SAFETY EVALUATION REPORT

Docket No. 72-1026
FuelSolutions^{TM} Storage Cask
Certificate of Compliance No. 1026
Amendment No. 1

SUMMARY

This Safety Evaluation Report (SER) documents the review and evaluation of an amendment application for the BNFL Fuel Solutions (BFS) storage cask system (FuelSolutions^{TM}). By application dated September 29, 1999, as supplemented April 6, July 27, August 1, and October 20, 2000, BFS requested an amendment to the Certificate of Compliance No. 1026 for the FuelSolutions^{TM} storage cask. BFS requested the addition of Big Rock Point (BRP) mixed oxide (MOX) fuel, partial fuel assemblies, and damaged fuel assemblies to the allowable FuelSolutions^{TM} W74 canister contents.

The application, as supplemented, included the necessary engineering analyses and proposed Safety Analysis Report (SAR) page changes. The proposed SAR revisions will be incorporated into the Final Safety Analysis Report (FSAR) that must be submitted within 90 days after the amendment has been approved (in accordance with 10 CFR 72.248(a)(1)).

The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the application, as supplemented, including the engineering analyses, proposed SAR revisions, and other supporting documents submitted with the application. Based on the statements and representations in the application, as supplemented, the staff concludes that the FuelSolutions^{TM} storage cask system, as amended, meets the requirements of 10 CFR Part 72.

1.0 GENERAL INFORMATION

The applicant requested that BRP MOX, partial, and damaged fuel assemblies be added to the allowable contents for storage in the FuelSolutions^{TM} W74 canister. Due to the limited scope of the amendment request, only those sections affected are addressed in this SER.

2.0 STRUCTURAL

This section evaluates the design basis loadings and corresponding structural performance of the W74 canister components for storing the MOX, partial, and damaged fuel assemblies. The intact MOX and partial fuel assemblies are stored in the W74 canister in the same manner as intact uranium oxide (UO_2) fuel assemblies. In addition, up to eight damaged MOX and UO_2 fuel assemblies can be placed in the specially designed damaged fuel cans, which, in turn, are stored in the fuel basket support tubes.

2.1 Design Basis Loadings

Fuel Assembly Weights and Dimensions. Section 2.2 of the SAR states that the BRP MOX fuel assemblies have the same envelope dimensions and weight as the UO_2 assemblies, and the weight of the BRP partial fuel assembly is bounded by that of the intact fuel assembly. SAR Table 3.2-1 lists the fuel weights in the upper and lower baskets based on the nominal spent fuel assembly weights and the bounding damaged fuel can weight of 200 lbs, which is greater than the calculated weight of 121 lbs. Thus, the staff agrees with the SAR conclusion that the existing fuel assembly weight and dimension parameters, which have been considered in determining the design basis mechanical loadings for the W74 canister and baskets, are bounding for the MOX, partial, and damaged fuel assemblies.

Canister Thermal and Internal Pressure Design Loads. Section 3 of the SAR evaluates the thermal and internal pressure design loads for normal, off-normal, and accident conditions for a W74 canister containing any amount of intact BRP MOX fuel and partial fuel assemblies and up to eight damaged fuel assemblies. The staff agrees with the SAR conclusion that the existing thermal and internal pressure design loads, which have been considered for the W74 canister and baskets, are bounding for the MOX, partial, and damaged fuel assemblies.

2.2 Structural Performance

W74 Canister Shell and Basket. The SAR considers effects of the BRP MOX, partial, and damaged fuel assemblies on the existing structural evaluations of the W74 canister shell and basket assemblies. As noted above, since the mechanical, thermal, and pressure loadings used in evaluating the existing canister shell and basket assemblies bound those associated with the MOX, partial, and damaged fuel assemblies, no additional structural evaluations are needed.

Fuel Rods. SAR Table 2.0-1 notes that partial fuel assemblies include those with missing corner rods and array interior or array edge rods. The extra spaces between fuel rods as created by missing rods could potentially allow the adjacent fuel rods to deform then fail with unrestricted lateral displacement in the event of storage cask tip-over, transfer cask side drop, or storage cask bottom end drop. SAR Section 3.8 determines the transverse and end impact load capabilities of 63 g and 86 g, respectively, for the fuel rods of an intact BRP fuel assembly. The SAR notes that the fuel rod weight, clad dimensions, and unsupported lengths used for the structural analysis of the BRP intact UO_2 fuel assemblies are bounding for all BRP partial and MOX fuel assemblies. This provides the basis to conclude that the impact load capabilities of the intact BRP fuels bound those of the intact MOX fuels. The staff agrees with the SAR conclusion that the impact load capabilities of the intact BRP fuels are also valid for the partial fuel assemblies.

Damaged Fuel Can. The 6.35-inch square by 84.9-inch long stainless steel damaged fuel can is designed in accordance with the applicable requirements of Section III, Subsection NG of the ASME Code. Fuel assemblies with fuel rod damage in excess of hairline cracks or pinhole leaks are placed in the damaged fuel can. SAR Table 2.0-1 and Section 2.2.3 note that fuel assemblies with damaged grid spacers, defined as damaged to a degree where fuel rod structural integrity cannot be assured or where grid spacers have shifted vertically from their design position, are also stored in damaged fuel cans.

SAR Section 3.4.3 provides stress analyses of the damaged fuel can components for the vertical lifting operation, considering a bounding weight of 720 lbs for the BRP fuel assembly plus the damaged fuel can. The analyses demonstrate that maximum stresses in the damaged fuel can, including the top lid assembly, are all lower than the corresponding stress allowables.

SAR Section 3.5 states that the design of the damaged fuel can is similar to that of the guide tube assembly in that both are fabricated with the SA-240 Type 316, 13 gage stainless steel sheets and has the same cross-section properties. The SAR considers the slightly higher weight of the damaged fuel can than that of the guide tube in the structural evaluation. In terms of support condition afforded by the basket, the SAR notes that the guide tubes are positioned inside the spacer plate openings with intermittent support by the spacer plates; whereas, the damaged fuel cans are placed within the basket support tube openings with continuous lateral support. On this basis, the SAR concludes and the staff agrees that the damaged fuel can is also structurally adequate because the maximum stresses in the damaged fuel can are bounded by those calculated for the guide tube. This demonstrates that the damaged fuel can satisfies the structural design criteria for the normal, off-normal, and accident conditions in accordance with the requirements of 10 CFR Part 72.

2.3 Materials

The damaged fuel cans are fabricated from Type 316 stainless steel. The MOX fuel cladding is the same zirconium alloy as is used for conventional UO_2 fuel. These materials are presently used in approved cask designs and, thus, do not introduce any new types of materials or potential for adverse chemical or galvanic reactions.

Fuel cladding condition for MOX fuel

Prior to making calculations of the allowable cladding temperature limit for storage, it is necessary to determine if the cladding for a MOX fuel was exposed to different operational conditions during its operating history. A change in operational conditions, such as a higher operating temperature, could cause a change in material behavior such as increasing the amount of reactor service induced hydrides within the cladding.

The design operating parameters of MOX fuel assemblies used at BRP are equal to or bounded by those for conventional fuel assemblies. As such, the bounding operational temperature (e.g., in-reactor) experience on the two fuel rod configurations (MOX and conventional) are similar. Since the operating temperature of the MOX fuel cladding is bounded by the conventional fuel cladding temperatures, there is no accelerated oxidation or hydriding rate due to higher temperature. Consequently, the mechanical properties of the MOX fuel cladding will be the same as for conventional fuel.

