Possible Changes to
10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities.

The Nuclear Regulatory Commission (NRC) staff has released the following draft rule language in response to guidance from the Commission dated May 31, 2006, that directed the staff to release draft rule text, statements of consideration, and the technical basis for public review, and hold workshops, if necessary, prior to submission of a proposed rule. The change under consideration would clarify the regulations such that licensees would not be required to produce a separate criticality analysis for fuel within a dry storage cask or transportation container in a spent fuel pool.

The availability of the draft rule language and technical basis are intended to inform stakeholders of the current status of the NRC’s activities to clarify the regulatory boundary between 10 CFR Part 50 and 10 CFR Part 71 or Part 72 for criticality accident consideration. This early draft rule language and technical basis may be incomplete in one or more respects and may be subject to significant revisions during the rulemaking process. The NRC is not soliciting formal public comments on this draft rule language. No stakeholder requests for a comment period will be granted at this stage in the rulemaking process. Public comments will be requested on the proposed rule at a later date in accordance with the rulemaking provisions of the Administrative Procedures Act.

Draft Rule Language

Section 50.68 is revised by adding a new paragraph (c) to read as follows:

§ 50.68 Criticality accident requirements.

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(c) While a spent fuel transportation package approved under Part 71 of this chapter or spent fuel storage cask approved under Part 72 of this chapter is in the spent fuel pool:

(1) The requirements in § 50.68(b) do not apply to the fuel located within that package or cask; and

(2) The requirements in Part 71 or 72 of this chapter, as applicable, and the requirements of the Certificate of Compliance for that package or cask, apply to the fuel within that package or cask.

Technical Basis

I. Background:

In the production of electricity from commercial power reactors, spent fuel that is generated needs to be stored and safely managed. As part of the design of all commercial power reactors, spent fuel storage pools (SFP) were included to provide for the safe storage of spent fuel for a number of years. For many years there was sufficient room in the original spent fuel pools to continually store spent fuel without space restrictions being an immediate concern. In the 1960’s and 1970’s, when the spent fuel pools currently in use were designed and built, it was anticipated that the spent fuel would be moved off the reactor site for further processing and/or permanent disposal. The planned long-term approach is for disposal of this spent fuel in a permanent geological repository.

As delays were encountered with the development of the permanent geological disposal site, the spent fuel pools began to fill up and space restrictions became a concern. Since the

mid 1980's licensees, with NRC approval, have increased the storage capacity of the spent fuel pools by changing the designs of the storage racks to allow the fuel to be safely stored closer together. This was recognized as a short term solution, with the assumption that permanent disposal would be made available within a reasonable period. As additional delays were encountered with the permanent geological disposal of the spent fuel, the nuclear power industry, in conjunction with the NRC, developed alternative storage solutions, including storing the spent fuel in dry storage casks on their sites.

Maintaining the capacity to store spent fuel in a spent fuel pool is important for safety. Being able to store the spent fuel in a water filled spent fuel pool allows the fuel that is removed from the reactor core at the start of a refueling outage to be safely cooled at the time it is generating the greatest decay heat. Also, the water provides shielding for the workers involved in conducting maintenance on the various systems and components necessary to safely operate the reactor. During a refueling outage inspection and maintenance activities need to be performed on the systems and components that would normally protect the fuel from damage as a result of the operation of the reactor. These inspections and maintenance activities can be accomplished more effectively and efficiently by draining the water from the reactor coolant and other supporting systems. Placing the fuel assemblies in the spent fuel pool during this period allows the reactor coolant and other systems to be drained while keeping the spent fuel safe (covered with water). Therefore, it is important to maintain the capability to completely remove all of the fuel assemblies from the reactor vessel during a refueling outage (full core offload capability). From an operational perspective, additional capacity should be maintained to accommodate a full core offload as well as the storage of new fuel that replaces the spent fuel permanently removed from the reactor core.

Storage of spent fuel can be done safely in a water filled spent fuel pool under 10 CFR Part 50, a transportation package under 10 CFR Part 71, or a dry storage cask under 10 CFR Part 72. The primary technical challenges involve removing the heat generated by the spent fuel (decay heat), storing the fuel in an arrangement that avoids an accidental criticality, and providing radiation shielding. Removing the decay heat keeps the spent fuel from becoming damaged due to excessive heatup. Dry storage casks are designed to be capable of removing the decay heat generated by the fuel when filled with water or when dry without the need for active heat removal systems. Avoiding an accidental criticality is important to preclude the possibility of overheating the spent fuel and damaging the fuel. When dry, casks are subcritical by the absence of water as a neutron moderator, as well as by geometric design, and through the use of neutron poison materials such as boral and poison plates. When the casks are flooded with water, they may also rely on soluble boron to maintain the subcritical condition. Therefore, a boron dilution event is the scenario that could result in an accidental criticality with the possibility of excessive fuel temperature and subsequent fuel damage. Radiation shielding, provided by the water in a spent fuel pool or the container material in a dry storage cask, is important to protect people that may be near the spent fuel from unacceptable exposure to radiation. The NRC has promulgated regulations governing the capability of both spent fuel pools (10 CFR Parts 50 and 70), dry storage casks (10 CFR Part 72) and transportation packages (10 CFR Part 71) to address these technical challenges for the protection of public health and safety.

