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September 26, 2007

U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852-2738

Attn: Document Control Desk

Subject: Submittal of Supplemental Information for the NAC MAGNASTOR System Application, Docket No. 72-1031 (TAC No. L23764)

Reference: Resubmittal of NAC MAGNASTOR System Application for Approval Docket No. 72-1031 (TAC No. L23764), NAC International, August 6, 2007

Based on a NRC/NAC conference call on September 25, 2007, NAC International (NAC) hereby submits eight copies of supplemental information to the above-referenced NAC MAGNASTOR Spent Fuel Storage System Application for a Certificate of Compliance (CoC) in accordance with 10 CFR Part 72. The supplemental information consists of clarification of the damaged fuel definition in Chapters 1 and 13, and clarification of the application of ISG-11, Revision 3, and an editorial change to a reference in Chapter 8 of the MAGNASTOR Safety Analysis Report (SAR).

This submittal consists of this transmittal letter and the MAGNASTOR SAR, Revision 07A changed pages. Consistent with NAC administrative practice, each changed page is uniquely identified in the header as a Revision 07A page and the changes are clearly marked by revision bars. Note that page 8.11-3 is included as a Revision 07A page due to text flow. Upon final approval, the changed pages will be reformatted and incorporated into the MAGNASTOR SAR. A List of Effective Pages is provided for easy identification of the revised pages.

NAC requests completion of the draft CoC and SER for this application in a timely manner. NAC staff is available to meet with the NRC staff, should it be determined that face-to-face discussion would expedite the review and approval process.

If you have any comments or questions, please contact me on my direct line at (678) 328-1274.

Sincerely,

Anthony L Patko

Anthony L. Patko
Director, Licensing
Engineering

Enclosures

NMSS01

ED20070062

NMSS

September 2007

Revision 07A

# MAGNASTOR

(Modular Advanced Generation Nuclear All-purpose STORage)

# SAFETY ANALYSIS REPORT

Docket No. 72-1031

NAC INTERNATIONAL

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# Chapter 1

## 1.1 Terminology

This section lists and defines the terms used in this SAR.

### Adapter Plate

A carbon steel plate assembly positioned on the top of the concrete cask and used to align the transfer cask. It supports the operating mechanism for opening and closing the transfer cask shield doors.

### Assembly Defect

Any change in the physical as-built condition of the assembly, with the exception of normal in-reactor changes such as elongation from irradiation growth or assembly bow. Example of assembly defects include: (a) missing rods, (b) broken or missing grids or grid straps (spacer), and (c) missing or broken grid springs, etc. An assembly with a defect is damaged only if it cannot meet its fuel-specific and system-related functions.

### Breached Spent Fuel Rod

Spent fuel with cladding defects that permit the release of gas from the interior of the fuel rod. A fuel rod breach may be a minor defect (i.e., hairline crack or pinhole), allowing the rod to be classified as undamaged, or be a gross breach requiring a damaged fuel classification.

### Burnup

Amount of energy generated during irradiation – measured in MWd/MTU.

#### Assembly Average Burnup

Value calculated by averaging the burnup over the entire fuel region ($UO_2$) of an individual fuel assembly.

#### Peak Average Rod Burnup

Value calculated by averaging the burnup in any rod over the length of the rod, then using the highest burnup calculated as the peak average rod burnup.

### Concrete Cask

A concrete cylinder that holds the TSC during storage. The concrete cask is formed around a steel inner liner and base and is closed by a lid.

#### Base

A carbon steel weldment incorporating the air inlets and the pedestal that supports the TSC inside of the concrete cask.

#### Lid

A thick concrete and carbon steel closure for the concrete cask. The lid precludes access to the TSC and provides radiation shielding.

### Liner

A carbon steel shell that forms the inside diameter of the concrete cask. The liner serves as the inner form during concrete pouring and provides radiation shielding and structural protection for the TSC.

### Standoffs (Channels)

Carbon steel weldments attached to the liner that assist in centering the TSC in the concrete cask and supporting the TSC and its contents in a nonmechanistic tip-over event.

## Confinement System

The components of the TSC assembly that retain the spent fuel during storage.

## Contents

Up to 37 PWR fuel assemblies or up to 87 BWR fuel assemblies. The fuel assemblies are confined in a TSC. Non-fuel hardware may be inserted into PWR fuel assemblies and BWR fuel assemblies may include channels.

## Damaged Fuel

Spent nuclear fuel (SNF) that cannot fulfill its fuel-specific or system-related function. Spent fuel is classified as damaged under the following conditions.