The 35 GWd/MTU burnup value of the BRP MOX fuel is below the design basis 40 GWd/MTU burnup for the conventional BRP fuel. Consequently, the MOX fuel internal rod pressures and operating temperature effects will be bounded by those for the conventional BRP fuel.

The generated fission gas inventory is lower due to the lower burnup value for the MOX fuel. Assuming the same release fraction as for conventional fuel, the MOX fuel fission gas available for release to the interior of the fuel pin is bounded.

The other parameters such as cladding dimensions, gas plenum volume, and fill gas pressure are similar for the MOX and conventional assemblies. Given the lower fission gas release for the MOX fuel, the cladding stress levels determined for design basis BRP conventional fuel are bounding for the BRP MOX fuel.

Allowable cladding temperatures

Because the cladding stress levels are lower for MOX fuel, the allowable cladding temperatures in storage and loading for the conventional fuel are conservative for the BRP MOX fuel.

Due to the lower burnup for the BRP MOX fuel, the maximum heat generation is bounded by the calculations for the conventional fuel. The longer cooling time for the BRP MOX fuel means an adjustment to the maximum allowable cladding temperature is required, but the methodology is the same as for conventional fuel. Thus, no change to the calculation method is necessary to establish the maximum allowable cladding temperature for MOX fuel. Revised values of the maximum allowable cladding temperature were calculated and provided. For long term storage, the maximum cladding temperature is 385.5°C. The short-term allowable fuel cladding temperature under normal and off-normal conditions is 400°C. Under transfer conditions (cask loading/unloading), the limiting temperature remains 570°C, as for conventional fuel.

For damaged fuel assemblies placed in damaged fuel cans, the above temperature limits remain. This precludes degradation of undamaged fuel pins that may be within a damaged fuel assembly.

2.4 Conclusion

The staff concurs with the SAR conclusion that the W74 canister and baskets are structurally adequate for all BRP fuel assemblies under the normal, off-normal, and accident conditions in accordance with the requirements of 10 CFR Part 72. The staff also finds that no significant change to the materials used in the fabrication of the W74 canister, or stored in the W74 canister, would occur as a result of storing MOX fuel or damaged fuel canister. No potentially detrimental chemical or galvanic reactions are introduced by the changes. The cladding temperature limits are modified as a result of the longer cooling time but are not a function of either the damaged fuel cans or the MOX fuel.

3.0 THERMAL

This amendment is seeking approval to store any amount of MOX fuel assemblies having the same envelope dimensions and weight as the previously approved UO_2 assemblies. The applicant states that the BRP MOX fuel has a significantly longer cooling time than that required for UO_2 fuel. The applicant asserts that the MOX fuel has a thermal source term that is bounded by the design basis UO_2 assembly source. The applicant also asserts that the BRP MOX fuel assemblies have a lower internal rod pressure and will, therefore, result in lower cladding stress levels than the design basis BRP fuel assemblies. Hence, the long-term allowable cladding temperature limit is used for both fuel types, UO_2 and MOX, as a bounding value. All existing BRP MOX fuel has a burnup level under 35 GWd/MTU and an assembly cooling time of at least 15 years.

This amendment is also seeking approval for storage of any amount of partial fuel assemblies and up to eight damaged fuel assemblies. The partial fuel assemblies can be either a UO_2 or MOX fuel types. Partial fuel assemblies are defined, in this instance, as assemblies having fuel rods missing from the design basis assembly array. The applicant asserts that for a given burnup, initial enrichment, and cooling time, a lower number of rods, in a partial fuel assembly, results in a lower assembly fuel loading and, therefore a lower level of assembly heat generation. Thus, for a canister loaded with one or more partial BRP assemblies, with the cooling times defined by the applicant, the resulting heat load will always be bounded by the allowable 24.8kW. Similarly, the fuel rods remaining in the assembly will continue to be bounded by the original analyses for rod pressure given their similar configuration and operational parameters. The applicant also asserts that the effective thermal conductivities for the BRP partial assemblies are similar to and bounded by those intact BRP fuel assemblies.

Damaged fuel assemblies are defined as those assemblies containing fuel rods which exhibit cladding damage greater than pinholes or hairline cracks. Fuel assemblies with damaged grid spacers, defined as damaged to the extent that the structural integrity of the fuel rod cannot be assured or where grid spacers have shifted vertically from their design position, are also stored in damaged fuel cans. The damaged fuel assemblies may be either UO_2 or MOX fuel assemblies. BRP damaged fuel, in the as loaded condition, does not include gross assembly failure wherein the assembly dimensions extend beyond the enveloping dimensions of either the UO_2 or MOX intact fuel. BRP damaged fuel assemblies are to be placed into damaged fuel cans which are located in the prescribed eight locations in the upper and lower baskets of the W74 canister.

The applicant asserts that the total heat generation for the damaged UO_2 and MOX fuel assemblies remains bounded by the original analyses. The applicant states that, provided the fuel remains in its as loaded original configuration and for a given burnup and cooling time, the damaged fuel axial flux profile is bounded by that of the intact fuel assemblies. Similarly, the applicant asserts that when the configuration remains unaltered the effective thermal conductivity of the damaged fuel assembly will also remain bounded by the UO_2 and MOX intact fuel assemblies. The applicant states that the steady state effects of the damaged fuel can would be a slight increase in damaged fuel cladding temperatures, but would not result in a change in the spacer plate temperature distribution. The applicant concludes that the effect of the damaged fuel can on the overall heat transfer coefficient of the damaged fuel assemblies is deemed negligible. Additionally, despite the presence of the damaged fuel can, the allowable temperature for the damaged fuel remains the same as that for the undamaged fuel. The applicant concludes that the damaged fuel assemblies will not exceed established cladding temperature limits. For normal and off-normal cases, the short-term cladding temperature limit for intact fuel assemblies has a substantial margin, and for hypothetical accident cases, similar margins also exist.

Regarding canister internal pressure, the applicant asserts that internal rod gasses contained in failed fuel rods in the damaged fuel assemblies would already have been released prior to loading. The addition of damaged fuel assemblies to the fuel load would not contribute any additional interior canister pressure and, therefore, the original analyses remain bounding.

The applicant addressed the issue of fuel damage under off-normal and hypothetical accident conditions that might alter the configuration, i.e., fracturing and collapse, of the fuel rods such that the existing analyses may not remain bounding. The applicant concluded that, given bounding scenarios where fuel rod failure has occurred and redistributed to the bottom of the basket, the heat transfer effects of the fractured or collapsed fuel in the damaged fuel can on the surrounding intact fuel assemblies and the components of the basket and canister shell, will still remain below the allowable design limits.

3.1 Evaluation Methods

MOX Fuel Assemblies

The applicant asserted and demonstrated by analysis, using the ORIGEN 2.1, point depletion code, that for the MOX fuel, the maximum heat generation level for any assembly is less than 150 watts/assembly. This is less than the design basis heat generation level of 412 watts/assembly that forms the basis of the canister thermal rating and minimum required assembly cooling times. In this regard, the staff agrees that the original analyses remain bounding. The applicant asserts that the axial heat flux distribution determined for the UO_2 fuel is applicable also to the MOX fuel assemblies. With the same physical dimension of both types of assemblies, the fact that the MOX assemblies also contain a large number of UO_2 fuel rods around their periphery, and given their irradiation in the same reactor core, the staff agrees that the axial heat flux profile is expected to be very similar for the UO_2 and MOX fuel assemblies. After review of the submittal, the staff agrees with the applicant's assertion that the allowable cladding temperature limits remain bounding for the MOX fuel. This is based on similarity in parameters (cladding dimensions, gas plenum volume, fill gas pressure) between the UO_2 and MOX fuels and considering that the MOX fuel has a lower burnup value (35 GWd/MTU) than the UO_2 fuel (40 GWd/MTU). Additionally, when using a 30% release fraction, which results in a lower MOX fuel internal rod pressure, the staff agrees that the cladding stress levels determined for the design basis UO_2 fuel (at any given temperature) are bounding for the MOX fuel. Since the MOX fuel assemblies have lower fission gas quantities, and, therefore, lower internal rod pressures than the design basis fuel assemblies, the staff concurs that the canister internal pressures determined for a UO_2 fuel assembly load remain bounding for a canister containing any amount of MOX fuel.