Since the original design of commercial reactors included spent fuel pools, the spent fuel is stored in these pools when it initially comes out of the reactor. Decay heat from this spent fuel is primarily produced by the radioactive decay of fission products generated during the period the fuel is in the reactor core. As the fission products decay, the amount of decay heat generated in the spent fuel also decreases. So, over time the spent fuel becomes cooler,

requiring less heat removal capability. Since the decay heat is higher when the spent fuel is removed from the reactor, it is more efficient to cool the fuel in a spent fuel pool where the fuel is surrounded by water. This allows the heat to be transferred to the water in the pool. The spent fuel pool requires a dedicated cooling system to maintain the temperature of the water in the pool cool enough to prevent the water from boiling. The spent fuel is allowed to cool down in the spent fuel pool for several years before it is placed in a dry cask storage cask or transportation package. When placed in a dry storage cask or transportation package, the amount of heat generated by the spent fuel is low enough that the fuel can be cooled by the gas surrounding the fuel with the heat being transferred through the cask or package to the surrounding air. Once placed in the dry storage cask or transportation package, the fuel will remain cool enough to prevent fuel damage without the need for an auxiliary cooling system.

Spent fuel pools, dry storage casks and transportation packages are designed to preclude an accidental criticality primarily by relying on the geometrical configuration of how the spent fuel is stored. Both wet and dry storage rely on material that absorbs the neutrons necessary for the fission process to occur (fixed neutron poisons, such as boral, poison plates, etc.). This material is inserted when building the storage racks or when building the cask/package. This material is integral to the storage racks in the spent fuel pool and in the cask/package used to physically hold the spent fuel in place. This establishes the geometrical configuration of the how the spent fuel is stored. Criticality is of a greater concern when the fuel is stored in a spent fuel pool because the water used to cool the fuel is also a very effective moderator that facilitates the nuclear fission process. In dry storage, the spent fuel is surrounded by a gas that does not act as a moderator, therefore, criticality is a significantly smaller concern and the spent fuel can be safely stored closer together than in a spent fuel pool.

Transfer of the spent fuel from the spent fuel pool to the cask/package is performed while the cask/package is submerged in the spent fuel pool. When the cask/package is in the spent fuel pool, the fuel stored in the cask/package is surrounded by water, making an accidental criticality a concern. To preclude an accidental criticality in this circumstance, other physical processes or systems are used, primarily by putting a neutron poison (boron) in the water. Before any spent fuel is placed in either a spent fuel pool or a cask/package, a detailed analysis is conducted that demonstrates that the geometrical configuration and other physical systems or processes provide reasonable assurance that an accidental criticality will be prevented.

It is also possible that the spent fuel would need to be transferred out of a dry storage cask and back in to the spent fuel pool. This might arise in one of two situations. The first situation is that it might be necessary to inspect the spent fuel or the dry storage cask itself. This would necessitate transferring some or all of the spent fuel in the dry storage cask back into the spent fuel pool. The second and more probable situation that would require unloading the spent fuel from the dry storage cask back into the spent fuel pool, would be in preparation for shipment of the spent fuel. Before the spent fuel in a dry storage cask licensed pursuant to 10 CFR Part 72 only (not also licensed pursuant to 10 CFR Part 71) can be shipped, it must first be transferred to an approved transportation package licensed pursuant to 10 CFR Part 71. In order to place the spent fuel into the transportation package, it must first be unloaded from the dry storage cask back into the spent fuel pool. The dry storage cask is then removed from the spent fuel pool and is replaced by the transportation package. The spent fuel is then loaded into the transportation package.

As described in more detail below, there are sufficient regulatory controls in place to provide reasonable assurance that spent fuel can be safely stored both in spent fuel pools and

in dry storage casks or transportation packages. The purpose for the change to 10 CFR 50.68 is to reduce the regulatory burden imposed on licensees by removing a requirement for an unnecessary criticality analysis. This change clarifies that, when loading spent fuel into a dry storage cask or transportation package while in the spent fuel pool, the license requirements and controls (including the physical processes and systems) relied on by the NRC in its determination that a specific dry storage cask or transportation package is acceptable shall be followed and provide the basis for the NRC concluding that public health and safety are maintained.

