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

SAFETY EVALUATION BY

THE OFFICE OF NUCLEAR MATERIAL SAFETY AND SAFEGUARDS,

RELATED TO CRITICALITY EXEMPTION

TO POSSESSION-ONLY LICENSE NO. DPR-73

TMI-2 SOLUTIONS, LLC

THREE MILE ISLAND NUCLEAR STATION, UNIT NO. 2

DOCKET NO. 50-320

1.0 INTRODUCTION AND BACKGROUND

The Three Mile Island Nuclear Station (TMINS), located in the Londonderry Township of Dauphin County, is approximately 10 miles southeast of Harrisburg, Pennsylvania. Three Mile Island Nuclear Station, Unit No. 1 (TMI-1) and Three Mile Island Nuclear Station, Unit No. 2 (TMI-2) are located on TMINS. TMINS encompasses approximately 440 acres, and includes adjacent islands to the North, a strip of land on the mainland along the eastern shore of the river, and the area on the eastern shore of Shelley Island that is within the exclusion area (a 2,000-foot radius from a point equidistant between the centers of the TMI-1 and TMI-2 reactor buildings).

By letter dated September 29, 2022, Attachment 2, (Agencywide Document Access and Management System (ADAMS) Accession No. ML22276A024), TMI-2 Solutions, LLC (TMI-2 Solutions, or Licensee) requested an exemption from Title 10 of the *Code of Federal Regulations* (10 CFR) Section 70.24, “Criticality accident requirements” for Three Mile Island Nuclear Station, Unit No. 2 (TMI-2). The proposed action would exempt TMI-2 Solutions from the requirement to maintain a radiation monitoring system in each area where certain quantities of licensed special nuclear material (SNM) is handled, used, or stored that would energize clearly audible alarm signals if accidental criticality occurred, and from the requirement to maintain associated emergency procedures.

In its exemption request (ML22276A024), the Licensee pointed out that the Nuclear Regulatory Commission (NRC) granted TMI-2 an exemption from the requirements of 10 CFR 70.24, criticality accident requirements for SNM storage areas, on June 15, 1992 (ML20210D729). The Licensee further noted that the June 15, 1992, exemption states:

> "... it is appropriate to request an exemption from 10 CFR 70.24 if an evaluation determines that a potential for criticality does not exist, as for example where the quantities or form of SNM make criticality practically impossible or where geometric spacing is used to preclude criticality."

The 1992 exemption was granted based on the lack of a credible criticality hazard related to the storage of fissionable material.

On June 15, 1992, the U.S. NRC, or Commission) granted the Licensee an exemption from 10 CFR 70.24, with certain restrictions (Package No. ML20210D728). That exemption, however, only covered the initial cleanup of TMI-2 fuel debris. With TMI-2 currently progressing to radiological decontamination that 1992 exemption will no longer apply. Therefore, TMI-2 requested an exemption from 10 CFR 70.24 that will extend through the radiological decommissioning phase and until license termination.

1.1 Proposed Action:

The proposed action is an exemption from the requirements of 10 CFR 70.24 for a monitoring system capable of detecting a criticality accident in SNM storage areas and the maintenance of associated emergency procedures during radiological decommissioning and through the termination of the POL-73 for TMI-2. The Licensee submitted the application for this exemption on September 29, 2022 (Attachment 2 of ML22276A024).

According to TMI-2 Solutions in its application for the exemption, this request is supported by an updated calculation regarding safe fuel mass limit (SFML) at TMI-2. The updated calculation takes credit for impurities and actual enrichment based on the results of physical samples taken during the defueling effort and demonstrates that criticality is not credible even if all of the remaining material at TMI-2 is moved or relocated. Therefore, with no credible risk of criticality remaining at TMI-2, TMI-2 Solutions contends that the exemption from the 10 CFR 70.24 criticality alarm requirements is appropriate for the activities at TMI-2 Solutions through license termination.

2.0 APPLICABLE REGULATIONS AND GUIDANCE

This safety evaluation assesses the acceptability of the proposed TMI-2 Solutions' exemption request. The regulatory requirements and associated guidance on which the NRC based its evaluation of this exemption request are detailed below.

10 CFR 70.24

10 CFR 70.24 requires, in relevant part, that each licensee authorized to possess SNM in certain quantities, shall maintain in each area in which such licensed SNM is handled, used, or stored a criticality accident alarm system. The purpose of 10 CFR 70.24 is to ensure that if a criticality were to occur, personnel would be alerted to that fact and would take appropriate action.