Partial Fuel Assemblies

For the partial fuel assemblies to be loaded in the W74 canister, the original analyses for the BRP intact UO_2 fuel remains bounding. As mentioned above, given the similar fuel parameters of the UO_2 fuel in a full assembly and a partial fuel assembly, a partial fuel assembly with fewer fuel rods will generate less heat energy. Thus, a cask loaded with partial fuel assemblies will have a heat output that remains bounded by the original analyses maximum of 24.8kW. The applicant asserts that the effective thermal conductivity for the partial fuel assemblies is similar to and bounded by those of the intact fuel assemblies. The staff agrees with the applicant because radiative heat transfer between fuel rods is the primary mode of heat transfer across the assembly fuel rod array. Each row of fuel rods forms a barrier to effective radiative heat transfer through the assembly. Absorption and reradiation through those rows of fuel rods, impeding radiative heat transfer, results in increased effective assembly thermal conductivity. Hence, removing fuel rods from the radiation pathway will result in a larger effective assembly thermal conductivity and a greater ability for the assembly to shed heat energy. In addition, with larger void spaces within the fuel assembly, convective heat transfer effects would also increase. The staff performed confirmatory calculations to determine the magnitude of the effects of reduced conduction heat transfer by removal of fuel rods. The staff, in agreement with the applicant, concludes that the effect of reduced conduction is more than offset by the increased radiation and convective heat transfer effects. The staff, therefore, concludes that the original analyses, in this regard, will remain bounding for the partial fuel assemblies.

Damaged Fuel Assemblies

For the damaged fuel assemblies, the original analyses remain bounding for those fuel assemblies that remain in the as loaded configuration. Similarly, the design temperature limits remain bounding for fuel that, in an off-normal or hypothetical accident condition, fractures and/or collapses within the damaged fuel can. The damaged fuel assemblies include fuel types similar to those previously analyzed, the only factor differing being the presence of pinhole leaks, hairline cracks, or having damaged or slipped grid spacers. Given this, the staff agrees that a cask loaded with damaged fuel assemblies will have a heat output that remains bounded by the original analyses maximum of 24.8kW. Similarly, when the damaged fuel remains in the as loaded configuration, which is commensurately bounded by the physical dimensions of the undamaged UO_2 fuel, the fuel originates from the same reactor core, and using given burnup and cooling times, the staff agrees that the axial heat flux profile will be bounded by that of the undamaged fuel.

The staff agrees that the presence of pinhole leaks and hairline cracks will not affect pin-to-pin heat transfer via radiation or conduction/convection. Additionally, the absence of rod fill gas and internal pressure will not affect the computed effective conductivity because the applicant conservatively ignored the presence of these factors in their original methodology. The staff concurs that the determination of overall effective thermal conductivity of the undamaged fuel will remain bounding for the damaged fuel assemblies. Analogous to this, due to the absence of fill gasses in the damaged fuel rods, there will be no introduction of fission gasses to the canister atmosphere from the damaged fuel rods nor will there be the propensity for additional canister pressure due to rod failures beyond that which has already been determined for the undamaged fuel assemblies.

The applicant determined that the presence of the damaged fuel can would result in a slight increase in damaged fuel cladding temperatures but would not result in a change in the spacer plate temperature distribution. The staff agrees that the methodology for determining damaged fuel cladding temperatures, given the presence of the damaged fuel can, is appropriate. Notably that, given the added thermal resistance of the damaged fuel can, the increase in temperature of the damaged fuel within the can is approximately 5.8°C above that of undamaged fuel if it were placed in the same location. The staff verified through confirmatory calculations that the conclusions reached by the applicant are acceptable. Specifically that the peak cladding temperatures remain bounded by the original limits determined for the undamaged fuel assemblies.

Accident Conditions

The staff reviewed the applicant's analysis of hypothetical scenarios where fuel fracturing and collapse could occur during off-normal and hypothetical accident conditions. The applicant evaluated two scenarios, side drop accident where damaged fuel could potentially fracture and collapse against the side wall of the damaged fuel can and an end drop accident where damaged fuel could potentially fracture and collapse and form a rubble pile at one end of the damaged fuel can.

For the side drop scenario the staff reviewed the applicant's methodology and agrees that a side drop scenario would not significantly affect the heat transfer within the damaged fuel can. The fuel, when collapsed against the side wall, would be reconfigured such that fuel rod sections would be in direct contact with each other and/or the wall of the damaged fuel can, thus the heat transfer would actually improve. This is facilitated by the direct contact between the fuel rods and the increase in surface area in contact as the debris spreads across the width of the fuel can. Additionally, for the side drop scenario, given that the fuel will remain evenly distributed along the length of the damaged fuel can (and basket), the axial heat flux distribution will remain unchanged. The staff reviewed the applicant's analysis for this scenario and found it acceptable.

The scenario whereby the fractured and collapsed fuel rubble pile accumulates at one end of the damaged fuel can could result from a side drop that is upended or a simple end drop. The applicant analyzed the rubble pile as three different configurations, as a tightly packed group of rods, a loosely packed group of rods, and a porous media. In reviewing the applicant's analyses, the staff agrees that the loosely packed rubble pile is the most bounding configuration due to its lower overall effective heat transfer coefficient. This overall effective heat transfer coefficient was used to determine the temperature profile within the rubble pile. The heat transfer mechanisms at the void space above the rubble pile are a combination of convection and radiation between the walls of the damaged fuel can. The BFS analyses assumed fuel conditions at the "Normal Hot" storage and "Off Normal Hot" transfer initial conditions. The effects of this localized heat source were evaluated to determine the effects on the fuel rod cladding of the surrounding fuel assemblies. Using the same methodology as used when analyzing the undamaged fuel, except now with the localized heat source of the damaged fuel rubble pile, the applicant determined that there existed a downward shift in the overall temperature profile but that the increase in localized peak temperature near the rubble pile is still well below the peak fuel cladding temperature within the canister. The staff reviewed the applicant's findings and is in agreement with the conclusions that the peak cladding temperatures within the W74 canister are nearly identical for both scenarios containing a basket/canister with a rubble pile and a canister containing undamaged fuel. Specifically, that the presence of the damaged fuel can and its contents have a negligible effect, i.e., 1°C for the "Normal Hot" initial condition and 10°C for the "Off Normal Hot" initial condition, on the overall peak cladding temperatures within the canister. The largest temperature deviation of 30°C was seen at the support tube location. Given these temperature increases in all damaged fuel locations, the original allowable peak temperatures determined for the undamaged fuel case remains bounding. The staff, therefore, concludes that the presence of damaged fuel cans and the damaged fuel, in either intact or in a reconfigured rubble pile, will not significantly affect the ability of the canister and contents to perform within the bounds of the original analysis and maximum allowable temperature limits.

3.2 Conclusion

The staff has reviewed the material properties and component specifications used in the thermal evaluation and concludes that they are sufficient to provide the basis for evaluation of the new fuel load types against the requirements of 10 CFR Part 72. Additionally, the methods used in the thermal evaluation are described in sufficient detail to permit an independent review, with confirmatory calculations, of the package thermal design.