1) There is visible deformation of the rods in the SNF assembly.
   Note: This is not referring to the uniform bowing that occurs in the reactor; this refers to bowing that significantly opens up the lattice spacing.
2) Individual fuel rods are missing from the assembly and the missing rods are not replaced by dummy rods that displace a volume equal to, or greater than, the original fuel rods.
3) The SNF assembly has missing, displaced or damaged structural components such that either:
   3.1) Radiological and/or criticality safety is adversely affected (e.g., significantly changed rod pitch); or
   3.2) The assembly cannot be handled by normal means (i.e., crane and grapple).

Assemblies with the following structural defects meet MAGNASTOR system-related functional requirements and are, therefore, classified as undamaged.

   3.3) Assemblies with missing or damaged grids, grid straps and/or grid springs resulting in an unsupported fuel rod length not to exceed 60 inches. Assemblies containing fuel rods with damaged or missing grids, grid straps and/or grid springs producing an unsupported length greater than 60 inches are classified as damaged.

4) Any SNF assembly that contains fuel rods for which reactor operating records (or other records or tests) cannot support the conclusion that they do not contain gross breaches.
   Note: Breached fuel rods with minor cladding defects (i.e, pinhole leaks or hairline cracks that will not permit significant release of particulate matter from the spent fuel rod) meet MAGNASTOR system-related functional requirements and are, therefore, classified as undamaged.

# Chapter 8

## 8.11 Cladding Integrity

The MAGNASTOR system and processes minimize spent fuel cladding deterioration during transfer and storage conditions by controlling the spent fuel rod environment, in particular clad temperature and the atmosphere contacting the clad.

Fuel cladding is maintained in storage by providing a high purity helium atmosphere at a positive pressure, limiting the amount of oxidants in the canister and controlling clad temperature. Oxidants are limited to less than one mole. Maximum fuel clad temperature is limited to less than 400°C for normal and transfer conditions and to less than 570°C for off-normal and accident events. Thermal cycles during system drying operations that exceed 65°C are restricted to no more than 10 cycles for fuel having burnup greater than 45 GWd/MTU [35] [38].

Oxidants are removed from the canister by the vacuum drying process. During vacuum drying, the residual moisture and free water in the cavity are vaporized as the internal pressure is reduced. The resultant vapor and residual gasses are removed from the canister through the vent and drain ports by the vacuum pump. The internal decay heat of the fuel contents assists in the vaporization process as the canister internals and fuel temperatures increase during the drying process. The vacuum pumping operation is continued until the cavity pressure is reduced to below 10 torr, which corresponds to one-half the vapor pressure of water at 72°F. Under normal loading conditions, the actual temperatures of the canister internals will exceed this temperature. The canister is then isolated from the vacuum pump and the pump is turned off. If free water exists in the canister, the water will vaporize and increase the canister pressure to above the 10 torr acceptance criterion during the dryness verification minimum hold period of 10 minutes. Upon successful completion of the dryness verification, the vacuum pump is restarted and the canister continues to be evacuated until the NUREG-1536 [39] recommended pressure of less than 3 torr is reached. The continued reduction in cavity pressure from 10 torr to less than 3 torr removes any residual noncondensing and oxidizing gases to a level of less than 1 mole. The canister is then backfilled with high purity helium ($\geq$ 99.995%) to a positive pressure. Implementation of the defined vacuum drying procedures provides assurance that the final canister internal atmosphere is a positive pressure of high purity helium that contains less than 1 mole of oxidizing gases, and that the residual oxidizing gas concentration is less than 0.25 vol%, as recommended in PNL-6365 [40].

To prevent oxidation of the uranium oxide ($UO_2$) fuel pellets in breached rods, classified as undamaged, provided the breach is no greater than a hairline crack or pinhole, operational steps in Section 9.1.1 specify that fuel rods shall not be exposed to air during canister draining operations in accordance with the guidance in Interim Staff Guidance (ISG)-22 [37].

The MAGNASTOR system operating procedures and specific operational completion times have been determined and defined to preclude thermally induced fuel rod cladding deterioration by limiting fuel rod cladding hoop stress and reducing the potential for the reorientation of hydrides. The thermal analyses presented in Chapter 4 provide the system temperatures for loading operations, normal conditions, and off-normal and accident events. The temperature control criteria applicable to the MAGNASTOR system are as follows:

1. Maximum calculated fuel cladding temperatures are limited to 400°C (752°F) for normal conditions of storage and short-term loading operations.
2. During loading operations, repeated thermal cycling (repeated heat-up/cool-down cycles) is limited to a total of 10 cycles for fuel with burnup greater than 45 GWd/MTU. A thermal cycle is defined as a clad temperature change greater than 65°C [35].
3. For off-normal and accident conditions, the maximum cladding temperature should not exceed 570°C.