10 CFR 70.17

10 CFR 70.17 allows the Commission to grant, upon application of any interested person or upon its own initiative, exemptions from the requirements of Part 70 as the Commission determines are authorized by law, will not endanger life or property or the common defense and security, and are otherwise in the public interest.

3.0 TECHNICAL EVALUATION

The NRC staff has reviewed the Licensee's regulatory and technical analyses in support of its proposed exemption, as described in its exemption application dated September 29, 2022.

3.1 Proposed License Changes

The proposed action would exempt the Licensee from the requirements of 10 CFR 70.24, which requires a monitoring system that will energize clear audible alarms if accidental criticality occurs in each area in which SNM is handled, used, or stored. The proposed action would also exempt the Licensee from the requirements to maintain emergency procedures for each area in which licensed SNM is handled, used, or stored to ensure that all personnel withdraw to an area of safety upon the sounding of the alarm, to familiarize personnel with the evacuation plan, and to designate responsible individuals for determining the cause of the alarm, and to place radiation survey instruments in accessible locations for use in such an emergency.

3.2 Nuclear Criticality Safety

The NRC staff recently approved an updated SFML calculation at TMI-2 (ML23051A042). In its request, the Licensee demonstrated that there is no credible criticality hazard at TMI-2. Because criticality is not credible at the plant, an exemption from the Criticality Accident Alarm System (CAAS) is acceptable.

The NRC staff reviewed the Licensee's updated SFML relative to the associated activities that are to be conducted via the 10 CFR 50.59 process involving the remaining debris material to determine whether subcriticality is assured under normal and all credible abnormal conditions.

The TMI-2 reactor underwent under various stages of defueling and cleanup activities from 1979 through 1993, with the primary defueling activities occurring in the late 1980s. Defueling activities originally focused on the removal of fissionable material from the reactor vessel (RV), removing approximately 99 percent of the original core inventory. This was accomplished using a previous SFML calculation that was in place before License Amendment No. 67 was issued on March 31, 2023 (ML23051A042), which was established based on conservative assumptions.

An estimated 1097 kilograms (kg) of residual UO_2, ~1.2 percent of original TMI-2 inventory, is still present within the RV and in various locations outside of the RV. To support the defueling of the remaining fissionable material, TMI-2 Solutions established an updated SFML based on more realistic conditions and sampling data. The new SFML, which was approved through License Amendment No. 67, bounds all remaining activities including removal of debris material from the RV, movement to the reactor cavity or other area intended for segmentation, and movement to loading of the transportable storage container (TSC).

The remaining debris material is in the form of finely divided, small particle-size sediment material; resolidified material either tightly adherent to components or in areas inaccessible to defueling at the time of the initial clean up after the 1979 accident up until the completion of the defueling[1]; and adherent films on surfaces contained within piping, tanks, and other components. The debris material is present both inside and outside of the RV, with most of the

1 See "TMI Nuclear Station Unit 2 Defueling Completion Report" (Ref.3)

mass residing in the lower head of the RV. Licensee evaluations of the residual fuel suggests that no discrete (i.e., neutronically de-coupled) location has in excess of 127 kg UO_2, and the total estimate of mass present outside of the RV is 170 kg UO_2.

3.2.1 Description of Normal and Credible Abnormal Conditions

Under anticipated normal conditions, segmentation and loading of TSCs will occur in the reactor cavity where material is transported to after it is removed. Most of the component segmentation will occur under water in a flooded reactor cavity; however, some segmentation may not occur under water, but rather on a concrete platform. Material and component removal from each area will be treated as separate operations to ensure that debris material from two separate areas will not be removed at the same time; however, a partially filled TSC from one area may remain for loading from the next area if there is remaining void space.

Credible abnormal conditions associated with decommissioning operations may include the mishandling of components with fissionable material to increase moderation, reflection conditions, or interaction. This could potentially occur through the removal and accumulation of fissionable-bearing components from multiple areas into a single location or through the accumulation of fissionable-bearing segmented pieces in the Waste Zone (e.g., segmented pieces that do not fit into the waste basket liner that have been set aside).

