Attachment 2

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Holtec Report No. HI-2053369, Holtec Justification for ANO Exemption Request for Loading of Damaged Fuel

HOLTEC INTERNATIONAL

Holtec Center, 555 Lincoln Drive West, Marlton, NJ 08053
Telephone (856) 797- 0900
Fax (856) 797 - 0909

Justification for ANO Exemption Request for Loading of Damaged Fuel

FOR

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Summary of Revisions

Revision 0: Initial Issue

Revision 1: Reclassified report as nonproprietary. Deleted "Holtec Proprietary" from the footer on all pages.

1. INTRODUCTION

1.1 Statement of Purpose

This report documents the evaluation of four MPC-32/HI-STORM storage systems at Arkansas Nuclear One (ANO) loaded with up to two damaged fuel assemblies each without the use of damaged fuel containers (DFC). This evaluation only addresses storage conditions for the HI-STORM 100 CoC Rev 1 [3] issued under 10CFR72. A technical review of all relevant disciplines against the HI-STORM 100 FSAR [2] was conducted and some calculations were performed to justify the currently loaded configuration. This report provides the results of the review and calculations with the intent for use in supporting an exemption request to be submitted by ANO.

2. TECHNICAL REVIEW AND JUSTIFICATION

2.1 Criticality Assessment

This section contains an assessment of the impact of the damaged fuel rods on the reactivity (maximum k_{eff}) of the MPCs. Normal, off-normal and accident conditions are considered, as well as storage conditions and unloading operations.

2.1.1 Normal Condition of Storage

Significant damage to the suspected rods could potentially result in an increase in reactivity due to the possible relocation of fuel pellets. However, Section 6.1 of the HI-STORM FSAR [2] states that "The HI-STORM 100 System for storage (concrete overpack) is dry (no moderator), and thus, the reactivity is very low (k_{eff}<0.52)." Under normal conditions of storage, there is therefore a large safety margin to the regulatory limit of k_{eff} of 0.95. The effect of the assumed damage on the reactivity would be very small compared to this safety margin, due to the small number of suspected rods compared to the total number of rods in each MPC and limited potential displacement of fuel pellets. In summary, it can be concluded that the reactivity remains well below the regulatory limit, and that the system is therefore safe from a criticality perspective under normal storage conditions even under the assumption of significant damage to the suspected rods.

2.1.2 Unloading of the MPC

As stated before, significant damage to the suspected rods could potentially result in a relocation of fuel pellets. During and after the reflooding of the MPC, this could lead to an increase in reactivity. However, based on the small number of damaged rods per MPC (maximum of two rods), the reactivity effect is expected to be negligible or very small, and would easily be accommodated by the existing margins in the calculations. Nevertheless, evaluations were performed in [1] to confirm this conclusion. The evaluations address two potential configurations: relocation of fuel within the assembly, and relocation of fuel outside of the assembly and basket. The evaluations are performed for fuel with 5.0 wt% ^{235}U enrichment and a soluble boron concentration in the water of 1900 ppm, consistent with the requirement for loading and unloading fuel of assembly class 16x16A in the MPC-32 as specified in proposed HI-STORM CoC Rev 2 (LAR 1014-2) [4]. HI-STORM CoC Rev. 1 [3] has a higher soluble boron requirement of 2600 ppm. The conditions analyzed here (1900 ppm) have a higher reactivity than the condition required in CoC Rev. 1 (2600 ppm). The results are therefore bounding in terms of reactivity for both CoC Rev. 1 and proposed Rev. 2 conditions.

2.1.3 Relocation of Fuel within the Assembly

Relocation of fuel pellets within an assembly will lead to sections of the assembly with less fuel than the intact assembly, while other sections of the assembly will have more fuel than the intact assembly. For simplification, both conditions are evaluated separately. Also, evaluations are performed assuming the specific condition to be present in all 32 assemblies in the MPC, while the maximum number of assemblies with damaged rods per MPC is two. To simulate less fuel, a single fuel rod in each assembly is removed and replaced by water. To simulate more fuel, a single fuel rod in each assembly is replaced by a square rod of fuel which has approximately four times the amount of fuel per unit length. The fuel cladding is neglected in the latter case. The condition is applied to various fuel rod locations in the assembly, including locations on the periphery of the assembly, adjacent to a guide tube, and in a location completely surrounded by intact fuel rods. The results of the evaluations are summarized as follows:

- Removing a fuel rod in each assembly results in a reduction in the k_{eff} value of about 0.0030 delta-k. The effect of removing only two rods in the entire MPC would therefore have a reactivity effect well below the statistical uncertainty of these calculations (two times standard deviation of these calculations is typically about 0.0012 delta-k), and is therefore considered insignificant. These results are insensitive to the location of the assumed condition within the fuel assembly.
- Increasing the amount of fuel in each assembly results in a slight increase in k_{eff} of about 0.0025 delta-k when the damaged rod is located on the periphery of the assembly, and a slight reduction in k_{eff} when the damaged rod location is inside the assembly. The effect of this condition in only two assemblies is therefore insignificant.

2.1.4 Relocation of Fuel Outside the Fuel Assembly and Basket

If any of the damaged fuel would relocate outside of the fuel assemblies, it could potentially accumulate in an area of the basket where no neutron poison plates are present. The amount of fuel in two fuel rods could, under hypothetical and ideal geometric and moderating conditions (pure water), result in a k_{eff} value exceeding 0.95. However, during unloading, the MPC is flooded with borated water, which significantly reduces reactivity. As confirmation, a simple geometry is analyzed, consisting of an array of fuel fragments in a large body of borated water. All other materials, i.e. MPC, basket and fuel assemblies are neglected. The spacing of the fragments is varied to determine the optimum moderation condition. As expected, the k_{eff} of these configurations is very low, with highest values around 0.5. This confirms that fuel fragments accumulating outside of the fuel assemblies and basket in the MPC during unloading are not a criticality concern.

2.1.5 Off-normal and Accident Conditions

As discussed in Chapter 6 and Chapter 11 of the HI-STORM FSAR [2], there is no credible or postulated off-normal or accident condition which has any effect on the criticality control features of the system. The discussion of criticality safety under normal conditions of storage and during unloading above is therefore directly applicable to any off-normal and accident condition.

2.1.6 Summary

In summary, any potential relocation of the damaged fuel rods in the MPC has a negligible effect on the k_{eff} of the system. This is predominantly due to the fact that the number of damaged fuel rods is small (no more than two rods per MPC). During storage operation, the MPC is internally dry, resulting in a low k_{eff} and large reactivity margins. For unloading operations, where the MPC is flooded with borated water, confirmatory calculations for possible configurations were performed in[1] and confirm that the effect of fuel relocation on the k_{eff} of the system is insignificant.

2.2 Thermal Assessment

A single MPC would only contain two damaged fuel rods, which is a small fraction of the total number of fuel rods (less than 0.3% of the rods in an MPC-32). The presence of such a small amount of damaged fuel rods would not have a significant impact on the thermal performance of the HI-STORM System. For the purposes of this assessment, however, it is assumed that the presence of damaged fuel rods could **potentially** impact thermal performance. As such, it is necessary to evaluate what impact, if any, the presence of up to two damaged fuel rods will have on the **actual** thermal performance.

2.2.1 Actual Impacts on Temperature

First, the actual impact on the temperatures in the HI-STORM System will be addressed. The MPC is backfilled with helium, which provides cooling for fuel assemblies through conduction and natural circulation. The damage to the rods is such that the rods remain in their correct physical positions within the fuel assembly. The performance of the conduction heat transfer mechanism is dependent on the fuel geometry, so this mechanism would not be impacted by the presence of the damaged fuel rods. The performance of the natural convection heat transfer mechanism is dependent on the hydraulic resistance of the fuel assemblies, which is also dependent on the fuel geometry. As the fuel geometry is not changed, this mechanism would also not be impacted by the presence by the damaged fuel rods.

In addition, all of the fuel assemblies with damaged rods are located near the periphery of the MPC fuel basket, which has two temperature consequences. First, the temperatures for fuel assemblies located near the fuel basket periphery are significantly lower than the peak cladding temperatures that occur near the center of the fuel basket. This will reduce the potential for additional cladding damage on the affected rods. Second, the hydraulic resistance of periphery assemblies has been shown to have only a minor impact on peak cladding temperatures that occur near the center of the fuel basket. Thus, even if the rod damage were to become severe enough in the future to increase the hydraulic resistance of the fuel assemblies, it will not increase the peak cladding temperatures. Therefore, the normal condition design temperatures specified in Table 2.2.3 of the HI-STORM FSAR [2] will not be exceeded as a result of the presence damaged fuel rods.

