UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION REPORT
Docket No. 71-9319
Model Nos. MAP-12 and MAP-13
Certificate of Compliance No. 9319
Revision No. 13

SUMMARY

By letter dated March 31, 2021 (Agencywide Documents Access and Management System Accession No ML21090A322), Framatome Inc., (or the applicant) requested an amendment to Certificate of Compliance (CoC) No. 9319 for the MAP packaging.

The applicant increased enrichment to less than or equal to 8.0 weight percent uranium-235 (^{235}U) and added a 17x17 Type 3 fuel design to the authorized contents. For fresh fuel assemblies containing sintered uranium dioxide fuel pellets enriched up to and including 5.0 weight percent ^{235}U, the Criticality Safety Index (CSI) for the MAP is 2.8. For fresh fuel assemblies containing sintered uranium dioxide fuel pellets enriched between 5.0 and up to 7.0 weight percent ^{235}U, the CSI for the MAP is 8.4. For enrichments above 7.0 and up to 8.0 weight percent ^{235}U, the CSI for the MAP is 25.0. Only the 17x17 Type 3 fuel assemblies were evaluated for the higher enrichment for which gadolinium is required, as a neutron absorber, based on a graded approach versus the uranium enrichment value.

The staff reviewed the application and determined that the changes do not affect the ability of the package to meet the requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 71. The certificate has been updated to Revision No. 13.

EVALUATION

The applicant corrected a few errors found in the previous revision of the Safety Analysis Report, including the (i) total activity value for U^{238} from 3.03 10^{-1} Ci to 3.18 10^{-1} Ci for the ≤ 5.0 wt.% ^{235}U section, and (ii) the gamma emitters value to 6.38 MeV-Bq/kgU from 6.46 MeV-Bq/kgU.

The applicant discussed in Section 2.11 the new 17x17 Type 3 fuel design and compared it to the structural test conditions. The applicant also added a discussion of decay heat for the new contents. Sections 4.2.1.2, 4.2.3, and 4.3.2.2, were revised to calculate the maximum allowable leakage rate to reflect the applicable enrichment range; the latest version of ANSI N14.5-2014 is now referenced in the containment chapter of the application.

The staff also reviewed the updated drawing (Drawing 02-9045401) for the MAP-12/13 package. The staff determined that the drawing changes were limited clarifications, i.e., bottom to top of door hinge height from (21.6) to (21.5) at Zone A-8; FWD end door location from (2.37) to (2.38) at Zone B-8; adding for completeness a 4X fillet weld callout at Zone A-4 as it was inadvertently missing on its previous version. The staff determined that the revised drawings

were consistent with the guidance in NUREG/CR-5502 and contain material specifications, dimensions and tolerances, welding specifications and nondestructive examination requirements.

The staff reviewed the applicant's justifications for allowing a trace amount of material as defined in Table 1 and Table 2 of this CoC, and finds the justifications presented to be acceptable. Although the pregnancy of some of the isotopes, e.g. U-232, in the slightly contaminated uranium will elevate the A_2 value and the radiation sources, the limits in Tables 1 and 2 are to be applied at the time of shipment, thus not allowing a significant amount of time for the build-up of high gamma emitting daughter products. It is unrealistic to specify radionuclide values exactly at the time of shipment because radioactive daughters are constantly building up; therefore, a trace amount of contaminants is accounted for within the allowable gamma source and this amount will not cause a significant increase in the A_2 value and radiation sources. Based on this reason, the staff determines that the trace amount of material, as defined in Tables 1 and 2 of the CoC, will not impose significant additional impacts on the safety of the package with respect to the containment and shielding design, and the package will continue to meet the respective parts of the regulatory requirements of 10 CFR Part 71. The trace amount of fissile isotopes, as specified in Table 1, will not also cause significant changes to the neutron multiplication factor, k_{eff}, because their quantities are negligible with respect to the criticality safety of the package.