3.2.2 Nuclear Criticality Safety Analysis

The Licensee performed a set of nuclear criticality safety (NCS) calculations using Monte Carlo N-Particle (MCNP) 6.2 with the (Evaluated Nuclear Data File (ENDF)/B-VIII.0 cross section library to bound the normal conditions of its proposed activities. Credible abnormal conditions are discussed in Section 3.2.2.3 of this report. The details of the Licensee's validation of MCNP 6.2 are discussed in Section 3.2.2.4 of this report. The bounding configurations included the following:

- Optimally-moderated, fully-reflected heterogeneous sphere with impurities (fuel and impurities in a hexagonal lattice contained in a spherical geometry);
- Optimally-moderated, fully-reflected heterogeneous sphere with poisoned moderator (fuel in a hexagonal lattice contained in a spherical geometry); and
- Optimally-moderated, fully-reflected heterogeneous sphere with impurities and poisoned moderator (fuel and impurities in a hexagonal lattice contained in a spherical geometry).

For each configuration evaluated, the Licensee applied the following assumptions:

- Fuel pellet volume equivalent to a standard size fuel pellet, but in a spherical geometry and in a hexagonal lattice;
- Uniform, homogeneous distribution of impurities (when considered) within the fuel sphere;
- Full, tight-fitting (essentially infinite) water reflection;
- Fuel composition of TMI-2 average fuel (i.e., a homogeneous mixture of the three TMI-2 fuel batches);
- No credit for existing structural or solid poison materials (e.g., borosilicate glass); and
- Limited credit for the presence of fission product poisons.

The NRC staff reviewed the Licensee's analysis and associated assumptions for the key parameters of UO_2 density, geometry, heterogeneity, fissionable material composition, impurity composition, moderation, and reflection. The NRC staff's evaluation for each parameter is discussed below.

- *Density (UO_2).* The Licensee considered the full theoretical density of UO_2 (10.97 g/cm^3), a reduced density based on burn-up history (10.55 g/cm^3), and the as-built density of 10.14 g/cm^3. The Licensee determined that changes to UO_2 density resulted in a minimal effect on reactivity, and the Licensee ultimately used the full theoretical density in the establishment of its updated SFML. Although the UO_2 density may vary throughout the remaining debris material, the use of full theoretical density is bounding. Therefore, the NRC staff considers the use of full theoretical UO_2 density to be conservative and bounding for the normal and credible abnormal conditions of the proposed activities.

- *Geometry.* The Licensee assumed a fuel and impurities (fuel/impurities) hexagonal lattice contained within a spherical geometry. Fuel pellets were also assumed to be spherical in a hexagonal lattice. The exact geometry of the fuel is not well-known and may vary spatially throughout; therefore, the NRC staff considers the use of a bounding geometry appropriate. In general, spherical geometries are bounding due to the effects of surface area-to-volume- ratio on neutron reflection. The use of a hexagonal lattice affords the ability to closely pack fuel elements, which maximizes the range in which interspersed moderation can be assessed (*Moderation* is discussed below). Therefore, the NRC staff determined that the Licensee's use of a hexagonal lattice and spherical geometry for both fuel pellets and the fuel/impurities mixture was conservative and bounding for the normal and credible abnormal conditions of the proposed activities.

- *Heterogeneity.* The Licensee assumed a heterogeneous sphere to model the fuel configuration. The exact configuration of the fuel is not well-known and may vary spatially throughout; therefore, the NRC staff considers the use of a bounding assumption with respect to heterogeneity is appropriate. In many cases, homogeneous mixtures represent the most reactive configuration; however, this is not necessarily true in some cases (e.g., certain low-enriched uranium systems). The NRC staff reviewed scoping calculations in NSTS-ES-01, "Safe Fuel Mass Limit Criticality Safety Analysis for TMI-2 Decommissioning" (Ref. 7) and performed independent scoping calculations to assess whether a heterogeneous system is bounding (primarily to a homogeneous system) in this case. The NRC staff determined that a heterogeneous model was more reactive than a homogeneous model and, therefore, bounds both heterogeneous and homogenous systems. Therefore, the NRC staff determined that the Licensee's use of a heterogeneous model was conservative and bounding for the normal and credible abnormal conditions of the proposed changes and the activities conducted under 10 CFR 50.59 involving debris material.

- *Fissionable Material Composition.* The Licensee represented the fissionable material as a homogeneous medium. The enrichment of the fuel was assumed to be the average of the three known fuel batches for TMI-2. The unburned fuel enrichments for the three batches were 1.98 weight percent (wt. %) (56 assemblies), 2.64 wt. % (61 assemblies), and 2.96 wt. % (60 assemblies), which equates to an average enrichment of 2.54 wt. % $^{235}U/U$. The TMI-2 fuel experienced the equivalent of approximately 94 effective full-power days of burn-up at the time of the accident. The actual exposure history for each fuel batch, using existing plant data, was applied to estimate burn-up effects. The exposures and core operating history were applied to a SCALE/ORIGEN-S model to calculate isotopic inventory at the time of the accident. The incorporation of the burn-up effects for each fuel batch was used to produce a net enrichment of 2.24 wt. % $^{235}U/U$ for a homogeneous mixture of the three batches. The starting fuel composition was decayed using SCALE/ORIGEN to the year 2022.

