identified as not being bounded by HAC testing of a fuel assembly. Hence, the applicant withdrew its request for the content to include shipment of individual rods.

4.5 Leak Rate Testing

Leakage tests are performed on each rod fabricated to confirm the containment boundary leakage rate is less than 1E-07 ref-cc/sec prior to shipment.

Added assurance to inhibit release of radioactive material from the cladding is provided by the physical form of the fuel pellets (sintered) which inhibits the likelihood of the formation of aerosols. The performance tests documented in Section 2.12.1 of the application demonstrate that no pellets are released from the cladding as a result of HAC.

5.0 SHIELDING

Under conditions normally incident to transportation the radiation level does not exceed 2 mSv/h at any point on the external surface of the package. Additionally, the transport index does not exceed 10. The radiation level is less than 0.1 mSv/h at a distance of approximately 3.3 ft from the surface of the package. The radiation dose rate limits are in compliance with 10 CFR 71.47.

6.0 CRITICALITY

6.1 Introduction

This section of the application provided criticality safety analyses for the MAP-12 and MAP-13 Type AF and Type BF unirradiated fuel assembly packages under both NCT and HAC. AREVA demonstrated through analyses that the packages satisfy the criticality safety requirements pursuant to 10 CFR Part 71.

The packages are designed to transport up to two unirradiated PWR fuel assemblies with square lattices of 14 x 14, 15 x 15, 16 x 16, or 17 x 17. The maximum ^{235}U enrichment is 5 wt% for all of the contents. The CSI for all packages is 2.8.

The applicant used SCALE-VI system computer code to perform criticality safety analyses for the package design. The applicant benchmarked with area of applicability analyses of the computer code to these specific packages. An upper safety limit (USL) of 0.94 is obtained for the applicable experiments.

6.2 Description of Criticality Design

The package criticality safety control design is described in Section 6.2 of the application. Criticality safety control for the MAP-12 and MAP-13 packages is provided by the combination of mechanical limit of package geometries, fixed neutron absorbers, neutron trap, fixed moderating materials, and moderator exclusion using the fuel cladding as containment boundary. Figures 6-1 and 6-2 in the application provide isometric and cross-sectional views of the MAP packages.

The packages contain neutron absorbers in the form of borated aluminum plates. The neutron-moderating materials are neoprene pads and polyurethane foam. Nylon 6,6 plates are also included in the flux trap to enhance the effectiveness of the neutron absorbers.

The fuel pellet/cladding gaps of the fuel rods in fuel assemblies were modeled as flooded during HAC, pursuant to the requirements of 10 CFR 71.73. No moderator exclusion was assumed during hypothetical accidents.

The applicant provides information on the criticality evaluations for the MAP-12 and MAP-13 packages. Table 6-1 provides a summary for the evaluation results for both single package and array of packages under NCT and HAC.

The applicant also performed criticality safety analyses for arrays of various packages pursuant to 10 CFR 71.55. Criticality Safety Index (CSI) has been obtained for these various loading patterns. The CSI for the fuel assembly packages is 2.8 with an array of maximum of 36 damaged packages under HAC.

6.3 Fissile Material Contents

The packaging is designed to transport up to two (2) PWR fuel assemblies with square lattices of 14 x 14, 15 x 15, 16 x 16, or 17 x 17. Table 1-2 of the application provides the maximum quantity of different material constituents of the fuel rods. Table 6-2 of the application provides modeled uranium isotope distribution and shows that a 5 wt% ^{235}U was used in the model.

6.4 Modeling Considerations

Section 6.4 of the application provides information on the MAP package for criticality safety evaluations. The applicant demonstrated in Section 6.7.1 of the application that the 15 x 15 fuel assembly has the bounding values for all fuel assembly types to be transported by the MAP-12 or MAP-13 packages. Consequently, all criticality safety evaluations in the application used the 15 x 15, Type 1 fuel assembly as the basis. Table 6-4 of the application presents data for this assembly type.

The criticality safety analyses are carried out using the SCALE-IV computer code system. The CSAS26 code option is used for criticality calculations. The 238-group ENDF/B-V library is used in the analyses. The applicant demonstrates with calculation results that a single package is subcritical under both NCT and HAC. The staff performed confirmatory analyses and determined that the applicant modeled the package correctly and the results are in good agreement with that of the staff's analyses, the staff concludes that the applicant has provided reasonable assurance that the packages meet the requirements of 10 CFR 71.55.

The applicant states its major assumptions in the model of the fuel assemblies to be transported with the Model Nos. MAP-12 and MAP-13. The applicant further provides justifications by comparing the model to as-built and as-found conditions under NCT and HAC respectively. Table 6-9 of the application provides a summary of packaging modeling and conservatisms considered in the modeling.