Based on the review of the statements and representations in the application, the staff concludes that the FuelSolutions™ W74 Canister amendment request to store MOX fuel and partial and damaged fuel assemblies has been adequately described and evaluated. The thermal performance of the package remains bounding for storage of the fuel types described in the application and meets the applicable regulatory requirements of 10 CFR Part 72.

4.0 SHIELDING

The following requested changes required an update of the shielding analyses for the W74 canister:

1. Inclusion of BRP MOX fuel for storage;

2. Inclusion of two UO_2 BRP assemblies that contain two inserted MOX fuel rods;

3. Inclusion of BRP partial fuel assemblies for storage;

4. Inclusion of BRP damaged fuel assemblies for storage; and

5. Increasing the permissible cobalt content up to 15g per UO_2 BRP assembly.

A brief description of the applicant's evaluation and the staff's confirmatory review on each of the changes are described below. The applicant provided supporting analyses similar to the analyses previously reviewed by the staff for the FuelSolutions™ storage system.

4.1 Inclusion of BRP Mixed-Oxide Fuel for Storage

The applicant requested that BRP MOX fuel be approved for storage in the W74 canister. There are three BRP MOX fuel assembly designs, the J2 (9x9) assembly, the DA (11x11) assembly and the G-Pu (11x11), assembly. The applicant calculated the gamma and neutron radiation sources using ORIGEN 2.1 with the BWRPUU.LIB cross-section library. The MOX fuel assembly parameters are provided in SAR Table 5.5-1 and TS Table 2.1-8. The applicant compared the source terms from the three BRP MOX assembly types with that of design basis BRP UO_2 fuel. This comparison is presented in Table 5.5-2 of the SAR. Table 5.5-2 demonstrates that the BRP MOX fuel assembly source term is bounded by the design basis BRP UO_2 fuel.

The staff reviewed the source terms calculated by the applicant. For confirmatory analyses, the staff calculated independent source terms using SAS2H/ORIGEN-S sequences of the SCALE 4.4 code. The staff used the 238 group ENDF/B-V cross-section set. A comparison between the applicant's results and the confirmatory calculations showed a variation in the results which is expected when two different codes with different cross-section libraries are used for calculating the source term. Overall, the differences between the applicant's and confirmatory results fell within acceptable bounds. In addition, both the applicant's and confirmatory results were well bounded by the design basis UO_2 BRP assembly. Staff verified that all fuel assembly parameters important to shielding have been included in the Technical Specifications (TS) .

The staff agrees that BRP MOX fuel assemblies are acceptable for storage in the FuelSolutions™ storage system.

4.2 Inclusion of Two UO_2 BRP Assemblies Containing Two MOX Fuel Rods

The applicant requested that two UO_2 fuel assemblies each containing two MOX fuel rods be approved for storage in the W74 canister. The applicant stated that these assemblies are acceptable for storage since these assemblies are bounded by the design basis UO_2 BRP source terms. These assemblies are UO_2 fuel and each have only two MOX rods out of a total of 77 rods. The two assemblies will have a cooling time of over 25 years at the time of loading and their burnups were under 20 GWd/MTU.

The staff reviewed the applicant's justification. The staff agrees that two fuel assemblies as described in Section 5.5.2 are bounded by the design basis UO_2 fuel. The staff has reviewed the TS provided in Chapter 12 and found that the applicant has limited the TS to only permit storage of these two assemblies. The staff concludes that storing these two assemblies is acceptable in the FuelSolutions™ storage system.

4.3 Inclusion of BRP Partial Fuel Assemblies

The applicant requested that partial fuel assemblies be approved for storage in the W74 canister. The shielding analysis for the FuelSolutions™ storage system assumes combinations of burnup, cooling time and initial enrichment along with a maximum assembly uranium loading of 0.1421 MTU/assembly. The applicant performed shielding sensitivity calculations which demonstrated that increases in the gamma and neutron source strengths result in an increase in surface dose rates, despite the increase in assembly self-shielding due to the increase in uranium mass. The applicant concluded that partial fuel assemblies produce lower external dose rates than intact fuel assemblies.

The staff performed confirmatory shielding calculations using the SAS2H module of the SCALE4.4 code. The staff determined that the loss of assembly self-shielding was off-set by the loss in source strength. The staff determined that intact assemblies are bounding. The staff concludes that storing partial BRP fuel assemblies is acceptable in the FuelSolutions™ storage system.

4.4 Inclusion of BRP Damaged Fuel Assemblies

The applicant requested that damaged fuel assemblies be approved for storage in the W74 canister. Damaged fuel assemblies would be stored in damaged fuel cans which are loaded into the eight support tube locations in the W74 basket. The damaged fuel cans consist of stainless steel walls with borated stainless steel poison plates which provides some additional shielding. In addition, the damaged fuel is required to meet the same fuel assembly parameters and cooling times for intact BRP fuel as described in Section 2.0 of the TS. The applicant demonstrated that there are no credible normal or off-normal conditions that would produce significant loads on the assembly and, therefore, it would remain intact. Therefore, the design basis shielding analyses under normal conditions is bounding for BRP damaged fuel assembly.

There is a potential for the damaged fuel to collapse into rubble under accident conditions. The applicant considered the effects of a “pile” of damaged fuel sitting at the bottom of each damaged fuel can. The applicant reasoned that a “pile” of damaged fuel sitting at the bottom of each damaged fuel can would result in dose rates higher than originally calculated, but those dose rates would still be well below the 5000 mrem limit at the site boundary.

The staff reviewed the applicant’s justification and agrees that, under normal and off-normal conditions, the inclusion of damaged fuel assemblies in damaged fuel canisters is bounded by the design basis UO_2 fuel shielding analysis. Under accident conditions, the staff agrees that a collapse of the damaged fuel within the damage fuel can would result in an increase in the external dose rates but still remain well below the dose limits set by 10 CFR 72.106. The staff concludes that storing damaged fuel assemblies is acceptable in the FuelSolutions™ storage system.

4.5 Increasing Cobalt Content Up To 15 g per UO_2 BRP assembly

The applicant requested the inclusion of UO_2 assemblies with cobalt contents up to 15 g/assembly. The original analysis presented in the SAR limited the per assembly cobalt content to 2.9 g/assembly. The applicant scaled the previous cobalt source term by a factor of 5.172 (15 ÷ 2.9). This source term was added to the gamma group with energies between 1.0 and 1.5 MeV. The applicant then decayed the source to the appropriate decay time as presented in Table 5.2-2, Fuel Cooling Table, to limit the storage cask side dose rate to 50 mrem/hr. The applicant’s supporting analysis was similar to the shielding analysis previously reviewed by the staff.

The staff performed an independent confirmatory calculation using the SAS2H module of the SCALE4.4 code. The confirmatory analysis assumed 2.9 g/assembly cobalt content at various combinations of fuel burnup, initial enrichment, and cooling time (as defined in Table 5.2-1) and calculated side doses around 45 mrem/hr. Confirmatory analyses also considered 15.0 g/assembly cobalt content at various combinations of fuel burnup, initial enrichment, and cooling time (as defined in Table 5.2-2) and calculated side doses around 42 mrem/hr. Comparison between the applicant’s results and the confirmatory calculations shows a variation in the results which is expected when two different codes utilizing different cross-section libraries are used for calculating the source term and subsequent dose rates. Overall, the differences between the applicant’s and confirmatory results are within acceptable bounds.

The staff concludes that storing BRP UO_2 fuel with up to 15 g/assembly cobalt content, which meet the fuel cooling tables provided in Section 2.0 of the TS, is acceptable for storage in the W74 canister.