The NRC staff reviewed the Licensee's calculations, the sampling data detailed in the "TMI Nuclear Station Unit 2 Defueling Completion Report" (Ref.3), and the information contained in TMI2-EN-RPT-0001, "Determination of the Safe Fuel Mass Limit for Decommissioning TMI-2" (Ref. 1), to evaluate whether the Licensee's assumptions regarding fissionable material composition, enrichment, and homogeneity were acceptable. Additionally, the NRC staff performed an independent confirmatory analysis using the SCALE/ORIGEN package. With respect to composition and burn-up, the NRC staff observed via its independent analysis that the decayed fissionable material composition was more reactive than that of the original burn-up composition. The staff determined that this was primarily due to the decrease in europium (Eu)-154 and ^{155}Eu abundance. The NRC staff determined that the Licensee's assumptions regarding fissionable material burn-up were acceptable and more conservative than the assumptions used for the Licensee's original SFML. With respect to fissionable material enrichment, the NRC staff confirmed via its independent analysis that the Licensee's calculated net enrichment of 2.24 wt. percent $^{235}U/U$ for a homogeneous mixture of the three fuel batches was acceptable. The NRC staff noted that the 34 samples obtained from the bottom head of the RV had an average enrichment of 2.23 wt. percent $^{235}U/U$, which is in good agreement with the Licensee's calculated net enrichment of 2.24 wt. percent $^{235}U/U$. The NRC staff also noted that defueling data suggests that approximately 65 percent of the batch 3 fuel, which had an initial enrichment of 2.96 wt. percent $^{235}U/U$, has already been removed from the RV. Therefore, the remaining fuel consists primarily of batches 1 and 2 with enrichments of 1.98 wt. percent and 2.64 wt. percent $^{235}U/U$, respectively. This provides additional assurance that the Licensee's calculated net enrichment of 2.24 wt. percent $^{235}U/U$ is bounding and acceptable.

With respect to homogeneity, a substantial amount of core debris material was removed during defueling in the late 1980s. Prior to the defueling, a sampling of core debris material from the center and radius was performed, removing material from three depths: 1) surface of the rubble bed; 2) three inches deep into the rubble bed; and 3) twenty-two inches deep into the rubble bed. The samples showed a high degree of homogeneity, and the degree of mixing and relocation of core constituents suggested that molten core materials were mixed vigorously. The samples indicated that most of the debris material in the RV was mixed to create a degree of homogeneity as evidenced by the narrow range of uranium and zirconium (Zr) composition observed in obtained samples (62.3 percent - 69.5 wt. percent U with an average of 65.1 wt. percent, and 11.7 wt. percent - 15 wt. percent Zr with an average of 12.6 wt. percent) and the distribution of impurities (the distribution of impurities is discussed below in the *Impurity Composition* section). The ratio of uranium-to-zirconium (U/Zr) for the obtained samples was observed to be higher (~5.9) than that of as-built (~3.6), providing further evidence of significant mixing of all core constituents. The NRC staff considers the samples to be reasonably representative of the remaining debris material in TMI-2 based on the numerous locations sampled and potential fuel relocation pathways. Therefore, the staff considers it unlikely that areas containing exceedingly high uranium concentrations exist. The NRC staff determined that the Licensee's assumption that the fissionable material is homogenous is acceptable.

Impurity Composition. Fissionable material, control rods, structural materials, and other miscellaneous materials were melted and mixed during the 1979 accident. The remaining material contains both fissionable material and non-fissionable materials (i.e., impurities) from structural materials, control rods, burnable poison rods, coolant poison, and cladding. Core debris material in the lower head region of the RV is most representative of what remains in the RV at the present time. For this reason, the Licensee based its assumptions for impurity composition on samples obtained from the lower head region of the RV as detailed in “TMI Nuclear Station Unit 2 Defueling Completion Report” (Ref. 3). Based on these samples, the fuel composition (UO_2 + fission products) was assumed to be 83.79 wt. percent, while the remainder (16.21 wt. percent) was assumed to be impurities.

