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U.S Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555-0001

Dresden Nuclear Power Station, Units 1 and 2
Facility Operating License Nos. DPR-2 and DPR-19
NRC Docket Nos 50-10, 50-237, and 72-37

Subject: Request for Additional Information for the HI-STORM 100 Cask System Exemption Request

References:

(1) Letter from R. M. Krich (Exelon Generation Company, LLC) to US NRC, "Request for Exemption from 10 CFR 72.212, 'Conditions of general license issued under 10 CFR 72.210,' and 10 CFR 72.214, 'List of approved spent fuel storage casks,' Regarding the Conditions of Use for the HI-STORM 100 Cask System and for the HI-STAR 100 Cask System," dated January 11, 2001

(2) Letter from R. M. Krich (Exelon Generation Company, LLC) to US NRC, "Request for Exemption from 10 CFR 72.212, 'Conditions of General license issued under 10 CFR 72 210,' and 10 CFR 72.214, 'List of approved spent fuel storage casks,' Regarding the Conditions of Use for the HI-STORM 100 Cask System," dated January 11, 2001

(3) Letter from C P. Jackson (US NRC) to R. M. Krich (Exelon Generation Company, LLC), "Dresden Independent Spent Fuel Storage Exemption Requests," dated January 29, 2001

In the Reference 1 and Reference 2 letters, in accordance with 10 CFR 72.7, "Specific exemptions," we requested NRC approval of a temporary exemption from the requirements of 10 CFR 72.212, "Conditions of general license issued under 10 CFR 72.210," and 10 CFR 72.214, "List of approved spent fuel storage casks," for the HI-STORM 100 cask system produced by Holtec International, Inc. (i.e., Holtec).

In the Reference 3 letter, we were requested to provide additional information related to the HI-STORM 100 exemption request. The additional information is provided in the enclosure to this letter.

NMSS01 Public

If you have any questions about this letter, please contact K. M. Root at (630) 663-7292.

Respectfully,

R. M. Krich
Director - Licensing
Mid-West Regional Operating Group

Enclosure - Additional Information Related to the HI-STORM 100 Cask System Exemption Request

bcc: Regional Administrator - NRC Region III
NRC Project Manager, NRR - Dresden Nuclear Power Station, Unit 1
NRC Project Manager, NRR - Dresden Nuclear Power Station, Units 2 and 3
Decommissioning Branch Chief - NRC Region III
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Office of Nuclear Facility Safety - IDNS
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ENCLOSURE

Additional Information Related to the HI-STORM 100 Cask System Exemption Request

References:
(1) Letter from R. M. Krich (Exelon Generation Company, LLC) to US NRC, "Request for Exemption from 10 CFR 72.212, 'Conditions of general license issued under 10 CFR 72.210,' and 10 CFR 72.214, 'List of approved spent fuel storage casks,' Regarding the Conditions of Use for the HI-STORM 100 Cask System and for the HI-STAR 100 Cask System," dated January 11, 2001

(2) Letter from R. M. Krich (Exelon Generation Company, LLC) to US NRC, "Request for Exemption from 10 CFR 72 212, 'Conditions of General license issued under 10 CFR 72.210,' and 10 CFR 72.214, 'List of approved spent fuel storage casks,' Regarding the Conditions of Use for the HI-STORM 100 Cask System," dated January 11, 2001

(3) Letter from C. P. Jackson (US NRC) to R. M. Krich (Exelon Generation Company, LLC), "Dresden Independent Spent Fuel Storage Exemption Requests," dated January 29, 2001

(4) Holtec International, Inc. letter, "USNRC Docket No. 72-1014; HI-STORM 100 Certificate of Compliance 1014; HI-STORM 100 License Amendment Request 1014-1, Revision 1, Supplement 1," dated October 6, 2000

In the Reference 1 and Reference 2 letters, in accordance with 10 CFR 72.7, "Specific exemptions," we requested NRC approval of a temporary exemption from the requirements of 10 CFR 72.212, "Conditions of general license issued under 10 CFR 72.210," and 10 CFR 72.214, "List of approved spent fuel storage casks," for the HI-STORM 100 cask system produced by Holtec International, Inc. (i.e., Holtec).

In the Reference 3 letter, we were requested to provide additional information related to the HI-STORM 100 exemption request. The additional information is provided below

CASK PAD PARAMETERS

We were requested to provide the revised impact analysis with the new cask pad parameters showing acceptable results for the design events (i.e., the design basis drop and tip-over events). The revised impact analysis, which was previously provided in the Reference 4 letter, is provided in the attachment to this enclosure.