II. Regulatory Evaluation:

The regulation at 10 CFR 50.68 requires that pressurized water reactor (PWR) SFPs remain subcritical in an unborated, maximum moderation condition. To demonstrate that the fuel in the SFP remains subcritical in this condition, 10 CFR 50.68 allows credit for the operating history of the fuel (fuel burnup) when analyzing the storage configuration of the spent fuel. Taking the burnup of the spent fuel into consideration reduces the reactivity of the fuel and reduces the need for soluble boron to demonstrate subcriticality. Meeting the unborated condition requirement provides reasonable assurance that potential boron dilution events that could occur during the storage period of spent fuel in the SFP would not result in an accidental criticality. Boron dilution events could occur due to leakage from the spent fuel pool requiring replenishment from an unborated water source. For example, a SFP liner rupture due to an earthquake could result in a rapid drain down of the SFP as could a rupture of the SFP cooling system. Dilution could also result from the introduction of unborated water in the vicinity of the SFP, such as from a fire suppression system. For the rapid drain down scenario, the SFP might be replenished with unborated sources of water in an effort to quickly reestablish spent fuel cooling and to provide shielding. It is necessary to reestablish spent fuel cooling during a rapid drain down event to preclude the possibility of the elevated cladding temperature that could cause overheating of the fuel and a loss of fuel cladding integrity. Because of the very low likelihood of a rapid drain down event, it is not considered part of the licensing basis for commercial nuclear power reactors.

Storage casks are approved for use by the NRC by the issuance of specific and general licenses pursuant to 10 CFR Part 72. Transportation packages for spent fuel are licensed pursuant to 10 CFR Part 71. 10 CFR Part 71 currently requires that the criticality safety system for transportation packages be designed with the assumption that a package can be flooded with fresh water (i.e., no soluble boron). Therefore, the transportation packages are already analyzed in a manner that complies with the 10 CFR 50.68 assumption. The following discussions will then focus only on storage casks. However, the transportation packages are included in the proposed change in order to allow loading/unloading operation of a transportation package into a 10 CFR Part 50 facility (i.e., spent fuel pool) without the need for a specific license or exemption considerations under 10 CFR Part 50.

The certificates and licenses issued by the NRC for these storage casks and the requirements of 10 CFR Part 72 include controls for fuel loading, storage, and unloading that provide reasonable assurance that spent fuel cooling is maintained and an accidental criticality is avoided. These controls are not identical to the requirements contained in 10 CFR 50.68, but instead allow for an alternate means of assuring safety by providing additional requirements that are not present in 10 CFR 50.68. NRC approval of the storage cask designs was, in part, predicated on the assumption that unirradiated commercial nuclear fuel (fresh fuel) of no more than 5 weight percent enrichment would remain subcritical when stored in its dry configuration and that it would remain subcritical with a sufficient boron concentration (if any boron was

required) when stored in a water filled configuration, such as when it is in a SFP at a commercial power reactor. Under 10 CFR Part 72, reliance is placed on soluble boron to assure subcriticality when the cask is full of water, rather than relying on fuel burnup. The fresh fuel assumption allowed the NRC to generically approve storage casks without regard to the operating history of the fuel from a criticality perspective by establishing a bounding case for the various fuel types that could be stored in the approved storage casks. If generic fuel burnup data were available, the NRC may have been able to approve storage cask designs without the need for boron to assure subcriticality, but would have put in place a minimum fuel burnup requirement instead. By having the 10 CFR Part 72 controls in place, loading, storage, and unloading of spent fuel can be accomplished in a manner that precludes an accidental criticality while maintaining sufficient fuel cooling capabilities.

III. Problem Statement:

On March 23, 2005, the NRC issued Regulatory Issue Summary (RIS) 2005-05 addressing spent fuel criticality analyses for SFPs under 10 CFR 50.68 and Independent Spent Fuel Storage Installations (ISFSI) under 10 CFR Part 72. The intent of the RIS was to advise reactor licensees that they must meet both the requirements of 10 CFR 50.68 and 10 CFR Part 72 with respect to subcriticality during storage cask loading in SFPs. Different assumptions are relied on under these regulations to achieve the same underlying purpose, namely to place spent fuel in a condition such that it remains cooled and to preclude an accidental criticality.

The need to meet both regulations and the differences in the assumptions creates an additional burden on licensees to show that credit for boron is not required to preclude an accidental criticality in a storage cask when filled with water. This condition exists for NRC approved high density storage casks used for storing PWR fuel. As permitted under 10 CFR Part 72, boron can be relied on at PWR SFPs to maintain subcriticality during storage cask loading or unloading. However, 10 CFR 50.68 requires that spent fuel assemblies be subcritical with unborated water in SFPs. In order to satisfy both of these requirements, a site specific analysis that demonstrates that the storage casks would remain subcritical for the specific irradiated fuel loading planned, without credit for boron, would be required. In this analysis, the licensee would rely on the fuel burnup to determine the margin to criticality for the specific cask loading. The analysis would be similar to that conducted for the SFP itself, but would take into account the unique design features of the storage cask when determining the minimum burnup required for spent fuel storage in the specific cask.