4.6 Conclusion

Based on the applicant’s shielding evaluation, as confirmed by staff analysis, the staff concludes that the changes to the contents of the FuelSolutions™ storage system do not affect the ability of the system to provide adequate protection against direct radiation from its contents under all normal, off-normal and accident conditions.

5.0 CRITICALITY

This section evaluates the applicant's criticality analyses for adding MOX, partial, and damaged fuel assemblies to the fuel categories that may be stored in the W74 canister. The staff has reviewed the amended canister design features and criticality analyses in the context of the staff's previous approval for storing fuels in the W74 canister and has performed independent calculations to verify the applicant's conclusions. The staff's evaluation confirms that the requested fuel payloads in the W74 canister meet the requirements of 10 CFR 72.24(c)-(d), 72.124, and 72.236(c) and (g) [1], yielding a maximum neutron multiplication factor (k_{eff}) that remains below 0.95 under all normal and accident conditions.

5.1 Amended Spent Fuel Contents

The staff's previous SER for the W74 canister approved the loading of up to 64 intact UO_2 assemblies of the BRP BWR fuel design classes GE 9x9, Siemens 9x9, and Siemens 11x11. That analysis identified the intact BRP Siemens 11x11 assembly, with a peak planar-average enrichment of 4.1 wt% ^{235}U, as the most reactive allowed contents. This amendment application seeks approval to add intact MOX fuel assemblies, partial assemblies of UO_2 or MOX fuel, and damaged assemblies of UO_2 or MOX fuel to the allowed BRP contents of the W74 canister. The amended canister contents include mixed payloads of 64 assemblies from all proposed categories of UO_2 and MOX fuels, including up to eight damaged assemblies. TS Tables 2.1-1 through 2.1-8 specify the amended payload contents that are addressed in this evaluation. The fuel and loading specifications considered in the criticality analyses are summarized in Tables 5-1 and 5-2 of this SER.

Table 5-1. Summary of Amended W74 Loading Specifications Affecting Criticality

Loading Spec.	W74 Canister Loading Positions	Number and Type of BRP Assemblies[2]	Initial Enrichment Limits
W74-1[1]	All	$\leq$64 intact UO_2	Peak planar-average $\leq$ 4.1 wt%
W74-2	All	$\leq$64 intact MOX	See Table 5-2 in this SER
W74-3	All	$\leq$64 partial UO_2 9x9	Peak planar-average $\leq$ 3.55 wt%
		$\leq$64 partial UO_2 11x11	Peak planar-average $\leq$ 3.6 wt%
W74-4	All	$\leq$64 partial MOX	See Table 5-2 in this SER
W74-5	Support tubes[3]	$\leq$8 damaged UO_2	Maximum pellet $\leq$ 4.61 wt%
W74-6	Support tubes[3]	$\leq$8 damaged MOX	Maximum pellet: $E_{U\text{-}235} + 0.7 \times P_{Pu} \leq 4.61\%$ [4]

(1) Previously approved fuel payloads described in TS Tables 2.1-1 and 2.1-7 and SAR Table 6.1-1.

(2) Mixed payloads totaling 64 assemblies from all BRP fuel categories are allowed in the W74 canister.

(3) Each damaged assembly must be placed in a damaged fuel can and loaded into one of the eight corner support tubes in the W74 canister.

(4) $E_{U\text{-}235}$ is the enrichment (wt% ^{235}U) of uranium in the fuel pellet. P_{Pu} is the overall weight percentage of plutonium in the heavy metal (U + Pu) of the fuel pellet.

Table 5-2. Parameters Affecting the Analyzed Reactivity of BRP MOX Fuel Assemblies

BRP MOX Assembly Type	Maximum Heavy Metal Loading (kg)	Maximum Initial Enrichment (wt%)	Representative Fuel Pin Composition Mappings
J2 (9x9)	124	Maximum pin: $^{235}U \leq 4.50$ $PuO_2 \leq 3.65$	Intact: SAR Fig. 6.6-1 Partial: SAR Fig. 6.6-5 & 6.6-6
DA (11x11)	126	Maximum pin: $^{235}U \leq 2.40$ $PuO_2 \leq 2.45$	Intact: SAR Fig. 6.6-2 Partial: N/A
G-Pu (11x11)	131	Maximum pin: $^{235}U \leq 4.60$ $PuO_2 \leq 5.45$	Intact: SAR Fig. 6.6-3 Partial: SAR Fig. 6.6-7 & 6.6-8
UO_2 (9x9) with 2 MOX rods (BRP assemblies E65 and E72)	143	Peak planar-avg: $^{235}U \leq 4.1$ (Actual pins: $^{235}U \leq 4.5$ $PuO_2 \leq 2.0$)[1]	Intact: SAR Fig. 6.6-4 Partial: N/A

(1) The two assemblies in this category are readily shown to be substantially less reactive than the most reactive intact 9x9 UO_2 assemblies without MOX rods.

Consistent with staff guidance in ISG-1[1], a fuel assembly is considered damaged if any of its fuel rods have known or suspected defects greater than pinhole leaks or hairline cracks. The application further considers a fuel assembly to be damaged if any of the grid spacers are not located in their design location or are damaged to a degree where fuel rod structural integrity cannot be assured.

SAR Figures 6.6-1 through 6.6-8 illustrate the eight fuel composition mappings that represent, either accurately or conservatively, the known rod configurations of all intact and partial MOX assemblies in the BRP spent fuel inventory. The MOX assemblies are essentially identical in geometry and dimensions to the UO_2 fuel assemblies. The uranium and plutonium isotopic fractions used in the applicant's criticality analyses for the J2, DA, and G-Pu MOX assembly types are based on the nominal and as-fabricated pre-irradiation values taken from fuel-vendor records and plant records. For the two UO_2 assemblies that contain two MOX rods each (i.e., the last MOX fuel category in Table 6-2 above), no information was readily available on the MOX plutonium isotopics and a conservative isotopic composition of 85% ^{239}Pu and 15% ^{240}Pu was assumed. The staff concurs that this assumed isotopic composition readily bounds the reactivity of all plutonium isotopic compositions in MOX fuels. The MOX isotopic compositions used in the applicant's criticality calculations are listed in SAR Table 6.6-2.

5.2 Amended Canister Design Features and Configurations

The W74 damaged fuel can is the principal new design feature considered in this amendment. The cross-section of the damaged fuel can closely resembles that of a W74 guide tube. The only difference is that the damaged fuel can has poison plates on all four walls, whereas Type A guide tubes have only two absorber plates and Type B guide tubes have just one. Drawing 3319 in SAR Section 1.5.1 details the design of the damaged fuel can. Screened top and bottom closures serve to contain any gross fuel fragments arising in accidents while allowing the free flow of water to and from the can during wet loading/unloading operations and under postulated accident conditions with internal flooding. TS Tables 2.1-5 and 2.1-6 specify that only damaged, partial, or intact fuel assemblies may be placed in the damaged fuel cans; fuel debris or loose rods are not allowed. Analyses presented in SAR Section 6.6.3.4 confirm that moderation configurations resulting from postulated uneven flooding or draining of the corner-loaded damaged fuel cans (e.g., due to assumed clogging of screens with accident debris) are no more reactive than cases with uniform flooding. The staff agrees that the design of the W74 damaged fuel can provides reasonable assurance that the ranges of credible fuel configurations resulting from normal and accident conditions are no more reactive than those considered in the applicant's analysis.