Certificate of Compliance (CoC) No. 1014, Appendix B, "Approved Contents and Design Features for the HI-STORM 100 Cask System," Design Features 3.4, "Site-Specific Parameters and Analyses," specifies, in part, the requirements for the strength of the concrete storage pads upon which the HI-STORM 100 casks will be placed In the design basis non-mechanistic tip-over event is 39.91 g for the Parameter Set B design parameters.

SPENT FUEL STORAGE CASK HEAT REMOVAL SYSTEM

In the Reference 2 letter, we identified an issue regarding the potential for the Limiting Condition for Operation (LCO) 3.1.2, "SFSC Heat Removal System," in CoC No. 1014, Appendix A, "Technical Specifications for the HI-STORM 100 Cask System," to not be met as a result of the DNPS design basis flooding accident. However, we are pursuing a means by which blockage of the cask inlet ducts would not result in the Spent Fuel Storage Cask (SFSC) Heat Removal System being inoperable for longer than the Completion Times of LCO 3.1.2 in the event of a design basis flooding accident at DNPS. Therefore, since the Completion Times of LCO 3 1 2 can be met in the event of a design basis flooding accident at DNPS, we are withdrawing this element of the previously submitted exemption request.

FUEL ASSEMBLY CHARACTERISTICS

We were requested to provide the following additional information regarding the Boiling Water Reactor (BWR) fuel assembly characteristics for those fuel assembly parameter limits specified in the Reference 2 letter.

- An explanation with a basis for why the revised fuel characteristics are within the bounds of the analysis performed for the currently approved fuel characteristics,
- For the fuel characteristics that are not bounded by the existing analysis used for the currently approved fuel, confirm that the revised analysis was performed using a previously NRC reviewed and approved methodology,
- For the fuel characteristics that are not bounded by the existing analysis used for the currently approved fuel, specify the revised analysis result and demonstrate all applicable acceptance criteria are met.

Table 2 1-3, "BWR Fuel Assembly Characteristics," in CoC No. 1014, Appendix B, specifies, in part, the fuel assembly parameters for fuel assembly array/classes 6x6A, 6x6B, and 8x8A.

Increased Maximum Design Initial Uranium Mass

Some of the DNPS, Unit 1 fuel assemblies have design initial uranium masses slightly above the specified limit (i.e., ≤ 108 kg/assembly), including the tolerance allowed by Table 2.1-3 Note 3, for the fuel assembly array/classes 6x6A and 6x6B.

In lieu of the maximum design initial uranium mass currently specified in Table 2.1-3, we are proposing to use a maximum design initial uranium mass of ≤ 110 kg/assembly including the tolerance allowed by Table 2.1-3 Note 3, which will envelop these DNPS, Unit 1 fuel assemblies. The following provides the basis for why this proposed revision to the maximum design initial uranium mass is within the bounds of the analysis performed for the currently approved fuel assembly characteristics.

In lieu of the fuel assembly parameter limits currently specified in Table 2.1-3, we are proposing to use the following limits, which will envelop the characteristics of those DNPS, Unit 1 fuel assemblies.

Fuel assembly array/class 6x6A fuel rod clad ID ≤ 0.5105 inches
Fuel assembly array/class 6x6A fuel pellet diameter ≤ 0.4980 inches
Fuel assembly array/classes 6x6A and 6x6B fuel rod pitch ≤ 0.710 inches
Fuel assembly array/classes 6x6A, 6x6B, and 8x8A active fuel length ≤ 120 inches
Fuel assembly array/classes 6x6A and 6x6B number of fuel rod locations "35 or 36"
Fuel assembly array/class 8x8A number of fuel rod locations "63 or 64"
Fuel assembly array/classes 6x6A, 6x6B, and 8x8A number of water rods "1 or 0"
Fuel assembly array/classes 6x6A, 6x6B, and 8x8A water rod thickness ≥ 0 inches

The following provides the basis for why this proposed revision to the fuel assembly parameter limits is within the bounds of the analyses performed for the currently approved fuel assembly characteristics.

- Structural Evaluation

  The proposed changes to the fuel assembly parameter limits do not increase the weight of the contents or the cask. Therefore, the proposed changes do not affect the existing structural evaluation.

- Thermal Evaluation

  The proposed changes to the fuel assembly parameter limits do not increase the decay heat load or change the heat transfer characteristics of the cask. Therefore, the proposed changes to the fuel assembly parameter limits are bounded by the existing thermal analyses for previously approved contents, with the exception noted below.