In a July 25, 2005, letter to the NRC, the Nuclear Energy Institute (NEI) indicated that the implementation of the RIS recommendations would “create an unnecessary burden for both industry and the NRC with no associated safety benefit for public.” In other words, preparing an amendment application by performing a redundant criticality analysis consistent with 10 CFR 50.68 would cause “an unnecessary administrative burden for licensees with no commensurate safety benefits” because the dry storage cask had already been approved based on the criticality analysis and assumptions required by 10 CFR Part 72, i.e., boron credit with no burnup credit. NEI reiterated its position at a meeting with the NRC staff on November 10, 2005.

Subsequent to the November 10, 2005, meeting, the NRC decided to examine the likelihood of criticality in casks while submerged in SFPs during loading or unloading in the event of a boron dilution in SFPs due to natural phenomena and other scenarios. Based on the low likelihood of such an event, NRC has determined that a revision to 10 CFR 50.68 clarifying that the requirements of 10 CFR Part 71 or 72, as appropriate, apply to transportation packages

and storage casks during loading and unloading operations while submerged in a PWR SFP. This issue does not apply to boiling water reactors (BWR) because BWR SFPs do not contain boron and dry storage casks that are used to load BWR fuel do not rely on boron to maintain subcriticality. As discussed below, there is no safety benefit from requiring the licensee to conduct a site specific analysis to comply with 10 CFR 50.68(b) in support of dry storage cask loading, fuel storage, or unloading activities.

IV. Technical Evaluation:

In assessing the proposed change to 10 CFR 50.68, the staff considered what type of events could lead to damage of the fuel in a storage cask as a result of the proposed change. Since the central issue in the application of the regulations is whether boron is credited as a control for avoiding an accidental criticality, events that reduce the boron concentration in the storage cask were considered the only events that would be affected by the proposed change. There are two types of scenarios in which a boron dilution could occur. A rapid drain down and subsequent reflood of the SFP or in leakage from the SFP cooling system or from an unborated water source in the vicinity of the SFP (i.e., fire suppression system) that would go undetected by normal licensee activities (slow boron dilution event). Each of these scenarios are addressed below.

a. Slow Boron Dilution Event

The possibility of a slow boron dilution event resulting in an accidental criticality event in a storage cask in a SFP is highly unlikely based on the requirements contained in the technical specifications attached to the Certificate of Compliance issued under 10 CFR Part 71 or 72 for the specific cask design.

The storage cask technical specifications require measurements of the concentration of dissolved boron in a SFP before and during cask loading and unloading operations. At a point a few hours prior to insertion of the first fuel assembly into a storage cask, independent measurements of the dissolved boron concentration in the SFP are performed. During the loading and unloading operation, the dissolved boron concentration in the water is confirmed at intervals that do not exceed 72 hours. The measurements of the dissolved boron in the SFP are performed independently by two different individuals gathering two different samples. This redundancy reduces the possibility of an error and increases the accuracy of the measurement that is used to confirm that the boron concentration is in compliance with the storage cask's technical specifications. These measurements are continued until the storage cask is removed from the SFP or the fuel is removed from the cask.

In addition to the storage cask technical specification boron concentration sampling requirements, 10 CFR Part 72 also requires criticality monitoring. As stated in 10 CFR 72.124(c), a criticality monitoring system is required for dry storage cask loading, storage, or unloading operations:

> "A criticality monitoring system shall be maintained in each area where special nuclear material is handled, used, or stored which will energize clearly audible alarm signals if accidental criticality occurs. Underwater monitoring is not required when special nuclear material is handled or stored beneath water shielding. Monitoring of dry storage areas where special nuclear material is packaged in its stored configuration under a license issued under this subpart is not required."

Although 10 CFR 72.124(c) states "underwater [criticality] monitoring is not required," criticality monitoring is required when special nuclear material is handled, used, or stored at

facilities were the requirements of 10 CFR Part 72 apply. Criticality monitoring can be from above the water to satisfy this requirement. The facilities to which this requirement applies include 10 CFR Part 50 SFPs when loading, storing, or unloading fuel in storage casks licensed under 10 CFR Part 72. The underlying intent of 10 CFR 72.124(c) is that criticality monitors are required under circumstances were an accidental criticality could occur as the result of changes in the critical configuration of special nuclear material. As such, storage cask loading and unloading activities need to be monitored to provide reasonable assurance that these fuel handling activities (changes in the critical configuration) do not result in an accidental criticality.