A minor change has been introduced in how the neutron poison loading of the borated stainless steel absorber plates is specified. This change consists of modifying TS 4.1.3.1 to specify that the absorber plates must have a poison areal density (PAD) no less than 3.1 mg ^{10}B/cm^2. Under the previously approved specifications, which addressed a 1.0 wt% or 1.25 wt% minimum boron concentration in the plate material, but not the resulting PAD, applying worst-case tolerances on all absorber plate parameters would have led to deriving a minimum PAD of 2.9 g ^{10}B/cm^2 for use in the licensing basis criticality analysis. The amended specification increases the minimum PAD to 3.1 g ^{10}B/cm^2. The staff has confirmed that SAR Section 9.1.6 has added a matching acceptance testing criterion for confirming the minimum PAD. As in the previously approved W74 analysis, the applicant's criticality calculations take no more than 75%

credit for the minimum poison loading of the absorber plates. This conservative modeling treatment is consistent with specific recommendations in NUREG-1536[2].

5.3 Analysis Methods and Models

The computational methods used in the applicant's criticality analysis for this amendment are consistent with those used in the previously approved analysis for the W74 canister. The applicant's calculations again made use of the MCNP-4a code and its pointwise cross-section library derived mainly from the evaluated nuclear physics data found in ENDF/B-V. The NRC staff's independent calculations for this amendment analysis employed the MONK8a code with its quasi-pointwise cross-section library (13,193 energy groups) derived from the JEF2.2 file of evaluated nuclear physics data.

The configurations of canister and cask components considered in the applicant's analyses for this amendment are similar but not identical to those considered in the previously approved analyses for BRP intact UO_2 fuels. The W74 canister contains two essentially identical stacked baskets, each holding up to 32 fuel assemblies. SAR Figure 6.3-1 illustrates the basket computational model used in the previous analyses for payloads of intact UO_2 fuel assemblies. Two new basket models are used in the calculations for this amendment: (1) an "accurate" model, illustrated in SAR Figure 6.3-2, which is used for analyzing all payloads of MOX and/or damaged fuel assemblies; and (2) a "conservative" model, shown in SAR Figure 6.3-3, which is used for analyzing payloads of partial UO_2 assemblies.

Table 5-3 of this SER summarizes the assumed nominal parameters applied to each of the three basket models. Where needed for comparisons or evaluation of mixed payloads, the applicant's and staff's analyses also include cases in which the "accurate" model is applied to intact and partial UO_2 assemblies. The staff's independent calculations with payloads of partial UO_2 assemblies show that the "conservative" basket model gives computed k_{eff} values about 1 percent higher than the "accurate" model (i.e., $\Delta k/k = 0.0107 \pm 0.0011$). The staff's analyses with intermediate models attribute over half of this reactivity increase to the effects of reducing the specified absorber plate poison loading to 2.5 mg $^{10}B/cm^2$. These results are consistent with the applicant's calculated k_{eff} results reported in SAR Sections 6.6.2.2 and 6.6.3.3.

Table 5-3. Nominal Parameters in the Applicant's Analysis Models of the W74 Baskets

	Previous Model, SAR Fig. 6.3-1	"Accurate" Model, SAR Fig. 6.3-2	"Conservative" Model, SAR Fig. 6.3-3
W74 BRP Payload Applications	Intact UO_2 assemblies	All MOX and damaged assemblies	Partial UO_2 assemblies
Specified Absorber Plate PAD (1) [Boron Concentration]	2.5 mg $^{10}B/cm^2$ [1.0 wt% B]	3.1 mg $^{10}B/cm^2$ [1.25 wt% B]	2.5 mg $^{10}B/cm^2$ [1.0 wt% B]
Number of Neglected Absorber Plates	4 per basket (2)	None	4 per basket (2)
Thickness of Support Tube Walls	0.75 in	0.75 in	0.625 in
X=Y Coordinates of Support Tube Holes in Spacer Plates	17.5 in	17.65 in	17.5 in

(1) All models take 75% credit for the indicated poison areal density (PAD).
(2) A Type B fuel tube is modeled in place of a Type A fuel tube at four loading positions adjacent to the four support tubes.

As recommended in NUREG-1536, all analysis models apply worst-case dimensional tolerances to the stated nominal dimensions. The worst-case dimensional tolerances are listed in SAR Table 6.3-2. The staff has confirmed that all computational models used in the criticality analyses for this amendment appropriately account for worst-case material and dimensional tolerances in the W74 baskets.

As in the previously approved analyses for the W74 canister, the applicant's accident models consider transportation configurations corresponding to the hypothetical accident conditions defined in 10 CFR 71.73. Although the hypothetical accident conditions apply to transportation packages, the staff concurs with the applicant's determination that the maximum k_{eff} values computed for the assumed transportation accident configurations conservatively bound all values of k_{eff} computed for storage. More specifically, the evaluated transportation accident configurations are readily shown to be more reactive than all storage configurations arising in the structural and thermal analyses for normal, off-normal, and accident conditions of storage. The staff further agrees that the applicant's criticality analyses for storing BRP fuels in the W74 canister are technically consistent with the guidance and recommendations found in NUREG-1617[3] and NUREG/CR-5661[4].

SAR Figure 6.3-14 illustrates the most reactive analyzed pattern of spacer plate opening tolerances and lateral shifting of fuel tubes and fuel assemblies within the openings. The applicant's calculations for intact UO_2 fuels show this asymmetric pattern to be more reactive than the two patterns illustrated in SAR Figures 6.3-12 and 6.3-13. This result has been confirmed by the staff's independent calculations for a W74 payload of partial UO_2 assemblies. The staff's calculations have also evaluated an additional pattern of spacer plate tolerances and fuel shifting and found it to be no more reactive than that shown in SAR Figure 6.3-14. The applicant's and staff's models for accident conditions have also enlarged the maximum-tolerance widths of the spacer plate openings by 0.08 inches to conservatively account for the reduced assembly-to-assembly spacings made possible by the maximum permanent material deformations arising from postulated cask drop and tip-over accidents.

The analyzed configurations further assume that a drop accident detaches the fuel tubes from the basket internals and that the tubes and fuel are free to shift axially in opposite directions. The worst-case configuration arises in the top basket, with all fuel assemblies resting on the floor of the basket's fuel cavity and the tops of all fuel tubes deformed and stuck to the cavity ceiling. As illustrated in SAR Figure 6.3-10, this configuration is conservatively assumed to locate the bottom of the active fuel 1.63 inches below the bottom of the absorber plates on each fuel tube.

The applicant conducted specific test cases aimed at demonstrating adequate sampling and source convergence. These included: (1) increasing the number of neutrons per generation, (2) increasing the number of generations discarded before accumulating the tallies for k_{eff}, and (3) confining the starting-source estimate to the bottom segments of fuel below the absorber plates and comparing the converging axial source profile and k_{eff} results to those obtained with a standard starting source estimate (i.e., uniform in all fissile regions). The staff checked the applicant's MCNP4a test results and conclusions of adequate source convergence by conducting similar test cases with its own MONK8a computational models. The staff's test calculations were performed both with and without activating MONK8a's "superhistory powering" algorithm, thereby, spanning the range of convergence behaviors expected with the counterpart algorithm used in MCNP4a. The staff's case studies showed significant convergence acceleration with MONK8a's default superhistory algorithm turned on and confirmed the adequacy of the slower source convergence achieved without the acceleration algorithm, with either starting-source estimate, using 2000 neutrons per generation and 50 generations discarded. The staff's convergence study results and conclusions, therefore, corroborate those of the applicant.

5.4 Payload Analyses

As in the earlier W74 analyses for payloads of intact UO_2 assemblies, the current analyses assume flooding of the canister and fuel rods by unborated water and conservatively model all irradiated fuels as though they were unirradiated and without burnable poisons. The reduced reactivity of irradiated fuels and the absence of water in the W74 canister after closure will, therefore, generally lead to actual subcritical safety margins that are substantially larger than those calculated in the licensing-basis safety analyses for normal and accident conditions.