The applicant requested to modify the Certificate of Compliance (CoC) for the Model No. MAP 12/13 package to authorize 17x17 Type 3 pressurized water reactor (PWR) fuel assemblies, with uranium oxide (UO_2) fuel enriched up to 8.0 weight percent in ^{235}U (wt.%). Table 1-5 of the SAR includes 17x17 Type 3 fuel design parameters, and new Table 1-6 gives the gadolinium oxide (Gd_2O_3) requirements for 17x17 Type 3 fuel assemblies enriched above 5.0 wt.%. The applicant also determined new Criticality Safety Indexes (CSIs) for 17x17 Type 3 fuel assemblies enriched to greater than 5.0 wt.%, based on fuel enrichment and the required number of Gd_2O_3 rods. The CSI for the MAP 12/13 package is 8.4 for 17x17 Type 3 fuel enriched up to 6.0 wt.% with 4 Gd_2O_3 rods, up to 6.5 wt.% with 8 Gd_2O_3 rods, or up to 7.0 wt.% with 10 Gd_2O_3 rods. The CSI for the MAP 12/13 package with 17x17 Type 3 fuel enriched up to 8.0 wt.% with 12 Gd_2O_3 rods is 25.

The applicant revised the SAR for the MAP 12/13 package to include a new Appendix 6.11, which evaluates criticality safety of the package containing 17x17 Type 3 PWR fuel assemblies enriched up to 8.0 wt.%. The applicant listed the fuel parameters important to criticality safety in Table 6-3 of the SAR. All of the fuel materials are identical to the previously approved PWR fuel assembly materials, with the exception of the Gd_2O_3 required for UO_2 enriched to greater than 5.0 wt.%. The Gd_2O_3 requirements as a function of fuel enrichment are given in Table 6-2 of the SAR. The minimum concentration of Gd_2O_3 required in each required rod is 2.0 weight percent Gd_2O_3. The applicant conservatively modeled the Gd_2O_3 at 75% of the minimum required concentration, or 1.5 weight percent Gd_2O_3, consistent with the recommendation for neutron absorber credit in NUREG-2216, "Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material."

The MAP 12/13 packaging materials are unchanged from the previously approved design. The staff reviewed the materials properties for the new fuel assembly design and enrichment levels and finds that these properties are appropriate or conservative as represented in the criticality model of the package.

For rods that include Gd_2O_3, the applicant modeled the length of Gd_2O_3/UO_2 as 126 inches, since many fuel assemblies will have up to 12-inch blanket regions on the top and bottom of the fuel assembly with only UO_2 and no Gd_2O_3. To determine the most reactive configuration of required Gd_2O_3 rods in the assembly, the applicant modeled multiple patterns intended to conservatively decrease the effectiveness of the Gd_2O_3 in the fuel. The applicant evaluated symmetric and asymmetric Gd_2O_3 rod patterns, as shown in Tables 6-5 and 6-6 of Appendix 6.11. In general, rod patterns that group Gd_2O_3 rods close together, and near the periphery of the fuel assembly are more reactive. The patterns evaluated by the applicant are not meant to represent actual Gd_2O_3 rod patterns used in fuel assemblies (e.g., Gd_2O_3 rods are not typically grouped in one quadrant or placed in a peripheral row) but are meant to reasonably bound expected Gd_2O_3 rod patterns in terms of maximum fuel assembly reactivity.

The applicant discusses the results from the Gd_2O_3 rod pattern evaluation in Section 6.5 of Appendix 6.11 of the SAR. The applicant determined the most reactive patterns to be those with Gd_2O_3 rods clustered close together and moved close to the periphery of the fuel assembly (Pattern 1 from Table 6-5 for 6.5 wt.% fuel with 8 Gd_2O_3 rods, Pattern D from Table 6-6 for 7.0 wt.% fuel with 10 Gd_2O_3 rods, and Pattern D from Table 6-6 for 8.0 wt.% fuel with 12 Gd_2O_3 rods). The staff noted that the configuration with 6.0 wt.% and four Gd_2O_3 rods is bounded by the configuration with 6.5 wt.% fuel and eight Gd_2O_3 rods. The staff reviewed the applicant's evaluation of Gd_2O_3 rod configurations and finds that the applicant has identified the most reactive configuration of Gd_2O_3 rods for each enrichment range considered in the application.