Normal and accident condition thermal transients experienced by the MAGNASTOR canister, basket and contained fuel are controlled and introduce insignificant thermal loading and material stress to fuel rod cladding. Normal condition cooldown transients during cask operations may be introduced during vacuum drying when the canister dryness criteria are not met within the prescribed heat load-dependent time limit. If the dryness criteria are not met, the canister is backfilled to 7 bar gauge with helium, and the canister is cooled by the annulus cooling water system or by returning the canister to the pool as stated in Section 1.3.1.4. This backfill with helium may be performed when the temperatures in the mid to upper regions of the fuel basket are in the range of 700°F and the fuel local to the bottom plate is in the range of 250°F. Noting the significant difference in mass between helium and fuel, i.e., approximately five orders of magnitude, helium is heated with little temperature change to the fuel – the basket, canister bottom plate and shell mass add heat to the helium in combination with the fuel – reducing the thermal influence of the initial helium fill on the fuel cladding. Following the helium backfill, the canister is cooled by the annulus cooling water system or returned to the pool. Water in contact with the canister wall provides more effective heat transfer than the air boundary when the transfer cask is sitting in a cask processing area outside the pool. Although this water boundary provides a more effective heat transfer path, the influence of the canister cooling does not produce a thermal shock or significant through-wall gradient to the fuel rod cladding.

Investigation of the canister unloading sequence presented in Section 9.3 leads to similar conclusions as those for the introduction of helium gas discussed above. When the canister is first prepared for unloading and the port covers are removed, nitrogen gas is initially cycled through the canister for a minimum of 10 minutes to flush the radioactive gases from the canister. This gas cycling is similar to the helium backfill. Although nitrogen has a higher thermal capacitance than helium (about a factor of 10), when compared to the mass of the metal canister, basket and fuel, the influence of the nitrogen gas on the thermal gradient response in the fuel cladding remains insignificant. Following the nitrogen flush, water is introduced into the canister at a maximum rate of 8 gpm. The maximum flow rate is based on reflood thermal hydraulic analyses of a bounding canister configuration. The bounding maximum flow rate, water temperature and pressure are defined in step 14 of Section 9.3, "Wet Unloading a TSC." The water initially introduced into the canister flashes to steam in the drain tube and on contact with the bottom plate. Steam in the cavity permits additional heat to be removed from the basket and fuel in a smooth transition without introducing thermal shock through wall stresses. Once water is permitted to form on the canister bottom plate, the canister starts to fill at a maximum rate of 8 gpm. Addition of water at 8 gpm permits the water to rise in the canister at a maximum rate of 0.8 inch per minute. Thermal hydraulic analyses results show thermal cladding temperature radial gradients are less than 1°F during the reflooding of the canister. Such a small increase is consistent with the gradual cooling process created by the initial steam condition followed by water. The axial temperature gradient along the fuel assembly is actually larger than the radial gradient. However, in the fuel axial direction, thermal stresses are not developed since the fuel cladding is free to expand in the axial direction. The combination of initial nitrogen purge, followed by the cooling transition of the steam created in the canister cavity, provides a relatively smooth transition to water cooling and insignificant thermal stress in the fuel rod cladding.

There are no evaluated normal conditions, transfer conditions, off-normal events or accident conditions that result in deterioration of, or damage to, the fuel cladding or the TSC that preclude retrieval of the fuel from the TSC or retrieval of the TSC from the concrete cask for transport and ultimate disposal.