The following subsections summarize the staff's evaluations of the applicant's criticality analyses for the respective BRP payload categories in the W74 canister.

Intact and Partial MOX Assemblies

The analyses presented in SAR Section 6.6.1.1 use explicit models based on the detailed fuel rod mappings shown in SAR Figures 6.6-1 through 6.6-8, which exactly or conservatively represent every intact and partial MOX fuel assembly in the BRP spent fuel population. The explicit calculation results shown in SAR Table 6.6-3 show that all payloads of the MOX assemblies J2, DA, and G-Pu are much less reactive than the limiting UO_2 payload. In all cases, the MOX payloads have k_{eff} values 6.6 to 12.4 percent lower than the UO_2 payloads.

The staff notes that these calculations for intact and partial MOX assemblies assume unirradiated fuel compositions without burnable poisons, but do take credit for the decay of fissile ^{241}Pu to nonfissile ^{241}Am over the years prior to cask loading. With a ^{241}Pu half-life of roughly 15 years ($T_{½}$=14.35 years) and a stated minimum MOX cooling time of 15 years, the calculations assume that half of the as-fabricated ^{241}Pu content has decayed to ^{241}Am.

The staff's independent calculations have included supplementary cases with no credit for ^{241}Pu decay and no credit for absorption by ^{241}Am. In all cases, the affected MOX assembly types (J2, DA, and G-Pu) remain much less reactive than the limiting UO_2 assemblies; i.e., only part of the large reactivity differences between BRP MOX and UO_2 assemblies can be attributed to ^{241}Pu decay and ^{241}Am buildup. Thus, the staff's calculations show that the overall conclusions from the applicant's criticality analyses do not depend on crediting the decay of ^{241}Pu to ^{241}Am. This fact is further considered in the staff's evaluation of the applicant's MOX benchmark analysis.

Partial UO_2 Assemblies

Analyses presented in SAR Section 6.6.2.1 show that removing one fuel rod from one or more corners of an intact UO_2 fuel assembly always decreases the assembly's in-cask reactivity. Assemblies with missing corner rods may therefore be conservatively defined and analyzed as intact. The peak planar-average enrichment limit of 4.1 wt% therefore applies to assemblies with missing corner rods.

Removing rods from array-interior locations generally increases the reactivity of undermoderated fuel lattices. As in the analysis of intact UO_2 assemblies, the applicant's analysis of partial assemblies treats the multiple-enrichment BWR assemblies as having a uniform enrichment equal to the peak planar-average enrichment of all fuel rods present in the assembly. Such simplified models are generally shown to be slightly more reactive than explicit models of multiple rod enrichments.

The analysis in SAR Section 6.6.2.2 further simplifies the identification and modeling of the most reactive pattern and number of missing rods by using a model that conservatively maintains a uniform pitch between all remaining rods. For example, to bound the most reactive 11x11 assembly with missing interior rods, the applicant's analysis removes rods by row, leaving a 10x10, then 9x9 array, etc., and spreading the rod pitch in increments to fill the original volume of the intact assembly. This is done until a maximum k_{eff} is found at a rod pitch and array size with optimum moderation and leakage.

The applicant's models for assessing the optimum rod pitch and array size consider a single assembly reflected by water. The results can be expressed as an optimum H-to-^{235}U ratio, which in SAR Table 6.6-11 is reported to be 139.6 for GE 9x9 and 146.3 for Siemens 11x11. The applicant illustrates the conservatism of the resulting models by showing the single assemblies to be significantly more reactive than realistic partial-assembly models with optimum numbers of rods moved from selected array locations. The staff has directly confirmed the conservatism of the applicant's fuel models through in-cask payload calculations comparing the k_{eff} values computed with the optimum-pitch models against those with realistic models of optimum partial assemblies. Consistent with the applicant's analysis, the staff's realistic models of optimum partial assemblies show the in-cask k_{eff} to be maximized when 20 to 33 rods are removed in uniform patterns from the 9x9 and 11x11 assembly arrays.

Combining this conservative partial assembly model with the "conservative" model of the W74 baskets (i.e., see Table 6-3 in this SER) leads to conservative peak planar-average enrichment limits of 3.55 wt% for GE 9x9 and 3.6 wt% for Siemens 11x11 partial assemblies. The staff agrees that the applicant's analysis approach bounds with large margins the reactivities in W74 payloads of partial UO_2 assemblies.

Damaged UO_2 Assemblies

The analysis of damaged BRP fuel assemblies, loaded inside damaged fuel cans within some or all of the eight W74 corner support tubes, is described in SAR Section 6.6.3. The highly conservative damaged fuel model considers optimally moderated arrays of fresh, poison-free fuel pellets, approximated as spheres, filling the damaged fuel can volume. The optimally suspended fuel pellet array represents a bounding rearrangement of conservatively modeled (fresh) fuel materials inside a flooded damaged fuel can.

The optimization analysis results give an optimum H-to-^{235}U ratio of 180 for UO_2 pellets at the maximum 4.6 wt% enrichment. This bounding damaged fuel configuration is then assumed in all eight support tube locations, with the remaining 56 fuel tubes containing the most reactive allowed loadings of intact or partial UO_2 assemblies. The staff's analyses confirm the applicant's conclusion that the bias-adjusted k_{eff} of this conservative payload model remains below 0.95 under bounding accident conditions.

Damaged MOX Assemblies

Described in SAR Section 6.6.3.5, the analysis approach for damaged MOX assemblies is essentially identical to that for damaged UO_2 assemblies. The only difference is in the fuel composition considered. The analyses address several combinations of uranium enrichment and plutonium concentration, assuming a conservative plutonium isotopic composition of 85% ^{239}Pu and 15% ^{240}Pu. The evaluated compositions obey the formula: $E_{U\text{-}235} + 0.7 \times P_{Pu} \leq 4.61\%$, where $E_{U\text{-}235}$ is the ^{235}U enrichment (wt%) of uranium in the fuel pellet and P_{Pu} is the overall weight percentage of plutonium in the heavy metal (U + Pu) of the fuel pellet. This arbitrary formula was selected to bound all BRP MOX materials. The limiting intact UO_2 payloads, with these compositions of MOX fuel pellets optimally suspended in water in the damaged fuel cans, are shown to give a maximum bias-adjusted k_{eff} below 0.95.

The applicant's and staff's analyses show the computed payload values of k_{eff} to be only weakly sensitive to the assumed contents of the damaged fuel cans. This weak sensitivity can be explained in part by noting that the damaged fuel cans occupy just 8 of the 64 canister loading positions. Furthermore, the neutronic interactions between damaged fuel can contents and the rest of the payload are reduced by the peripheral location of the eight damaged fuel loading positions and by the absorption of neutrons in the can's absorber plates and support tube walls.

5.5 MOX Benchmark Analysis

SAR Section 6.5 describes the benchmark analysis for a set of 49 critical experiments shown to be applicable for validating the k_{eff} calculations for the previously approved W74 payloads of UO_2 assemblies. SAR Section 6.6.1.2 extends that benchmark analysis to include 24 MOX critical experiments relevant for validating the calculations for the requested MOX payloads. The staff's independent analyses show that eliminating credit for ^{241}Am buildup (and ^{241}Pu decay) does not alter the overall conclusion that the affected MOX payloads are much less reactive than the limiting payloads of UO_2 fuels. The staff agrees that the expanded set of benchmark experiments is adequate for validating the MOX calculations, as used to support the specific conclusions in this amendment.