Table 3.2.2.2-1 – Impurity Composition

Component	**Weight Percent (wt. %)**
Fuel Composition	83.79
Zirconium (Zr)	12.70
Iron (Fe)	2.44
Boron (B)	0.11
Cadmium (Cd)	0.00
Chromium (Cr)	0.75
Molybdenum (Mo)	0.15
Manganese (Mn)	0.06

TMI-2 Solutions performed a series of calculations varying the impurity composition from 0 percent to 16.21 percent with a fixed iron content of 90 percent (of the relative impurity mixture) and varied boron content. The Licensee determined that it was necessary to apply partial credit to the impurity composition, taking credit for 10 wt. % of the impurities, 50 percent of the sampled boron content of those impurities (i.e., 5 percent of the overall boron content), and 90 percent of the iron content (i.e., 45 percent of the overall iron content).

The NRC staff reviewed the Licensee’s calculations, the sampling data detailed in the “TMI Nuclear Station Unit 2 Defueling Completion Report” (Ref.3.) and the information contained in TMI2-EN-RPT-0001, “Determination of the Safe Fuel Mass Limit for Decommissioning TMI-2” (Ref. 1) to evaluate whether the Licensee’s assumptions regarding impurity composition were acceptable. The NRC staff noted that samples obtained from the RV and “B” steam generator tube sheet showed the presence of impurities, and the samples indicated that most of the debris material in the RV was mixed to create a degree of homogeneity as evidenced by 1) the narrow range of uranium and zirconium composition observed in obtained samples (62.3 percent - 69.5 wt. percent U with an average of 65.1 wt. percent, and 11.7 wt. percent - 15 wt. percent Zr with an average of 12.6 wt. percent); 2) the presence of gadolinium (Gd) in samples obtained from the core debris material bed; 3) presence of gadolinium at a location at least 30 centimeters from its original position in the TMI-2 core; and 4) the consistent, evenly-distributed and relatively stable presence of boron in all of the lower head samples. The NRC staff considers the samples to be reasonably representative of the remaining debris material in TMI-2 based on the numerous locations sampled and potential fuel relocation pathways. Therefore, the NRC staff determined that the Licensee’s assumption that impurities are distributed homogeneously is acceptable. The NRC staff also noted that homogenization of the impurity content of the RV lower head (83.79 wt. percent of the TMI-2 core mass) represents a significant conservatism over what would be derived assuming a homogeneous mixture of the initial core composition, where the UO_2 component is 65.8 wt. percent of the TMI-2 core mass. This provides additional conservatism with respect to the Licensee’s impurity composition assumptions.

With respect to applying partial credit to the boron and iron content of the impurities, the NRC staff performed a sensitivity study to assess the impacts of varied boron concentration. This study was performed due to boron having the highest (with respect to impurities) neutron absorption cross section for the energy region of interest and greatest impact on k_{eff}. The NRC staff observed that over the range of 0 – 100 percent boron impurity, the average worth was -0.48 percent Dk/k for each 1 percent addition and that as boron impurity increases, negative reactivity worth decreases. At 10 wt. percent impurity content, 20 percent of the boron impurity is worth -11.4 percent Dk/k, which equates to -0.57 percent Dk/k for each 1 percent addition. The NRC staff determined that for a 1200 kg U fuel loading (i.e., the proposed SFML) taking credit for 10 percent of the measured impurity content, 47 percent of the boron content must be credited to stay below the Licensee's upper subcritical limit (USL) of 0.95. This corresponds to an overall boron content of 0.0319 wt. percent of the remaining debris material.

Samples indicate that boron is deposited at a relatively constant concentration evenly throughout the lower head and is consistent with the amount of boron present in the reactor coolant. For iron, samples indicate that substantial amounts of structural material have been retained in the debris material, with iron having the highest concentration and being relatively constant throughout (1.8 – 3.7 wt. percent Fe with an average of 2.44 wt. percent). As previously stated, the NRC staff considers the samples to be reasonably representative of the remaining debris material in TMI-2 based on the numerous locations sampled and potential fuel relocation pathways. Therefore, the NRC staff considers it unlikely that large areas exist within the debris material in which little to no boron or iron is present. Even if this were to occur, the Licensee's SFML relies on only 10 wt. percent of the impurity content with credit for boron and iron content both further reduced by 50 percent and 90 percent, respectively. This corresponds to a credit of only 5 percent of the measured boron content and 45 percent of the measured iron content. Furthermore, as discussed in the *Fissionable Material Composition* section above, the NRC staff considers it unlikely based on sampling data that areas exist in which exceedingly high uranium concentrations exist. Therefore, the NRC staff considers it unlikely that an area in which little to no boron or iron exists, and the NRC staff considers it further unlikely that such an area would also be of high uranium concentration. For these reasons, the staff determined that the Licensee's assumptions and application of partial credit for boron and iron content (10 wt. percent of the impurities, 50 percent of the sampled boron content of those impurities, and 90 percent of the iron content) is acceptable, conservative, and bounding to any uncertainty associated with the impurity content. The NRC staff noted that borosilicate glass was added to TMI-2 in the 1990s, which was not considered as an impurity or credited, but would serve to neutronically isolate any debris material that is located or could relocate to the bottom of the RV (Refs. 10 and 11). This provides additional conservatism as the borosilicate glass further reduces the reactivity of the system. The NRC staff also noted that although gadolinia burnable poison rods were used in TMI-2 and gadolinium, therefore, may be present in certain locations (e.g., core debris material bed), the presence of gadolinium (a neutron absorber) was not credited.