When storing fuel in a storage cask that requires boron to remain subcritical while submerged in the SFP, the critical configuration can be affected by changes to the moderation (temperature changes of the water) or boron concentration. The primary concern during storage under these circumstances is the dilution of the boron concentration. Therefore, to meet the underlying intent of 10 CFR 72.124(c) either criticality monitors are required to detect an accidental criticality or controls are necessary to preclude a boron dilution event that could lead to an accidental criticality. As previously discussed, periodic sampling (at intervals no greater than 72 hours) of the boron concentration is required when fuel is stored in storage casks in the SFP. The requirement to periodically sample the boron concentration provides reasonable assurance that should a slow boron dilution event occur, it would be identified such that actions could be taken to preclude an accidental criticality and thereby meet the underlying intent of 10 CFR 72.124(c).

A slow boron dilution event would require that an unborated source of water be injected into the SFP and be undetected by normal plant operational activities for sufficient duration to allow the boron concentration to drop below the level required to maintain a storage cask subcritical. First, consider the nature of the boron dilution event that would be required to dilute the SFP boron concentration from the storage cask technical specification concentration level (typically about 2200 ppm) to the critical boron concentration value (typically around 1800 ppm). The in leakage rate would have to be large enough to dilute the entire volume of the pool between the time of the initial boron concentration sample and the time of the subsequent boron concentration sample and yet be small enough to remain undetected. Cask loading and unloading are conducted by licensed operators who are present during any fuel movement. It is reasonable to conclude that these operators would detect all but the smallest increases in SFP level that would be indicative of a slow boron dilution event. Second, consider the storage casks loading and unloading operation frequency and duration. The frequency and duration depend on the dry storage needs and the reactor facility design. Based on historical average data, only a few casks (on the order of about 5 casks) are loaded each year at an operating reactor that is in need of dry storage. Third, consider that the time a storage cask is actually loaded with fuel while in the SFP is typically between 24 and 72 hours. When all of these factors are considered, it is clear that the likelihood of an undetected slow boron dilution event occurring during the time that a storage cask is loaded with fuel in the SFP is very remote.

Another scenario that could result in a slow boron dilution event is the intentional injection of unborated water into the storage cask while loaded with fuel. A person would need access to a source of unborated water and a means for injecting the water directly into the cask (e.g., using a fire hose). While it is possible that someone could intentionally inject unborated water into the cask, it is highly unlikely that this could be done without being promptly detected by other licensee personnel monitoring cask loading or unloading activities. This scenario would result in a localized dilution of boron concentration in the storage cask. As the soluble boron concentration decreased in the storage cask, the fuel in the cask could become critical. The inadvertent criticality would be detected by the criticality monitors required by

10 CFR 72.124 during cask loading and unloading operations. As such, the licensee would be notified of the inadvertent criticality and could take action to stop the intentional injection of unborated water into the cask, re-establish a subcritical boron concentration in the cask, and terminate the inadvertent criticality event. This scenario is essentially the same as any other slow boron dilution event in that it requires an undetected injection of unborated water into a cask that is loaded with fuel.

With the controls of the storage cask technical specifications related to monitoring boron concentration, the requirements of 10 CFR 72.124(c) for criticality monitoring to detect and avoid an accidental criticality, and the very remote likelihood of an undetected slow boron dilution event occurring at the time a storage cask is being loaded, it is reasonable to conclude that considering a slow boron dilution event there is no safety benefit in requiring a licensee to conduct a site specific analysis to demonstrate that a dry storage cask will remain subcritical in an unborated condition as required by 10 CFR 50.68(b).

b. Rapid Drain Down Event

A rapid drain down event could be postulated if there were an event that caused a catastrophic failure of the SFP liner and supporting concrete structure. If there were a catastrophic failure of the SFP liner that resulted in a rapid drain down while a storage cask was in the SFP, the borated water in the storage cask would likely remain in the storage cask providing reasonable assurance that the fuel would be cooled and remain subcritical. However, if the storage cask were to become dry, the design of the storage cask would allow the fuel to remain cooled, and without water as a moderator the fuel in the storage cask would be significantly subcritical.

To assess whether there is a safety benefit from requiring licensees to conduct an analysis of storage casks assuming no boron as the result of a rapid SFP drain down event three factors were considered in the NRC's assessment. The first factor is the probability that a storage cask will be in the SFP, loaded with fuel. The second factor is whether there are credible scenarios that could result in the rapid drain down of the SFP. The third factor is whether a boron dilution event would occur in the storage casks if the rapid SFP drain down event were to occur. As described below, when taken together, it is clear that it is not necessary to require licensees to conduct additional criticality analyses to demonstrate that the storage casks will remain subcritical assuming no boron as required by 10 CFR 50.68 in response to a SFP rapid drain down event due to its highly unlikely occurrence.