31. ASME Boiler and Pressure Vessel Code, "Rules for Construction of Pressure Vessels," Section VIII, American Society of Mechanical Engineers, New York, NY, 2001 Edition with 2003 Addenda.
32. ASME Boiler and Pressure Vessel Code, Section III, Subsection NF, American Society of Mechanical Engineers, New York, NY, 2001 Edition with 2003 Addenda.
33. ASTM B29-03, "Standard Specification for Refined Lead," American Society for Testing and Materials, West Conshohocken, PA, 2003.
34. Cases of ASME Boiler and Pressure Vessel Code, Case N-707, "Use of SA-537, Class A Plate for Spent-Fuel Containment Internals in Non-pressure Retaining Applications Above 700°F (370°C)," Section III, Division 3.
35. B.F. Kammenzind, B. M. Berquist and R. Bajaj, "The Long Range Migration of Hydrogen Through Zircaloy in Response to Tensile and Compressive Stress Gradients," Zirconium in the Nuclear Industry: Twelfth International Symposium, ASTM STP 1354, G.P. Sabol and G.D. Moan, Eds., American Society for Testing and Materials, pp. 196-233, 2000.
36. "Mechanical Properties for Irradiated Zircaloy," K. J. Geelhood and C. E. Beyer, Pacific Northwest National Laboratory, Richland, WA, Transactions – American Nuclear Society, 2005, Vol. 93, pages 707-708.
37. Interim Staff Guidance -22, "Potential Rod Splitting due to Exposure to an Oxidizing Atmosphere During Short-term Cask Loading Operations in LWR or Other Uranium Oxide Based Fuel," U.S. Nuclear Regulatory Commission, May 8, 2006.
38. Interim Staff Guidance-11, Revision 3, "Cladding Considerations for the Transportation and Storage of Spent Fuel," U.S. Nuclear Regulatory Commission, November 17, 2003.
39. NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems," U.S. Nuclear Regulatory Commission, Washington, DC, January 1997.
40. PNL-6365, "Evaluation of Cover Gas Impurities and Their Effects on the Dry Storage of LWR Spent Fuel," Pacific Northwest Laboratory, Richland, WA, November 1987.

# Chapter 13

## 1.0 USE AND APPLICATION

### 1.1 Definitions

NOTE

The defined terms of this section appear in capitalized type and are applicable throughout these Technical Specifications and Bases.

| Term | Definition |
|---|---|
| ACTIONS | ACTIONS shall be that part of a Specification that prescribes Required Actions to be taken under designated Conditions within specified Completion Times. |
| ASSEMBLY DEFECT | Any change in the physical as-built condition of the assembly, with the exception of normal in-reactor changes such as elongation from irradiation growth or assembly bow. Example of assembly defects include: (a) missing rods, (b) broken or missing grids or grid straps (spacer), and (c) missing or broken grid springs, etc. An assembly with a defect is damaged only if it cannot meet its fuel-specific and system-related functions. |
| BREACHED SPENT FUEL ROD | Spent fuel with cladding defects that permit the release of gas from the interior of the fuel rod. A fuel rod breach may be a minor defect (i.e., hairline crack or pinhole), allowing the rod to be classified as undamaged, or be a gross breach requiring a damaged fuel classification. |
| BURNUP | Assembly Average Burnup:<br>Value calculated by averaging the burnup over the entire fuel region ($UO_2$) of an individual fuel assembly.<br>Peak Average Rod Burnup:<br>Value calculated by averaging the burnup in a rod over the length of the rod, then using the highest burnup calculated for any rod as the peak average rod burnup.<br>Nonfuel Assembly Hardware Burnup:<br>Equivalent accumulated irradiation exposure for activation evaluation. |
| CONCRETE CASK | The CONCRETE CASK is the vertical storage module that receives, holds and protects the sealed TSC for storage at the ISFSI. The CONCRETE CASK passively provides the radiation shielding, structural protection, and heat dissipation capabilities for the safe storage of spent fuel in a TSC. |

(continued)

DAMAGED FUEL

Spent nuclear fuel (SNF) that cannot fulfill its fuel-specific or system-related function. Spent fuel is classified as damaged under the following conditions.

1. There is visible deformation of the rods in the SNF assembly.

   Note: This is not referring to the uniform bowing that occurs in the reactor; this refers to bowing that significantly opens up the lattice spacing.

2. Individual fuel rods are missing from the assembly and the missing rods are not replaced by dummy rod that displaces a volume equal to, or greater than, the original fuel rod.

3. The SNF assembly has missing, displaced or damaged structural components such that either:

   3.1. Radiological and/or criticality safety is adversely affected (e.g., significantly changed rod pitch); or

   3.2. The assembly cannot be handled by normal means (i.e., crane and grapple).

Assemblies with the following structural defects meet MAGNASTOR system-related functional requirements and are, therefore, classified as undamaged.

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4. Any SNF assembly that contains fuel rods for which reactor operating records (or other records or tests) cannot support the conclusion that they do not contain gross breaches.

   Note: Breached fuel rods with minor cladding defects (i.e, pinhole leaks or hairline cracks that will not permit significant release of particulate matter from the spent fuel rod) meet MAGNASTOR system-related functional requirements and are, therefore, classified as undamaged.

5. The SNF assembly is no longer in the form of an intact fuel bundle (e.g., consists of or contains debris such as loose fuel pellets or rod segments).

(continued)