  Increasing the fuel rod clad ID resulted in a thinner cladding for the fuel assembly array/class 6x6A, which required a revision to the thermal analysis for this array/class. The revised thermal analysis for the fuel assembly array/class 6x6A was performed using a previously NRC reviewed and approved methodology. The bounding fuel cladding stress for the fuel assembly array/class 6x6A "thin clad" (i.e., fuel assembly array/class 6x6A with the thinner cladding) increased from 65.3 MPa to 94.1 MPa, resulting in a decrease in the peak cladding temperature limits as shown below.

ATTACHMENT

HI-STORM 100 Deceleration Under Postulated Vertical Drop and Tip-over Event

ACI 318 provisions places a restriction on the lower bound values of τ_p, f_c', and E that must be met in an ISFSI pad design.

The focus, however, is to quantify the peak decelerations that would be experienced by a loaded HI-STORM 100 cask under the postulated impact scenarios for the two pad designs defined by parameter Sets A and B, respectively. The information presented also serves to further authenticate the veracity of the Holtec DYNA3D model described in the 1997 benchmark report [A.4.]

A.2 Purpose

The purpose is to demonstrate that the rigid body deceleration experienced by the HI-STORM 100 System during a handling accident or non-mechanistic tip-over are below the design basis deceleration of 45g's (HI-STORM 100 FSAR Table 3.1.2). Two accidental drop scenarios of a loaded HI-STORM 100 cask on the ISFSI pad are considered. They are:

i. Tipover: A loaded HI-STORM 100 is assumed to undergo a non-mechanistic tipover event and impacting the ISFSI pad with an incipient impact angular velocity, which is readily calculated from elementary dynamics.

ii. End drop: The loaded HI-STORM 100 is assumed to drop from a specified height h, with its longitudinal axis in the vertical orientation, such that its bottom plate impacts the ISFSI pad.

It is shown in HI-STORM 100 FSAR Appendix 3.X that dynamic load factors are a function of the predominate natural frequency of vibration of the component for a given input load pulse shape. Dynamic load factors are applied, as necessary, to the results of specific component analyses performed using the loading from the design basis rigid body decelerations. Therefore, it is desired to demonstrate that the rigid body deceleration experienced in each of the drop scenarios is below the HI-STORM 100 45g design basis.

A.3 Background and Methodology

In 1997 Lawrence Livermore National Laboratory (LLNL) published the experimentally obtained results of the so-called fourth series billet tests [A.1] together with a companion report [A.2] documenting a numerical solution that simulated the drop test results with reasonable accuracy Subsequently, USNRC personnel published a paper [A.3] affirming the NRC's endorsement of the LLNL methodology. The LLNL simulation used modeling and simulation algorithms contained within the commercial computer code DYNA3D [A.6].

The LLNL cask drop model is not completely set forth in the above-mentioned LLNL reports. Using the essential information provided by the LLNL [A.2] report, however, Holtec is able to develop a the concrete, f_c' and stiffness of the sub-grade (expressed by its effective Young's modulus, E). The structural rigidity of the ISFSI pad will increase if any of the three above-mentioned parameters (t_p, f_c' or E) is increased. For the reference pad, the governing parameters (i.e., t_p, f_c' and E) are assumed to be identical to the pad defined by LLNL [A.2], which is also the same as the pad utilized in the benchmark report [A.4]. We refer to the LLNL ISFSI pad parameters as Set A. (Table A.1).

As can be seen from Table A.1, the nominal compressive strength f_c' in Set A is limited to 4200 psi. However, experience has shown that ISFSI owners have considerable practical difficulty in limiting the 28 day strength of poured concrete to 4200 psi, chiefly because a principal element of progress in reinforced concrete materials technology has been in realizing ever increasing concrete nominal strength. Inasmuch as a key objective of the ISFSI pad is to limit its structural rigidity (and not f_c' per se), and limiting f_c' to 4200 psi may be problematic in certain cases, an alternative set of reference pad parameters is defined (Set B in Table A.1), which permits a higher value of f_c' but much smaller values of pad thickness, t_p and sub-grade Young's modulus, E.

The ISFSI owner has the option of constructing the pad to comply with the limits of Set A or Set B without performing site-specific cask impact analyses. It is recognized that, for a specific ISFSI site, the reinforced concrete, as well as the underlying engineered fill properties, may be different at different locations on the pad or may be uniform, but non-compliant with either Set A or Set B. In that case, the site-specific conditions must be performed to demonstrate compliance with the design limits of the HI-STORM system (e.g., maximum rigid body g-load less than 45 g's). The essential data which define the pad (Set A and Set B) used to qualify the HI-STORM 100 are provided in Table A.1.