Moderation. The Licensee performed a series of calculations to optimize the moderator-to-fuel ratio by varying the fuel pellet diameter and lattice pitch (i.e., hydrogen-to-uranium ratio). The optimized moderator-to-fuel ratios determined by these calculations were used for each case in the establishment of the SFML.

The NRC staff reviewed the Licensee's series of calculations to optimize the moderator-to-fuel ratio and performed an independent confirmatory analysis. Many of the proposed activities will take place in the presence of significant amounts of moderating material (i.e., underwater), and the exact configuration of the fuel and moderating material is either not well-known or may change during the proposed activities. Therefore, the NRC staff determined that the Licensee's use of optimized moderator-to-fuel ratios was appropriate. The NRC staff confirmed via its independent confirmatory analysis that the values the Licensee identified as optimum represented worst-case moderation conditions and were, therefore, acceptable and bounding for the normal and credible abnormal conditions of the proposed activities.

Reflection. TMI-2 Solutions considered full, tight-fitting reflection for all cases. The Licensee also considered concrete as a reflector.

Many of the proposed activities will take place in the presence of significant amounts of reflecting material (i.e., underwater), and the exact configuration of the fuel and reflecting material is either not well-known or may change during the proposed activities. Additionally, certain activities may take place on a concrete slab. Therefore, the NRC staff determined that the Licensee's use of full, tight-fitting reflection and consideration of concrete was acceptable and bounding for the normal and credible abnormal conditions of the proposed changes and associated activities that are to be conducted via the 10 CFR 50.59 process involving the remaining debris material.

Results. The results of the Licensee's analysis established a new SFML of 1200 kg U (1361 kg UO_2), which takes credit for fuel exposure histories and 10 wt. percent of the impurities identified in the "TMI Nuclear Station Unit 2 Defueling Completion Report" (Ref. 3), with boron and iron further reduced by 50 percent and 10 percent, respectively. Based on the derived SFML, which is greater than the estimated remaining 1097 kg UO_2, the Licensee determined that all associated activities that are to be conducted via the 10 CFR 50.59 process involving the remaining debris material can be safely conducted, and that no credible criticality hazard exists. The NRC approved the updated SFML via Amendment No. 67.

3.2.3 Credible Abnormal Conditions

Credible abnormal conditions associated with decommissioning operations may include the mishandling of components with fissionable material to increase moderation, reflection conditions, or interaction. This could potentially occur through the removal and accumulation of fissionable-bearing components from multiple areas into a single location or through the accumulation of fissionable-bearing segmented pieces in the Waste Zone (e.g., segmented pieces that do not fit into the WBL that have been set aside).

Given the size and complexity of the reactor components and the effort required to remove and relocate each component, the NRC staff considers it unlikely that components from multiple areas would be allowed to accumulate in a single location. Similarly, the NRC staff considers it unlikely that an accumulation of segmented pieces in the Waste Zone would occur. Still, if such accumulations were to occur (whether they be comprised of reactor components or segmented pieces), the fissionable material is either adhered to, or non-uniformly distributed throughout, non-fissionable structural components. Therefore, the NRC staff determined that there is no credible upset that could lead to an accumulation of debris material mass in a geometrical configuration capable of criticality.