The applicant modeled the MAP 12/13 package using fuel assembly and packaging parameters found to be most reactive for the previously approved contents under normal conditions of transport and hypothetical accident conditions. Since the 17x17 Type 3 fuel assemblies include credit for Gd_2O_3 in the criticality analysis, the applicant performed a series of sensitivity analysis to determine the most reactive fuel and package parameters. The applicant's results confirmed the previously determined parameters continue to be the most reactive.

These sensitivity studies, discussed in Section 6.7 of Appendix 6.11 of the SAR, include partial and preferential flooding of the package, interspersed moderation variation between packages, Gd_2O_3 rod lattice orientation within the package, and package array size and orientation. For the flooding variation and package array orientation, the results of the sensitivity studies confirmed that the most reactive configuration (combination of flooding and orientation variables) for the 17x17 Type 3 fuel assembly contents is the same configuration determined from the applicant's previous evaluation as being the most reactive configuration. For Gd_2O_3 rod lattice orientation, the applicant found that the package was most reactive when the lattice is oriented such that the Gd_2O_3 rods are near the bottom of the package, in the "W" shaped configuration of the plates in the bottom of the fuel cavity. The staff reviewed the applicant's criticality model configuration and sensitivity studies performed by the applicant to find the most reactive configuration and finds that the applicant has identified the most reactive configuration of the package under normal conditions of transport and hypothetical accident conditions for the 17x17 Type 3 fuel assembly.

For the single package evaluation, the applicant evaluated the package under normal conditions of transport with no water in-leakage and with a full 30-centimeter (cm) water reflector. This is consistent with the package configuration used to evaluate the previously approved fuel contents. As expected, resulting k_{eff} values are very low, less than 0.3 for all enrichment ranges, since the package is very under-moderated under normal conditions of transport. For the single package under hypothetical accident conditions, the applicant evaluated the package with all floodable void spaces, including the fuel assembly contents, flooded with full density

water, and with a 30-cm water reflector outside the package. The resulting maximum reported k_{eff} value under hypothetical accident conditions was 0.9079 for 8.0 wt.% fuel with 12 Gd_2O_3 rods. This result bounds the single package with water in-leakage required to be evaluated under 10 CFR 71.55(b). For all single package models, the maximum reported k_{eff} values are well below the applicant's calculated Upper Subcritical Limit (USL) of 0.93088, determined in Section 6.8 of Appendix 6.11 of the SAR. The staff reviewed the applicant's single package evaluations and finds that the applicant has demonstrated that a single package with water in-leakage is subcritical per 10 CFR 71.55(b), and that a single package is subcritical under normal conditions of transport and hypothetical accident conditions per 10 CFR 71.55(d) and (e), respectively.

For package arrays under normal conditions of transport, the applicant modeled infinite arrays of the package containing 17x17 Type 3 fuel assemblies with the enrichment ranges and required number of Gd_2O_3 rods described previously. The applicant modeled the package with a dry inner container cavity, and with either flooded or dry outer container zones. The maximum k_{eff} value reported for the normal conditions of transport model is 0.3747 for the package with 8.0 wt.% fuel with 12 Gd2O3 rods, which is well below the USL of 0.93088.

For package arrays under hypothetical accident conditions, the applicant evaluated finite arrays of packages, with differing numbers of packages depending on fuel enrichment. For 7.0 and 6.5 wt.% fuel, the applicant evaluated an array of 12 packages, and for 8.0 wt.% fuel, the applicant evaluated an array of 4 packages (see Figure 6-3 of Appendix 6.11 of the SAR). The applicant modeled all packages with a flooded fuel cavity and voided outer cavity and modeled the array with a 30-cm water reflector. This flooding configuration was previously determined by the applicant to maximize neutron interaction between packages, and the applicant's result confirmed it remains the most reactive configuration for the 17x17 Type 3 fuel assembly design in the sensitivity analyses in Section 6.7 of Appendix 6.11 of the SAR. The maximum k_{eff} value reported for the hypothetical accident conditions model is 0.9306 for an array of 4 packages with 8.0 wt% fuel with 12 Gd2O3 rods. This k_{eff} is below the USL of 0.93088.