It should also be noted that the MPCs containing the damaged fuel rods were not vacuum dried but were instead demoisturized using the Forced Helium Dehydrator (FHD) System. Unlike vacuum drying, which subjects the fuel to large temperature rises that could have led to further degradation of the damaged fuel cladding, the FHD System thermostatically controls the temperature within the MPC to below normal storage levels. This further reduces the potential for additional cladding damage on the affected rods (see previous paragraph).

Because the cooling mechanisms that remove heat from the fuel assemblies and reject it to the ambient are, as described in the preceding paragraphs, undiminished by the presence of the damaged fuel rods, there would be no reduction in these mechanisms under any (normal, off-normal and hypothetical accident ambient) condition of storage.

2.2.2 Actual Impacts on Pressure

Next, the actual impact on the pressures in the HI-STORM System will be addressed. Because the damaged rods would have been breached prior to placement into dry storage, the rod fill gas and any gaseous fission products would have been released already. As such, there is no possibility for additional rod fill gas or gaseous fission products to be released into the MPC. The internal free volume of two fuel rods is negligible compared to the free volume within an MPC, so the presence of the damaged rods will have a negligible impact on MPC internal pressures. Therefore, the normal condition design pressures specified in Table 2.2.1 of the HI-STORM FSAR [2] will not be exceeded as a result of the damaged fuel rods.

Under off-normal and accident pressure conditions which result from fuel rod ruptures that release additional gases into the sealed MPC, the amount of rod fill gas and gaseous fission products will be slightly reduced as the damaged rods would have been breached prior to placement into dry storage. In addition, the presence of damaged fuel rods in an MPC will slightly increase the internal volume of the canister, which will reduce the pressure that occurs from subsequent postulated rod ruptures. Therefore, the off-normal and hypothetical accident condition design pressures specified in Table 2.2.1 of the HI-STORM FSAR [2] will not be exceeded as a result of the damaged fuel rods.

It is noted that the continuing radioactive decay of the fuel pellets would result in the production of additional amounts of gaseous fission products in the future. The amounts of any such gases would, however, be negligible compared to the amount of gases in an undamaged rod. The production of this small amount of gas will be bounded by the 1% fuel rod rupture condition evaluated as a normal event in the HI-STORM 100 FSAR [2].

2.2.3 Effects of Continued Degradation of the Rods' Integrity

The current condition of the damaged fuel rods is, as stated above, such that the fuel assembly geometry is basically intact (i.e., the fuel pellets are still contained within the cladding). Two previously discussed conditions preclude further degradation of the damaged fuel rods under normal conditions. First, all fuel assemblies with damaged fuel rods are located in peripheral fuel basket locations. The lower temperatures that occur near the periphery of the fuel basket result in lower thermal stresses in fuel rods in those locations. Second, the rods fill gas and gaseous fission products will have already been released from the damaged rods. This results in equal pressure both within and outside of the damaged fuel rods, totally eliminating hoop stress in the fuel cladding. The relatively low thermal stresses and the complete lack of hoop stress make propagation of the existing fuel rod damage highly unlikely. Nevertheless, the impact of a small number of fuel pellets or pieces of fuel cladding becoming dislodged from the damage fuel rods is considered.

If a fuel pellet or piece of fuel cladding were to block one of the rod-to-rod interstitial spaces, the impact on the thermosiphon natural convection heat transfer mechanism would be miniscule. This is due to the large number of such interstitial spaces within a single fuel assembly (there are 196 in a 15x15 array fuel assembly and 256 in a 17x17 array fuel assembly). Each interstitial space is connected to the four adjacent spaces, so helium could easily flow around any such localized blockage. The contact between any such dislodges fuel pellet and the surrounding fuel rods would still allow for effective removal of heat from the fuel pellet.