For the first factor, historical data suggests that approximately five storage casks are loaded on a annual basis at those facilities that need dry storage. The casks are typically in the SFP with fuel installed for as long as 72 hours. Using 72 hours and the historical data as initial assumptions, the probability of a storage cask loaded with spent fuel being in a SFP is about 4E-2/yr. Licensees only have the capability of moving one storage cask at a time into or out of the SFP. The total time it typically takes to bring a storage cask into the SFP, load it with fuel, and remove it from the SFP area for transport to the ISFSI is between 3 and 5 days. If a licensee were to continuously load storage casks, assuming the shortest duration to complete the transfer cycle (24 hours to transfer the cask from outside the building into the spent fuel pool; loading two to three assemblies per hour, or 12 hours to load the cask to capacity; and 36 hours for removing the cask from the spent fuel pool, sealing the cask and removing it from the building), the licensee would be able to load approximately 120 storage casks per year. Under these assumptions, the probability of having a storage cask loaded with fuel in the SFP would increase to 1.6E-1/year. If one assumes that it is possible to load 1 storage cask a week (for a total of 52 casks a year) this would result in a probability of having a cask that is loaded with fuel physically in the pool of 4E-1/year.

For the second factor, the NRC has assessed the possibility of rapid drain down events at SFPs. From NUREG-1738, "Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants," phenomena that could cause such a catastrophic failure include a storage cask drop (event frequency of about 2E-7/year), an aircraft impact (event frequency of about 2.9E-9/year), a tornado missile (event frequency of <1E-9/year) or a seismic event. A dropped storage cask does not affect the proposed change to 10 CFR 50.68 because the dilution of boron in the cask is the issue of interest. When moving a storage cask, it is either empty (no fuel) or has fuel stored in it with a closure lid installed. In each case a boron dilution event that could result in an accidental criticality in a dry storage cask would be precluded. The aircraft impact and tornado missile events are of such a low frequency that they do not need to be considered within the scope of the proposed change. However, the consequences of the aircraft and tornado events would be similar to a SFP liner rupture due to other events (such as an earthquake). This leaves a seismic event as the only initiating event for a rapid drain down of a SFP that may be credible.

In Sections 3.5.1 and 3.7.2 of NUREG-1738, the NRC describes the beyond design basis seismic event that would have to occur to result in a rapid drain down of a SFP. Given the robust structural design of the spent fuel pools, the NRC expects that a seismic event with a peak spectral acceleration several times larger than the safe shutdown earthquake (SSE) would be required to produce a catastrophic failure of the structure.

There are two information sources that the NRC relies upon to provide reasonable estimates of seismic event frequency: 1) Lawrence Livermore National Laboratory (LLNL) seismic hazard curves, published in NUREG-1488, "Revised Livermore Seismic Hazard Estimates for Sixty-Nine Nuclear Power Plant Sites East of the Rocky Mountains;" and 2) Electric Power Research Institute (EPRI) seismic hazard curves, published in EPRI NP-4726, "Seismic Hazard Methodology for the Central and Eastern United States." Both the LLNL and EPRI hazard estimates were developed as best estimates based on data extrapolation and expert opinion and are considered valid by the NRC.

In NUREG-1738, a general high confidence with a low probability of failure (HCLPF) capacity of 1.2g peak spectral acceleration (PSA), which is equivalent to about 0.5g peak ground acceleration (PGA), is established for SFPs. Under 10 CFR Part 100, “Seismic and Geologic Siting Criteria for Nuclear Power Plants,” the minimum SSE seismic PGA value is 0.1g. Typical PGA values for plants east of the Rocky Mountains range from 0.1g to 0.25g and the PGA values for plants west of the Rocky Mountains range from 0.25g to 0.75g. Using the LLNL seismic hazard curves, with a SFP HCLPF capacity of 1.2g PSA, the mean frequency of a seismically-induced rapid drain down event is estimated to be about 2E-6/year, ranging from less than 1E-7/year to 1.4E-5/year, depending on the site-specific seismic hazard. The EPRI seismic hazard curves provide a mean frequency of a seismically-induced rapid drain down event of about 2E-7/year, ranging from less than 1E-8/year to about 2E-6/year, depending on the site-specific seismic hazard.

For sites west of the Rocky Mountains, the SFP HCLPF capacity would be site-specific, but would be at least equal to the SSE. The SSE for Columbia is 0.25g PGA and has an annual probability of exceedance (APE) of 2E-4. However, it is important to note that a seismic event capable of rupturing the SFP would have to be much greater than the SSE. Therefore, it is reasonable to conclude that mean frequency of a seismically-induced rapid drain down event at Columbia is bounded by the analysis for plants East of the Rocky Mountains.