The HI-STORM 100 steel structural elements (outer shell, inner shell, radial plates, lid, etc.), are fabricated from SA-516 Grade 70. The steel is described as a bi-linear elastic-plastic material with limited strain failure by five material parameters (E, S_y, S_u, ϵ_u, and ν). The numerical values used in the finite element model are shown in Table A.2. The concrete located inside of the overpack for this dynamic analysis is defined to be identical with the concrete pad. This is conservative since the concrete assumed in the reference pad is reinforced. Therefore, the strength of the concrete inside the HI-STORM 100 absorbs less energy if it is also assumed to be reinforced.

A.4.2 Input Data

Table A.1 characterizes the properties of the full-scale reference target pad used in the analysis of the full size HI-STORM 100 System. The principal strength parameters that define the stiffness of the pad, namely, t_p, E and f_c' are input in the manner described in [A.2] and [A.4].

Table A.2 contains the material description parameters for the steel types, SA-516-70 used in the numerical investigation.

The MPC and the contained fuel are modeled in two parts that represent the lid and baseplate, and the fuel area. An elastic material is used for both parts. The finite-element mesh pertinent to the MPC contains 1122 solid finite-elements and is shown in HI-STORM 100 FSAR Figure 3.A.15. The mass density is appropriate to match a representative weight of 356,521 lb. that is approximately mid-way between the upper and lower weight estimates for a loaded HI-STORM 100.

The total weight used in the analysis is approximately 2,000 lb. lighter than the HI-STORM 100 containing the lightest weight MPC.

Analysis of a single mass impacting a spring with a given initial velocity shows that both the maximum deceleration "a_M" of the mass and the time duration of contact with the spring "t_c" are related to the dropped weight "w" and drop height "h" as follows:

$$a_M \sim \frac{\sqrt{h}}{\sqrt{w}}; t_o \sim \sqrt{w}$$

Therefore, the most conservatism is introduced into the results by using the minimum weight. It is emphasized that the finite element model described in the foregoing is identical in its approach to the "Holtec model" described in the benchmark report [A.4]. Gaps between the MPC and the overpack are included in the model.

A.6 Impact Velocity

a. Linear Velocity: Vertical Drops

For the vertical drop event, the impact velocity, v, is readily calculated from the Newtonian formula:

$$v = \sqrt{(2gh)}$$

where

g = acceleration due to gravity
h = free-fall height

This equation can be rewritten in the form

$$\frac{I_A}{2}\frac{d(\dot{\theta}_1)^2}{d\theta_1} = Mgr\sin\theta_1$$

which can be integrated over the limits $\theta_1 = 0$ to $\theta_1 = \theta_{2f}$ (See HI-STORM 100 FSAR Figure 3.A.17).

The final angular velocity θ_1 at the time instant just prior to contact with the ISFSI pad is given by the expression

$$\dot{\theta}_1(t_B) = \sqrt{\frac{2\,Mgr}{I_A}(1-\cos\theta_{2f})}$$

where, from HI-STORM 100 FSAR Figure 3.A.17

$$\theta_{2f} = \cos^{-1}\left(\frac{d}{2r_1}\right)$$

This equation establishes the initial conditions for the final phase of the tip-over analysis; namely, the portion of the motion when the cask is decelerated by the resistive force at the ISFSI pad interface.

Using the data germane to HI-STORM 100 (Table A.3), and the above equations, the angular velocity of impact is calculated as 1.49 rad/sec.

A.7 Results

A.7.1 Set A Pad Parameters

It has been previously demonstrated in the benchmark report [A.4] that bounding rigid body decelerations are achieved if the cask is assumed to be rigid with only the target (ISFSI pad) considered as an energy absorbing media. Therefore, for the determination of the bounding decelerations reported herein, the HI-STORM storage overpack was conservatively made rigid except for the radial channels that position the MPC inside of the overpack. The MPC material behavior was characterized in the identical manner used in the Livermore Laboratory analysis as was the target ISFSI pad and underlying soil. The LS-DYNA3D time-history results are processed using

A.7.2 Set B Parameters

As stated previously, Set B parameters produce a much more compliant pad than the LLNL reference pad (Set A). This fact is borne out by the tipover and end analyses performed on the pad defined by the Set B parameters. Table A.4 provides the filtered results for the two impact scenarios. In every case, the peak decelerations corresponding to Set B parameters are less than those for Set A (also provided in Table A.4).

Impact force and acceleration time history curves for Set B have the same general shape as those for Set A and are contained in the calculation package [A.7]. All significant results are summarized in Table A.4.