The applicant demonstrated in the application that the arrays of fuel packages remain subcritical at both NCT and HAC. Table 6-11 shows that the $k_{eff} + 2\sigma$ is 0.2127 for infinite array of packages under NCT and 0.9379 for array of packages under HAC; where N is the number of packages in a package array as defined in 10 CFR 71.59.

The applicant studies the impact to the k_{eff} from applicable variations of material specifications, assembly and package geometric dimension tolerances, and some simplifications in modeling.

The applicant also studied the criticality effect of fuel assembly shifting. The results show that the lateral shifting of fuel assemblies along the packaging will result in increase in k_{eff}. Figure 6-23 shows the k_{eff} as a function of distance of the lateral assembly shifting out of the package.

The staff reviewed this hypothetical scenario and determined that it is reasonable. The packaging case prevents the assemblies from further sliding out of the cask during HAC accident. The lateral shift will occur only when the foam, which forms a cradle for the two fuel assemblies in a package, is burned out.

The applicant also performed benchmark, trending, and uncertainty analyses for the computer code and models for these specific package designs to demonstrate that the computer code and model it used are valid and can produce results that are reliable and within the allowable uncertainty limits.

The applicant provides in the application also Upper Safety Limits, USL1 and USL2. The results show that an overall USL of 0.94 is valid to the calculated values of k_{eff} in these packages.

The applicant derived the CSI value by a package array size sensitive study. Figure 6-2 shows the change of k_{eff} as a function of array size with the FLIP1 configuration. From this figure, it can be observed that the k_{eff} value increases first, and then goes down as the number of packages increases. Finally the k_{eff} value jumps from 0.9356 to almost 0.9420.

The staff further examined the configuration of the array by rearranging the array with more favorable critical, i.e., a more cylindrical rather than a square geometry and found that k_{eff} did not exhibit significant variation. The k_{eff} variation in figure 6-29 is largely a reflection of statistical variation of the model output. The results of the criticality safety and hence the CSI value are valid.

The staff reviewed the amendment requests and evaluated the information provided. The staff also performed confirmatory analyses for the resultant various package loading configurations. Based on the review and then confirmatory analysis results, the staff found that the applicant has demonstrated, and the staff agrees, that the MAP-12 and MAP-13 packages meet the criticality safety requirements of 10 CFR Part 71.

7.0 PACKAGE OPERATIONS

The staff reviewed Section 7 of the application to verify that it meets the requirements of 10 CFR Part 71 and is adequate to assure the package will be operated in a manner consistent with its evaluation for approval.

Section 7 of the application includes the preparation for loading the package, loading the contents, preparation for transport, radiation survey, and package unloading.

Based on the statements and representations in the application, the staff concludes that the package operations meet the requirements of 10 CFR Part 71 and that they are adequate to assure the package will be operated in a manner consistent with its evaluation for approval. Further, the CoC has been conditioned to specify that the package must be prepared for shipment and operated in accordance with the Package Operations in Section 7 of the application, as supplemented.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

The staff reviewed Section 8 of the application to verify that the acceptance tests for the packaging meet the requirements of 10 CFR Part 71 and that the maintenance program is adequate to assure the packaging performance during its service life.

Section 8.1 of the application specifies the acceptance tests required to be performed prior to first use of the package. Fabrication specifications are listed in the drawings for the MAP package.

Section 8.2 of the application discusses a maintenance program to ensure continued performance of the MAP package. The maintenance program ensures that the packages with defects are segregated, dispositioned and brought back into compliance with the certificate before its next use.

Based on the statements and representations in the application, the staff concludes that the acceptance tests for the packaging meet the requirements of 10 CFR Part 71 and that the maintenance program is adequate to assure packaging performance during its service life. The CoC has been conditioned to specify that each package must meet the Acceptance Tests and Maintenance Program of Section 8 of the application.

CONDITIONS

In addition to the authorized contents listed in Sections 1.2 and the drawings listed in Section 1.4 of this safety evaluation report, the CoC includes the following conditions of approval:

Condition No. 6: In addition to the requirements of Subpart G of 10 CFR Part 71:

(a) The package shall be prepared for shipment and operation in accordance with Package Operations in Section 7 of this application, as supplemented.

(b) Each package must meet the Acceptance Tests and Maintenance Program of Section 8 of the application, as supplemented.

Condition No. 7: Each fuel assembly must be unsheathed or must be enclosed in an unsealed, polyethylene or polypropylene sheath, which may not extend beyond the ends of the fuel assembly. The ends of the sheath may not be folded or taped in any manner that would prevent the flow of liquids into or out of the sheathed fuel assembly.

Condition No. 8: The fuel rods must be leak tested after fabrication to ensure that each fuel rod has a leakage rate less than 1E-07 ref cc/sec.

Condition No. 9: Transport by air of fissile material is not authorized.

CONCLUSION

Based on the statements and representation contained in the application, as supplemented, and the conditions listed above, the staff concludes that the Model Nos. MAP-12 and MAP-13 packages meet the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9316, Revision No. 0,
on January 30, 2008.