Diablo Canyon’s SSE is 0.75g PGA with an APE of 2.5E-4. San Onofre’s SSE is 0.5g PGA with an APE of 5E-4. An SSE is the earthquake that is expected to occur that produces the maximum ground motion for which certain structures must remain capable of performing

their safety function. SFPs are designed to remain functional following an SSE. Further, as noted for all of the other SFPs, the as-designed and as-built structures have significant margin to failure and are capable of remaining functional (not subject to a rapid drain down event) for earthquakes well above the SSE. Both the Diablo Canyon and San Onofre SFPs were designed and constructed in a manner that provides significant structural margin. Therefore, it is reasonable to conclude that the probability of an earthquake causing a rapid drain down event would be similar to the probabilities determined for plants East of the Rocky Mountains. As such, the NRC concluded that for these two plants, specific SFP failure probabilities where not a factor that would have an adverse affect on its determination with regard to the acceptability of the proposed change to 10 CFR 50.68.

Based on the above, it would take a seismic event significantly greater than the design basis SSE to credibly cause a SFP rapid drain down event. Using the most conservative results for a seismically-induced SFP rapid drain down event (1.4E-5) and the probability of having a storage cask with fuel installed in the pool (4E-1), the probability of having a SFP rapid drain down event when a storage cask is in the pool would likely be significantly less than 5.6E-6. This is a low probability of SFP failure when a dry storage cask is in the SFP. Coupled with the fact that to reach this low probability would require a seismic event well in excess of the SSE, the NRC concludes there is no safety benefit from requiring the licensee to conduct a site specific analysis in support of storage cask loading, fuel storage, or unloading activities.

For the third factor, a rapid drain down event is considered to be a gross, rapid loss of the water that provides cooling for the spent fuel. This event is beyond the licensing basis for PWR plants. Minor leakage is not considered to constitute failure. As such, a rapid drain down event would have to exceed the makeup capability of the normal and alternative water supplies by a significant amount to drain the pool in a short period. The makeup capacities available to refill the SFPs typically range from about 20 gallons per minute (gpm) for normal makeup to around 1000 gpm for alternative makeup supplies such as the fire suppression system. Many sites have the capability to supply borated water to refill the spent fuel pool. However, to assess the affect of a rapid drain down event on a boron dilution event in a dry storage cask, the NRC assumed that the makeup would be from an unborated water source such as a fire suppression system. The main concern with a rapid drain down event as it affects a dry storage cask is subsequently diluting the boron concentration in the cask during the attempt to refill the SFP to keep the fuel stored in the pool cooled to preclude overheating the fuel and a loss of fuel cladding integrity. Therefore, the assumption that a licensee would use an unborated source of water, such as the fire suppression system, with the largest capacity available to provide cooling water in its attempt to reflood the SFP following a rapid drain down event is reasonable given the importance of quickly re-establishing cooling of the fuel stored in the SFP. The need to establish alternative means for cooling the fuel stored in the SFP during a rapid drain down event is independent of whether a storage cask is located in the SFP and therefore, has no relation to the proposed change to 10 CFR 50.68.

The NRC considered four scenarios when assessing the affect of a rapid drain down event on diluting the boron concentration in a dry storage cask. First, the cask might drain as the SFP drains (some older cask designs have drain ports at the bottom of the cask) and the licensee is unable to reflood the SFP because the leak rate is well in excess of the normal or alternate makeup capacity available to reflood the SFP. This scenario results in the fuel stored in the dry storage cask in essentially the same condition under which it would be permanently stored. The geometrical configuration of the dry storage casks are such that without the water, the fuel will remain subcritical. Further, the dry storage cask is designed to remove the decay heat from the fuel in this configuration, so excessive cladding temperatures would not be

reached and there would be no fuel damage.

The second scenario involves those storage casks that do not have drain ports at the bottom of the cask and therefore would remain filled with water as the SFP experiences the rapid drain down event. In this scenario, the licensee would likely use the largest capacity, unborated source of cooling water to keep the spent fuel in the SFP storage racks cooled. As noted before, a rapid drain down event would significantly exceed the makeup capacity of available water systems and the licensee would need to use an alternative means, such as spraying the fuel stored in the SFP racks to keep the fuel cool. In this scenario, the water that remains in the dry storage cask would still be borated and would maintain the fuel storage in the cask subcritical. The fuel in the cask would remain cooled by the water surrounding it and the heat transfer through the cask consistent with the cask design. Again, in this situation, the fuel in the cask would be adequately cooled and maintained in a subcritical configuration providing reasonable assurance that excessive fuel cladding temperatures and subsequent fuel damage would not occur.