Because there is a large degree of uncertainty associated with the amount of fissionable mass in the RV (+/- 370 kg UO_2), the total mass within the RV could be in excess of the Licensee's proposed SFML of 1200 kg U (1361 kg UO_2). However, given the size of the RV and distribution of the debris material therein, it is not logistically possible for the entire fuel mass within the RV to be removed at one time. Furthermore, it is not possible for the entire fuel mass within the RV to be placed into a single TSC given the size restrictions of a TSC. Therefore, the NRC staff determined that there is no credible upset that could lead to an accumulation of fissionable mass in excess of the Licensee's proposed SFML. As an additional defense in depth consideration, the fissionable material is either adhered to, or non-uniformly distributed throughout, non-fissionable structural components, making the formation of an unfavorable geometric configuration unlikely. Therefore, the NRC staff determined that there is no credible upset that could lead to an accumulation of debris material mass in a geometrical configuration capable of criticality.

3.2.4 Minimum Margin of Subcriticality, Upper Subcritical Limit, and Estimation of Bias

Because the Licensee relied on the use of computational methods (MCNP 6.2) to establish the SFML and demonstrate the no credible criticality hazard exists, the NRC staff reviewed the Licensee's criticality code validation report, TMI-EN-RPT-0002, "MCNP Version 6.2 Bias Determination for Low Enrichment Uranium Using the ENDF/B-VIII.0 Cross Section Library," to evaluate the Licensee's proposed minimum margin of subcriticality (MMS) and associated USL.

The Licensee performed its validation using nine benchmark sets consisting of a total of 125 benchmark experiments to estimate a total bias (bias + bias uncertainty) of 0.0202, and the Licensee established a single USL of 0.95 and MMS of 0.0298 to bound the normal and credible abnormal conditions of all proposed decommissioning activities. The validation applied to heterogeneous spherical and annular low-enriched UO_2 and water systems with an area of applicability (AOA) that includes various fissionable material forms, fissionable system geometries, moderating and reflecting materials, and neutron absorbers. The details of the AOA are discussed in Table 3.3.2.4-1.

Table 3.2.2.4-1 – Validated AOA

Property	Area of Applicability
Fissionable Materials	Uranium (2 – 10 wt. percent) in the form of uranium dioxide (UO_2), uranium tetrafluoride (UF_4), and uranyl fluoride solution (UO_2F_2)
Geometry	array of fuel rods, array of rectangular parallelepipeds, UO_2 in cubes in a cubic array, finely divided particles in cubes, cylinders, spheres, slabs
Moderating Materials	water, paraffin, polyethylene
Reflecting Materials	none, water, acrylic, steel, plexiglass, paraffin, polyethylene, concrete
Absorbers, Poisons, and Structural Materials	aluminum alloys, steel, borated steel, Boral, boroflex, silver-indium-cadmium, copper, copper with cadmium, cadmium, Zircalloy-4, rubber
Average Energy of Neutrons Causing Fission (AENCF)	Range: 2.43E-02 – 2.88E-01 MeV Average: 1.40E-01 MeV
Bias + Bias Uncertainty	0.0202
MMS	0.0298
USL	0.95

The NRC staff determined that the validation of MCNP 6.2 was performed in accordance with American National Standards Institute/American Nuclear Society (ANSI/ANS)-8.24-2017, "Validation of Neutron Transport Methods for NCS," NUREG/CR-4604, "Statistical Methods for Nuclear Material Management," and NUREG/CR-6698, "Guide for Validation of NCS Calculational Methodology." The Licensee performed the Lilliefors Test to determine whether the selected data were normally distributed and performed trending analyses for the parameters of AENCF and enrichment to determine whether any notable trends in the bias existed. Because the data were found to be not normally distributed with no apparent trends in the bias, the Licensee estimated the bias using the single-sided tolerance limit statistical method, which is consistent with NUREG/CR-6698.