If a fuel pellet or piece of fuel cladding were to fall completely out of the fuel assembly and into the bottom mouseholes region of the fuel basket, the impact on the thermosiphon natural convection heat transfer mechanism would be similarly negligible. The mouseholes consist of a 3/8" high by 4" wide rectangular opening topped by a 4" diameter semicircular opening. None of the rectangular openings in the entire fuel basket are credited in the thermal analysis, so that the deposition of any fuel-related debris such as crud would be bounded. The size of the neglected rectangular openings is larger than the possible dislodged fuel pellets or cladding pieces. A fuel pellet in contact with the baseplate would efficiently reject heat to the baseplate through conduction and would continue to be cooled by the thermosiphon natural convection flow through the mouseholes.

There would not be an expected effect of corrosion to the MPC from fuel pellets being in contact with the stainless steel MPC surface in the dry, cool, and inert environment.

2.2.4 Summary of Thermal Assessment

In summary, the presence of the damaged fuel rods does not have any actual impact on the temperatures and pressures within the HI-STORM System. All cooling mechanisms will continue to perform as designed with no reduction in efficacy under all previously evaluated conditions of storage (normal, off-normal and accident).

2.3 Structural Assessment

The damaged fuel rods have no significant effect on the structural performance of the HI-STORM 100 System. The reasons for this conclusion are as follows. First, the damaged fuel rods have no physical effect on the HI-STORM overpack or the HI-TRAC transfer cask since they do not come in contact with the stored fuel. In addition, there were no visual indications of fuel assembly damage so the damaged fuel rods do not impact the MPC fuel basket. As explained in Section 2.2, the normal, off-normal, and accident condition pressures and temperatures specified in HI-STORM FSAR [2] Tables 2.2.1 and 2.2.3 are not exceeded as a result of the damaged fuel rods. The stresses in the overpack and the transfer cask due to normal and off-normal handling events remain as calculated in the HI-STORM FSAR [2], since the dead weight of the loaded casks and their centers of gravity are unaffected by the damaged fuel rods. Likewise, the impact decelerations experienced by the cask as a result of a handling accident or a hypothetical tip-over event are not increased, and the stability of the cask under the design basis environmental phenomena (i.e., tornado winds, earthquake, etc.) continues to be assured. Finally, the damaged fuel rods have no impact on the structural ability of the cask or the MPC to withstand pressure loads due to tornado winds, flood, or accident explosions.

2.4 Radiological Assessment

2.4.1 Shielding - Direct Radiation Dose

During loading operations, dose surveys were performed on each cask prior to placing them into service. These dose surveys demonstrated that the casks satisfied the HI-STORM 100 dose requirements in the HI-STORM CoC [3]. Therefore, the damaged fuel rods in these assemblies have no noticeable impact on the shielding performance of the overpack. In addition, Chapter 5 of the HI-STORM FSAR [2] has demonstrated that storing damaged fuel assemblies in the MPC-24 or MPC-68 has little impact on the external dose rates. This analysis was performed by simulating collapsed damaged fuel assemblies. License Amendment Request 1014-2 [4], which is currently in rulemaking, concludes, based on the analysis performed for the MPC-24 and the MPC-68 that the shielding of the MPC-32 will not be significantly affected by the storage of damaged fuel.

The postulated relocation of the fuel contained in two rods would have a negligible effect on the source distribution within the cask and similarly would not have an effect on the dose contribution at the site boundary.

2.4.2 Shielding - Effluent Radiation Dose

The normal condition effluent radiation dose evaluation in HI-STORM FSAR [2] assumes a 1% rod rupture. This bounds the number of fuel rods that have been stored as damaged. Therefore, the damaged fuel assemblies stored in the MPC-32 have no impact on the offsite effluent radiation dose.

License Amendment Request 1014-2 [4], which is currently in rulemaking, demonstrates that there is no credible leakage under normal conditions since the MPC meets the criteria specified in Interim Staff Guidance 18 [5]. This provides further evidence that the damaged fuel assemblies stored in the MPC-32 have no impact on the offsite effluent radiation dose.

2.5 Operations Assessment

Section 8.3 of the HI-STORM FSAR [2] covers the unloading of the HI-STORM 100 system in the spent fuel pool. Should it become necessary to unload the MPCs at the ANO plant that contain damaged fuel, the operations that could possibly be affected are more specifically discussed in Section 8.3.3 – Preparation for Unloading. The condition of the damaged fuel inside the MPC is unknown and therefore it is assumed that loose fuel pellets could potentially be lying on the bottom of the MPC. The only actions that this situation would affect are the cool down operations and the filling of the MPC with water.