The third scenario involves those dry storage casks that would remain filled with borated water. The possibility exists for a licensee to cause a boron dilution event in the dry storage cask when spraying the fuel stored in the SFP racks. The location of the dry storage cask might be close enough to the SFP storage racks that it could inadvertently be sprayed at the same time as the SFP racks, overfilling the dry storage cask, and eventually diluting the boron. Under these conditions, the boron concentration would slowly decrease and this scenario becomes very similar to a slow boron dilution event as discussed previously. The criticality monitors required for dry cask loading would still be available and would provide indication of an accidental criticality. With indication of an accidental criticality, it is reasonable to assume that the licensee would take action to stop the boron dilution from continuing and restore the dry storage cask to a subcritical configuration.

Actions the licensee could take to return the dry storage cask to a subcritical configuration could include:

1. Stop spraying unborated water into the dry storage cask and allow the water in the cask to heat up with a subsequent reduction in the moderation provided by the water that would eventually re-establish a subcritical configuration at a higher water temperature. In this condition, the temperature of the water may be high enough that the water would eventually boil off (be higher that 212 degrees F at atmospheric conditions). If this were to occur, the cask would eventually become dry and the fuel would be in a subcritical configuration and cooled consistent with the design of the cask. As the water boiled off, it would continue to provide cooling to the fuel such that the fuel would not experience significantly elevated temperatures and there would be no fuel damage; or

2. Spray water into the cask from a borated water source to increase the boron concentration, re-establishing a subcritical configuration and keeping the fuel cooled.

In each case, the fuel would not be subject to excessive temperatures and therefore, there would be no fuel damage that could impact public health and safety.

Under this third scenario there is also the possibility that the licensee might intentionally spray water into the dry storage cask in an attempt to keep the fuel in the cask cool. Given that the cask will already be filled with water and the importance of cooling the fuel in the SFP storage racks (where there is no water following a rapid drain down event), the NRC considers the possibility of the intentional diversion of cooling water from the fuel stored in the SFP racks to the fuel stored in the dry storage cask to be very remote. Therefore, the NRC does not consider this as a factor that would have an adverse affect on its determination with regard to the acceptability of the proposed change to 10 CFR 50.68. However, even if the licensee

intentionally diverted water from cooling the fuel in the SFP racks to the fuel in the dry storage cask, there would be a slow boron dilution event, a slow approach to criticality, and indication of an accidental criticality from the required criticality monitors. As such, this case would be very similar to the unintentional dilution case described above.

In the fourth scenario, the NRC assumed that the licensee was able to repair the damage to the SFP and reflood the pool. In this scenario as the licensee reflooded the SFP the dry storage cask would either reflood as the SFP was filled (for those casks with drain ports at the bottom); if the cask had dried out it would reflood once the water level in the SFP reached the top of the cask and water began spilling into the cask; or if the cask remained flooded following the rapid drain down event, there would be a slow dilution of the boron in the water in the cask as the SFP level continued to rise. In each of these cases, as the cask was filled with water or as the boron dilution of the water in the cask occurred, the possibility increases that an accidental criticality might occur. However, because of the relatively slow reactivity addition that would occur during each of these cases, the approach to criticality would be reasonably slow. As noted previously, the licensee is required to have criticality monitors in place during dry storage cask loading (or unloading) activities. These criticality monitors would provide indication that an accidental criticality had occurred. Once identified, it is reasonable that the licensee would take action to re-establish a subcritical configuration. However, as discussed above for the third scenario, even if there were an accidental criticality, the likelihood of fuel damage is very remote.

The possibility of an accidental criticality in the fourth scenario is even less likely given the following factors:

1. Dry storage casks are typically loaded with fuel that has significant burnup that reduces the reactivity of the assembly. As such, it is reasonable to conclude that even in an unborated condition, the fuel stored in the cask would remain subcritical.

2. As the licensee refilled the SFP, it is reasonable to assume that it would be injecting borated water to re-establish the boron concentration level required by plant technical specifications as soon as practical.

Based on the above, even if there was an event that caused a rapid drain down of a SFP while a dry storage cask was in the SFP, the likelihood of a boron dilution event causing fuel damage is very remote. Therefore, the NRC concludes there is no safety benefit from requiring the licensee to conduct a site specific analysis in support of dry storage cask loading, fuel storage, or unloading activities.

V. Conclusion:

As discussed above the NRC assessed the safety benefit of requiring licensees to conduct an additional criticality analysis to meet the requirements of 10 CFR 50.68 while loading a transportation package or dry storage cask in the SFP. The NRC determined that the controls required by 10 CFR Part 71 or 72 for the associated package or cask provide reasonable assurance that a slow boron dilution event would not result in elevated fuel temperature and subsequent fuel damage. Therefore, for a slow boron dilution event, there is no benefit to the additional criticality analysis. The NRC further determined that the probability of having a rapid drain down event result in elevated fuel temperatures and subsequent fuel damage was highly unlikely. Based on its analysis, the NRC concludes there is no safety benefit from requiring a licensee to conduct a site specific analysis in support of storage cask loading, fuel storage, or unloading activities and that the proposed rule change is therefore acceptable.