A.8 Computer Codes and Archival Information

The input and output files created to perform the analyses reported herein are archived in Holtec International calculation package [A.7].

A. 9 Conclusion

The DYNA3D analysis of HI-STORM 100 reported herein leads to the following conclusion:

a. If a loaded HI-STORM undergoes a free fall for a height of 11 inches in a vertical orientation on to a reference pad defined by Table A.1, the maximum rigid body deceleration is less than 45g's for both Set A and Set B pad parameters.

b. If a loaded HI-STORM 100 overpack pivots about its bottom edge and tips over on to a reference pad defined by Table A.1, then the maximum rigid body deceleration of the cask centerline at the plane of the top of the MPC fuel basket cellular region is less than 45g's for both Set A and Set B parameters..

Table A.4 provides key results for all drop cases studied herein for both pad parameter sets (A and B). If the pad designer maintains each of the three significant parameters (t_p, f_c', and E) below the limit for the specific set selected (Set A or Set B), then the stiffness of the pad at any ISFSI site will be lower and the computed decelerations at the ISFSI site will also be lower. Furthermore, it is recognized that a refinement of the cask dynamic model will accrue further reduction in the computed peak deceleration. For example, incorporation of the *structural* flexibility in the MPC enclosure vessel, fuel *basket*, etc., would lead to additional reductions in the computed values of the peak deceleration. These refinements, however, add to the computational complexity. Because g-

A.10 References

[A.1] Witte, M., et al., "Evaluation of Low-Velocity Impacts Tests of Solid Steel Billet onto Concrete Pads.", Lawrence Livermore National Laboratory, UCRL-ID-126274, Livermore, California, March 1997.

[A.2] Witte, M., et al., "Evaluation of Low-Velocity Impacts Tests of Solid Steel Billet onto Concrete Pads, and Application to Generic ISFSI Storage Cask for Tipover and Side Drop.", Lawrence Livermore National Laboratory, UCRL-ID-126295, Livermore, California, March 1997.

[A.3] Tang, D.T., Raddatz, M.G., and Sturz, F.C., "NRC Staff Technical Approach for Spent Fuel Cask Drop and Tipover Accident Analysis", SFPO, USNRC (1997).

[A.4] Simulescu, I., "Benchmarking of the Holtec LS-DYNA3D Model for Cask Drop Events", Holtec Report HI-971779, September 1997.

[A.5] LS-DYNA3D, Version 936-03, Livermore Software Technology Corporation, September 1996.

[A.6] Whirley, R.G., "DYNA3D, A Nonlinear, Explicit, Three-Dimensional Finite element Code for Solid and Structural Mechanics - User Manual.", Lawrence Livermore National Laboratory, UCRL-MA-107254, Revision 1, 1993.

[A.7] Zhai, J. "Analysis of the Loaded HI-STORM 100 System Under Drop and Tip-Over Scenarios", Holtec Report HI-2002474, July 2000.

Table A.2: Essential Steel Material Properties for HI-STORM 100 Overpack

Steel Type	Parameter	Value
SA-516-70 at T = 350 deg. F	E	2.800E + 07
	S_y	3.315E+04 psi
	S_u	7.000E+04 psi
	ϵ_u	0.21
	ν	0.30

Note that the properties of the steel components, except for the radial channels used to position the MPC, do not affect the results reported herein since the HI-STORM 100 is eventually assumed to behave as a rigid body (by internal constraint equations automatically computed by DYNA3D upon issue of a "make rigid" command). In HI-STORM 100 FSAR Section 3.4, however, stress and strain results for an additional tip-over analysis, performed using the actual material behavior ascribed to the storage overpack, are presented for the sole purpose of demonstrating ready retrievability of the MPC after the tip-over.

Table A.4: Filtered Results for Drop and Tip-Over Scenarios for HI-STORM 100[†]

Drop Event	Max. Displacement (inch)		Impact Velocity (in/sec)	Max. Deceleration[††] at the Top of the (g's) Basket		Duration of Deceleration Pulse (msec)	
	Set A	Set B		Set A	Set B	Set A	Set B
End Drop for 11 inches	0.65	0.81	92.2	43.98	41.53	3.3	3.0
Non-Mechanistic Tip-over	4.25	5.61	304.03	42.85	39.91	2.3	2.0

[†] The passband frequency of the Butterworth filter is 350 Hz.

[††] The distance of the top of the fuel basket is 206" from the pivot point. The distance of the top of the cask is 231.25" from the pivot point. Therefore, all displacements, velocities, and accelerations at the top of the fuel basket are 89.08% of those at the cask top (206"/231.25").