The cool down operations are accomplished by circulating helium in through the drain port, up through the MPC, and out through the vent port. The cool down can be done using the Forced Helium Dehydrator or the Helium Cooling and Circulating Skid. Either way, loose fuel pellets will not inhibit the flow of helium as they could not physically clog any of the MPC ports. Although fuel pellets could fall into the sump and temporarily block the flow path through the drain line, the high velocity cooling helium would blow the debris away form the end of the drain line. Filling the MPC with water through the drain line will also flush any debris away from the drain. Therefore the damaged fuel will not adversely affect the cool down operations.

The filling of the MPC with water is done in basically the same way as the cool down process except that only a water supply is connected to the drain port and a vent line is connected to the vent port of the MPC. Similarly the flow of water into the MPC from the drain line nor the escape of gases from the vent port could not possibly become blocked by loose fuel pellets, therefore no adverse affects to the water fill process will result from loose fuel pellets in the MPC.

Unloading of the MPC is thus unaffected by the condition of having damaged fuel which could consist of loose fuel pellets located in the MPC.

2.6 Accident Assessments

Chapter 11 of the HI-STORM FSAR [2] presents the evaluation of the HI-STORM 100 System for the effects of off-normal and postulated accident conditions. The presence of damaged fuel in the MPC has been considered with respect to each of these conditions and is found to have insignificant impact on their evaluations.

2.6.1 Off-Normal Conditions

Per Section 11.1 of the HI-STORM FSAR [2], the structural performance of the HI-STORM 100 System is affected by the following conditions:

Off-normal pressures
Off-normal environmental temperatures
Leakage of one seal
Off-normal handling of HI-TRAC
Off-normal load combinations

The thermal performance of the HI-STORM 100 System, as stated in Section 11.1 of the HI-STORM FSAR [2] is affected by the following conditions:

Off-normal pressures
Off-normal temperatures
Partial blockage of air inlets

All of the above conditions are shown in the HI-STORM FSAR [2] to produce stresses, pressures, and temperatures which are within allowable values. Therefore, as explained in previous sections of this report, damaged fuel inside the MPC will have no impact on the performance of the HI-STORM 100 System.

2.6.2 Accidents

The following postulated accident scenarios were reviewed with respect to the structural performance of the HI-STORM 100 System to determine that no adverse consequences would result from stored damaged fuel in the ANO MPCs:

HI-TRAC Transfer Cask handling accident
HI-STORM Overpack handling accident
Tip-over
Tornado
Flood
Earthquake
100% fuel rod rupture
Explosion
Burial under debris
Extreme environmental temperature

The following postulated accident scenarios were reviewed with respect to the thermal performance of the HI-STORM 100 System to determine that no adverse consequences would result from stored damaged fuel in the ANO MPCs:

HI-TRAC Transfer Cask handling accident
Tip-over
Fire
Partial blockage of MPC basket vent holes
Tornado
Flood
100% fuel rod rupture
Confinement boundary leakage
100% blockage of air inlets
Burial under debris
Extreme environmental temperatures

The following postulated accident scenarios were reviewed with respect to the shielding performance of the HI-STORM 100 System to determine that no adverse consequences would result from stored damaged fuel in the ANO MPCs:

HI-TRAC Transfer Cask handling accident
Tip-over
Fire
Tornado

The confinement boundary leakage accident was reviewed with respect to the confinement function of the HI-STORM 100 System to determine that no adverse consequences would result from stored damaged fuel in the ANO MPCs.

3. SUMMARY

An MPC-32/HI-STORM storage system loaded with up to two damaged assemblies has been evaluated against its licensing basis analysis. The evaluation has determined that continued storage in the current configuration is justified.

4. REFERENCES

[1] HI-2012771 Rev 7, *HI-STORM 100 and HI-STAR 100 Additional Criticality Calculations*, Holtec International.

[2] HI-2002444 Rev 2, HI-STORM 100 Final Safety Analysis Report.

[3] HI-STORM 100 Certificate of Compliance No. 1014, Rev. 1.

[4] HI-STORM 100 Certificate of Compliance No. 1014, Proposed Rev. 2 (LAR 1014-2).

[5] Interim Staff Guidance-18 Rev 0, The US Nuclear Regulatory Commission, May 2, 2003.