The applicant has stated that the benchmarks were applied to the same release of MCNP4a and the same cross-section library as used in the licensing-basis calculations. To account for the method biases and uncertainties revealed in the benchmark results, the applicant again applied the approved technique used with the earlier UO_2 benchmark analyses, i.e., upper safety limit (USL) Method 1 as described in Section 4 of NUREG/CR-6361[5]. The staff agrees that the applicant has correctly applied Method 1 in deriving conservative USL values appropriate for each BRP payload in the W74 canister.

5.6 Conclusion

Based on the staff's review of the amended SAR W74 canister and the staff's confirmatory analyses, the staff concludes that the criticality design features of the W74 canister of the FuelSolutions™ storage system are in compliance with 10 CFR Part 72 and that the applicable design and acceptance criteria have been satisfied. The evaluation of the criticality safety design provides reasonable assurance that the storage system will allow safe storage of spent fuel. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

6.0 CONFINEMENT EVALUATION

The following requested changes required an update of the confinement analyses for the W74 canister:

1. Inclusion of BRP MOX fuel for storage; and

2. Inclusion of BRP damage fuel assemblies for storage.

A brief description of the applicant's evaluation and the staff's confirmatory review on each of the changes are described below. The applicant provided supporting analyses similar to the analyses previously reviewed by the staff for the FuelSolutions™ storage system.

All other requested changes to the canister contents resulted in no effect on the confinement analyses and are not discussed in this Section.

6.1 Inclusion of BRP Mixed-Oxide Fuel

The applicant requested that MOX fuel be approved for storage in the W74 canister. There are three MOX fuel assembly designs, the J2 (9x9) assembly, the DA (11x11) assembly and the G-Pu (11x11) assembly. In Table 7.4-2 of the SAR, the applicant provides the isotopic activity of the three MOX fuel designs as well as the isotopic activity of the design basis BRP UO_2 fuel. The applicant compared the isotopic activity of the MOX fuel against the design basis fuel and found that the design basis fuel is bounding for all isotopes with the exceptions of Am-241 and Cm-241. In Section 7.4.2.1 of the SAR, the applicant states that the increases in these two isotopes are off-set by the decrease in all other isotopes, especially Co-60 from crud. The applicant concludes that the inclusion of MOX fuel in the W74 canister has no effect on off-site airborne doses.

The staff performed confirmatory analyses. Using the SAS2H/ORIGEN-S sequence of the SCALE4.4 code, the staff calculated the isotopic activity of the MOX fuel assembly designs and the UO_2 design basis fuel. The staff used the 238 group ENDF/B-V cross-section library. A comparison between the applicant's results and the staff's confirmatory calculations showed a variation in the results which is expected when two different codes with two different cross-section libraries are used for calculating a source term. Overall, the differences between the applicant's and confirmatory results fell within acceptable bounds. The staff's confirmatory calculations also demonstrated that the UO_2 design basis fuel is bounding for all isotopes with the exception of Am-241 and Cm-241. The staff performed confirmatory calculations using the methodology of ISG-5[6]. The staff agrees that the increases in the Am-241 and Cm-241 concentrations are off-set by the decrease in Co-60 and the other isotopes. The off-site dose rates from the MOX fuel are bounded by those calculated for the UO_2 design basis fuel described in the FuelSolutions™ SAR.

6.2 Inclusion of BRP Damaged Fuel Assemblies

The applicant requested that damage fuel assemblies be approved for storage in the W74 canister. Damaged fuel assemblies would be stored in damaged fuel cans which are loaded into one of the eight support tube locations in the W74 basket. The damaged fuel cans are screened on each end.

The applicant, through both utility documentation and fuel inspection, estimates that 3% of the rods of the fuel assembles are damaged prior to loading. The applicant conservatively increased the number of damaged rods to 10% as an upper bound in the analysis. The presence of failed fuel rods will contribute to the doses from fuel fines. The presence of failed fuel rods has no effect on the off-site airborne doses from fission gases, volatiles and CRUD. The applicant reviewed their normal and off-normal confinement analyses and considered the effects of storing damaged fuel in the W74 canister. Accidents were not evaluated because they assumed 100% of the rods have failed. In Section 7.2.1.1 of the SAR, the applicant states, based on design basis fuel, the contribution to the overall dose from the fuel fines is minimal. The applicant concludes that the overall number of failed fuel assemblies stored within the W74 is low and the additional dose from the fuel fines will have an insignificant effect on the overall airborne off-site dose.

The staff reviewed the applicant's analysis and agrees that damaged fuel assemblies do not have a significant impact on the off-site airborne doses from the package. The staff performed confirmatory analyses using the methodology of ISG-5 assuming that eight fuel assemblies have 10% damaged rods prior to loading. The staff's confirmatory analysis agrees with the applicant's conclusion that storage of damaged fuel assemblies does not have a significant impact on off-site airborne doses.

6.3 Conclusion

The staff concludes that BRP MOX fuel assemblies are acceptable for storage in the FuelSolutions^{TM} storage system. The staff agrees that damaged BRP assemblies are acceptable for storage in the FuelSolutions^{TM} storage system.

7.0 CONDITIONS FOR CASK USE - OPERATING CONTROLS AND LIMITS OR TECHNICAL SPECIFICATIONS

The proposed certificate changes for this amendment are as follows:

1. The following TS Tables have been added or revised for this amendment:

   Table 2.1-1 Specification for Intact UO_2 Fuel Assemblies
   Table 2.1-2 Specification for Intact MOX Fuel Assemblies
   Table 2.1-3 Specification for Partial UO_2 Fuel Assemblies
   Table 2.1-4 Specification for Partial MOX Fuel Assemblies
   Table 2.1-5 Specification for Damaged UO_2 Fuel Assemblies
   Table 2.1-6 Specification for Damaged MOX Fuel Assemblies
   Table 2.1-7 UO_2 Fuel Assemblies Acceptable for Storage in W74 Canister
   Table 2.1-8 MOX Fuel Assemblies Acceptable for Storage in W74 Canister
   Table 2.1-9 Fuel Cooling Table, low-cobalt
   Table 2.1-10 Fuel Cooling Table, high-cobalt

2. Section 4.1.3.1 Criticality was revised to specify the minimum boron content of the basket neutron absorber material.

The staff has reviewed these changes, as discussed in the SER, and have found them to be acceptable.

REFERENCES

1. Interim Staff Guidance (ISG) - 1, "Damaged Fuel," November 1998.

2. NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems," Revision 1, U.S. Nuclear Regulatory Commission, March 2000.

3. NUREG-1617, "Standard Review Plan for Transportation Packages for Spent Nuclear Fuel," U.S. Nuclear Regulatory Commission, March 2000.

4. NUREG/CR-5661, “Recommendations for Preparing the Criticality Safety Evaluation of Transportation Packages,” Dyer, H.R., and Parks, C.V., prepared by Oak Ridge National Laboratory for the U.S. Nuclear Regulatory Commission, April 1997.

5. NUREG/CR-6361, “Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages,” Lichtenwalter, J.J., etal., prepared by Oak Ridge National Laboratory for the U.S. Nuclear Regulatory Commission, March 1997.

6. Interim Staff Guidance (ISG) - 5, “Confinement Evaluation,” May 1999.

CONCLUSION - EVALUATION FINDINGS

The staff has reviewed the FuelSolutions™ storage cask system amendment application, as supplemented, including the engineering analyses, proposed SAR revisions, and other supporting documents submitted with the application. Based on the information provided in the application, as supplemented, the staff concludes that the FuelSolutions™ storage cask system, as amended, meets the requirements of 10 CFR Part 72.

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