The NRC staff determined that the Licensee's methods for estimating bias and establishing the USL used technically sound statistical approaches consistent with NUREG/CR-6698 and provided a high degree of confidence that the selected experiments evaluated under these methods will yield an accurate estimate of the bias. The NRC staff determined that the selected experiments were drawn from multiple, independent series and a well-established source (the International Handbook of Evaluated Criticality Safety Benchmark Experiments, Ref. 9). The NRC staff determined that the selected experiments appropriately spanned the entire range of specified important parameters (fissionable material form and composition; geometry; enrichment, moderating, reflecting, and absorber materials form and composition; and AENCF) without large gaps requiring extrapolation or wide interpolation, and that the specified ranges included appropriate considerations for the potential values of important parameters under all normal and credible abnormal conditions. The NRC staff determined that a sufficient quantity of benchmark experiments (125 experiments) to draw a physically and statistically meaningful result was ensured through the use of statistical techniques. The NRC staff determined that the selected benchmark experiments were sufficiently similar to the normal and credible abnormal conditions presented by the Licensee's associated activities that are to be conducted via the 10 CFR 50.59 process involving debris material and that they provide an acceptable level of assurance that the estimated bias is accurate and bounding to its various potential sources. The selected experiments were sufficiently similar for key parameters, and the key parameters used for benchmark experiment selection were those with the greatest effect on the bias, including fissionable material form and composition; enrichment; physical form and composition of moderating materials, reflecting materials, and neutron absorbers; and AENCF. The NRC staff determined that the MMS was generally large in comparison to the bias uncertainty. In aggregate, the NRC staff determined that the Licensee's proposed MMS (0.0298) and associated USL (0.95) were acceptable for the purposes of conducting NCS analyses using MCNP 6.2 with the ENDF/B-VIII.0 cross section library. Licensee's proposed MMS (0.0298) and associated USL (0.95) were acceptable for the purposes of conducting NCS analyses using MCNP 6.2 with the ENDF/B-VIII.0 cross section library.

3.3 Regulatory Evaluation

10 CFR 70.17(a) states that the Commission may, upon application of any interested person or upon its own initiative, grant exemptions from the requirements of the regulations in Part 70 as it determines are authorized by law, will not endanger life or property or the common defense and security, and are otherwise in the public interest.

The NRC staff has reviewed the exemption request and finds that granting the proposed exemption will not result in a violation of the Atomic Energy Act of 1954, as amended, the Commission's regulations, or other laws. As explained below, the proposed exemption will not endanger life or property, or the common defense and security, and is otherwise in the public interest. Therefore, the exemption is authorized by law. Additionally, the exemption will not endanger life or property or the common defense and security, and is otherwise in the public interest.

The exemption will not endanger life or property because, based on the NRC staff's evaluation (ML23017A131), the NRC staff determined that the Licensee's proposed decommissioning activities do not present any credible criticality hazards. Because there are no credible criticality hazards related to the Licensee's proposed decommissioning activities and because all activities will be conducted such that subcriticality is assured under normal and all credible abnormal conditions, the NRC staff concludes that the Licensee's program will provide reasonable assurance of adequate protection of the health and safety of workers and the public.

The exemption is consistent with the Common Defense and Security because the NRC staff determined there would be no impact to the physical protection plan, emergency preparedness, environmental monitoring, effluent monitoring, or material control and accountability programs at TMI-2.

As described in the NRC staff's nuclear criticality safety evaluation in this SER, the NRC staff conducted independent evaluations and concluded that criticality is not credible; therefore, an exemption from criticality monitoring requirements is warranted. The NRC staff agrees with the licensee's conclusion in its application that the requested exemption to the requirements of 10 CFR 70.24 does not involve information or activities that could potentially impact the common defense and security. The SFML calculation determined that there is no credible criticality hazard, and the existing administrative restrictions described in the TMI-2 Fuel Bearing Material Program prevent proliferation and limit aggregation. The elimination of the criticality monitoring requirements does not involve information or activities that could potentially impact the common defense and security of the United States.

Activities at the TMI-2 site do not pose any credible criticality hazards that would affect the ongoing health and safety of workers or the public, or informing decisions related to nuclear security. Therefore, for the reasons explained above, the exemption will not endanger life or property or the common defense and security.

The exemption is in the public interest because, as stated previously, the Licensee demonstrated that criticality is not credible during site decommissioning activities under credible normal and credible abnormal conditions. Therefore, conducting criticality monitoring at TMI-2 would expend NRC staff inspection and other NRC staff regulatory resources that could be used for other activities at the facility. Additionally, the Licensee states that, if the exemption request were denied, its personnel would experience a slight increase in occupational dose during the maintenance of criticality monitors, which would not be consistent with as low as reasonably achievable (ALARA) principles. The NRC staff agrees.

3.4 - References

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10. 1992-01-23, GPU, Addition of Borosilicate Glass to the Reactor Vessel
11. NUREG/KM-0001, Supplement 1, "Three Mile Island Accident of 1979 Knowledge Management Digest Recovery and Cleanup."

4.0 CONCLUSION

Based on the review of TMI-2 Solutions' application dated September 29, 2022, the NRC staff finds that the proposed request for exemption from the requirements of 10 CFR.70.24 is acceptable. Accordingly, the Commission has determined that, pursuant to 10 CFR Part 70, the exemption is authorized by law, will not endanger health or property or the common defense and security, and is otherwise in the public interest.

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