The applicant determined the CSI for the MAP 12/13 package with 17x17 Type 3 fuel assembly contents according to the requirements for package arrays in 10 CFR 71.59. Since the applicant demonstrated that infinite arrays of packages are subcritical under normal conditions of transport, the limiting array is for the package under hypothetical accident conditions. For packages containing 17x17 Type 3 fuel assemblies enriched to 7.0 wt.% or less, the applicant demonstrated that an array of 12 packages is subcritical, which results in a CSI of 8.4 (2N = 12, N = 6; 50/N = 8.33, rounded up to 8.4 per 10 CFR 71.59(b)). For packages containing 17x17 Type 3 fuel assemblies enriched to 8.0 wt.% or less, the applicant demonstrated that an array of 4 packages is subcritical, which results in a CSI of 25 (2N = 4, N = 2; 50/N = 25). The staff finds that the applicant has appropriately determined the package CSI in accordance with the requirements of 10 CFR 71.59.

The staff reviewed the configurations modeled by the applicant for the single package and array analyses. The staff finds with reasonable assurance that the applicant has identified the most reactive credible condition of the single package and arrays of packages, consistent with the condition of the package under normal conditions of transport and hypothetical accident conditions, and the chemical and physical form of the fissile and moderating contents.

For all calculations, the applicant used the CSAS6 sequence of the SCALE 6.2.4 computer code, with KENO VI and the 238-group ENDF/B-VII.0 cross section library. This differs from the code and cross section library used for calculations of the previously approved packaging and

contents configuration, which is benchmarked as discussed in Section 6.8 of the SAR. Therefore, the applicant provided a new benchmarking analysis in Section 6.8 of Appendix 6.11 of the SAR, which considers the revised code version as well as the new fuel assembly contents.

The applicant selected applicable benchmark experiments to validate the 17x17 Type 3 fuel assembly contents enriched up to 8.0 wt.% using sensitivity/uncertainty methods (S/U). The applicant used the TSUNAMI-3D sequence included in the SCALE 6.2.4 code package to calculate the sensitivity of the k_{eff} value from the bounding array case (known as the application model) to variations of the nuclear data used in the k_{eff} calculation. TSUNAMI-3D calculations generate sensitivity data files (SDFs) containing the sensitivity data. The applicant then used the TSUNAMI-IP sequence to compare the application SDF against potential critical benchmark experiment SDFs. TSUNAMI-IP generates correlation coefficients (ck values) that indicate the similarity between an application and an experiment. The applicant only used this S/U method to select applicable benchmarks for validation.

The experiments selected by the applicant for the higher enrichment validation can all be found in the International Handbook of Evaluated Criticality Safety Benchmark Experiments (ICSBEP Handbook). The critical experiment set for greater than 5.0 and up to 8 wt.% analyses included 143 experiments with ck values > 0.90. The applicant included an additional 20 experiments from the ICSBEP Handbook that didn't have applicable SDFs but were retained based on having similar attributes to the application as well as other included benchmark experiments. Table 6-20 of Appendix 6.11 of the SAR includes comparisons between the critical benchmark experiments and the MAP 12/13 package application case demonstrating the applicability of the included benchmarks. Many methods used to calculate bias and bias uncertainty (used to determine the USL) rely on the assumption that the population of critical experiments constitutes a normal distribution. Since the data set here does not follow a normal distribution, the applicant applied a non-parametric technique that uses an analysis of ranks to determine the USL. For this sample population size the rank index for a one-sided distribution-free tolerance limit with 95% confidence that 95% of the population is covered is 3, meaning the third lowest calculated k_{eff} value, which for the population of experiments selected by the applicant is 0.98088. Including an administrative margin of 0.05 yields a USL of 0.93088.

Typically, when using TSUNAMI-3D, the SDFs are validated as appropriate for use with direct perturbation calculations. SDFs require dividing the model into an appropriate grid to determine the sensitivities. Determining the right size grid/mesh size can be difficult. The need for finer meshes for fissile material regions must be balanced against the large computer memory requirement and longer computation time for a smaller mesh size. The applicant did not include validation of the application case SDF with direct perturbation calculations in the benchmarking discussion.

To confirm that the applicant's use of S/U methods was performed appropriately, the staff generated an SDF based on the sample TSUNAMI-3D input provided by the applicant. Direct perturbation calculations performed by the staff showed the ^{235}U sensitivity to be acceptable, but the sensitivities for moderating nuclides (hydrogen) were outside the recommended ranges. This indicates that the mesh size chosen by the applicant for the TSUNAMI 3D calculation may be slightly deficient. However, the staff finds that the applicant determined an appropriate USL using S/U methods since: 1) the SDF comparison was only used by the applicant to select benchmarks; 2) the applicant included additional applicable benchmarks; 3) the applicant's comparison of the selected benchmark experiment properties to the MAP package application case showed that the benchmark experiments selected were applicable considering traditional

validation parameters; and 4) staff's independent S/U analysis and USL determination (discussed below) confirms that the applicant's USL is conservative.

The staff performed confirmatory calculations using the SCALE 6.2.4 Monte Carlo radiation transport code, with the CSAS6 criticality sequence and the 238-group ENDF/B-VII neutron cross section library. The staff's confirmatory analyses consisted of models of the single package and arrays of packages under hypothetical accident conditions. Using modeling assumptions similar to the applicant's, the staff's independent evaluation resulted in k_{eff} values that were similar to, or bounded by, the applicant's results.

The staff also performed confirmatory benchmarking calculations. The staff performed independent TSUNAMI-3D calculations to generate a more acceptable SDF than the one generated by the applicant. The staff used a simplified model of half of a single package with a mirror boundary on one side to simulate a whole package and validated the resulting SDF with direct perturbation calculations. The staff then used TSUNAMI-IP to compare this SDF with SDFs from the Oak Ridge National Laboratory SCALE Verified, Archived Library of Inputs and Data (VALID) SDF library and SDFs available from the ICSBEP Handbook. From the VALID library, the staff found 46 experiments with ck values > 0.95. From the ICSBEP Handbook, the staff found 220 experiments with ck values > 0.95. Neither experiment set had a normalized distribution. Using the same non-parametric technique as described by the applicant, the staff determined USLs of 0.9446 (VALID) and 0.9367 (ICSBEP), both including the administrative margin of 0.05. Both USLs are slightly larger than the applicant-determined MAP package USL for up to 8.0 wt.% fuel of 0.93088, which demonstrates that the applicant's USL is conservative.

The staff reviewed the applicant's requested changes to the Certificate of Compliance, initial assumptions, model configurations, analyses, and results. The staff finds that the applicant has identified the most reactive configuration of the Model No. MAP 12/13 package with the requested contents, and that the criticality results are conservative. Therefore, the staff finds reasonable assurance that the package, with the requested contents, will meet the criticality safety requirements of 10 CFR Part 71.

Based on the discussion above, the staff found the applicant's proposed changes to the CoC would not affect the ability of the Model No. MAP package to meet the requirements of 10 CFR Part 71.

CONDITIONS

The following changes were made to the certificate of compliance:

Item No. 3(b) identifies the latest application dated March 31, 2021.

Condition No. 5(a)(3) is modified to include a new revision 6 of the licensing drawing 02-9045401.

Condition No. 5(b)(1)(i) revises the description of the contents as "slightly contaminated uranium with trace quantities limits" and corrects an error in Table 1.

Condition No. 5(b)(1)(ii) is added to include enriched commercial grade uranium or slightly contaminated uranium with trace quantities limits for enrichments between 5.0 and 8.0 weight percent U-235.

Condition No. 5(b)(2) added the maximum authorized concentrations for > 5.0 to ≤ 8.0 weight percent U-235a for the uranium oxide fuel rods in the 17x17 Type 3 array, as specified in Table 2 of the CoC.

Condition No. 5(b)(3)(ii) added in Table 4 of the CoC the parameters of the authorized fuel assemblies for ≤ 8.0 weight percent U-235.

Condition No. 5(c) includes the new CSI values for contents below 7.0 weight percent U-235 and below 8.0 weight percent U-235 .

Condition No. 9 has been modified to extend the previous revision of the certificate for approximately one year.

The expiration date of the certificate (Condition No. 10) was not modified.

The References section of the certificate was updated to include the application MAP PWR Fuel Shipping Package, FS1-0038397, Revision 5, dated March 29, 2021.

CONCLUSION

Based on the statements and representations in the application, the staff finds that these changes do not affect the ability of the package to meet the requirements of 10 CFR Part 71.

Issued with Certificate of Compliance No. 9319, Revision No. 13.