SAFETY EVALUATION REPORT
FOR THE
TRANSNUCLEAR INC., DRY STORAGE CASK
(TN-32)
DOCKET 72-1021 (M-56)

U.S. Nuclear Regulatory Commission
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INTRODUCTION

This Safety Evaluation Report (SER) documents the review and evaluation of the Topical Safety Analysis Report (TSAR) for the TN-32 Dry Storage Cask [1]. The TSAR was submitted by Transnuclear Inc. (hereafter denoted TN) following the Regulatory Guide 3.61[2] format, as applicable. This SER uses essentially the same chapter-level format, with some differences implemented for clarity and consistency.

The review of the TSAR addresses the handling and dry storage of spent fuel in a single dry storage cask design, the TN-32. The cask would be used at an Independent Spent Fuel Storage Installation (ISFSI) that would be licensed under 10 CFR Part 72 [3] at a reactor site operating with a Part 50 license.

The staff's assessment is based on whether the applicant meets the applicable requirements of 10 CFR Part 72 for independent storage of spent fuel and of 10 CFR Part 20 for radiation protection. Decommissioning, to the extent that it is treated in the TSAR, presumes that, as a bounding case, the TN-32 cask is unloaded at the reactor site and subsequently decontaminated before disposition or disposal.

The TN-32 cask is not designed nor intended to be used as a transportation cask. Therefore, the use or certification of the TN-32 cask under 10 CFR Part 71 for off-site transport of spent fuel is not a subject of this SER.

References

1. Topical Safety Analysis Report for the TN-32 Dry Storage Cask, Rev. 9. (This TSAR includes those sections of Rev. 0-8 that were unchanged in Rev. 9.) The following documents, which provide TN responses and/or revisions during the review process, are considered to be incorporated by reference into the SER as part of the TSAR itself:

Mason, Michael to Charles Haughney. "TN-32 Dry Storage Cask Topical Safety Analysis Report," E-13070, March 30, 1994.

Mason, Michael to Frederick Sturz. "Responses to Questions Dated September 29, 1994," E-13519, November 7, 1994.

Mason, Michael to Frederick Sturz. "Responses to Questions Dated February 16, 1995," E-13932, May 12, 1995.

Mason, Michael to Frederick Sturz. "Responses to Questions Dated September 19, 1995," E-14266, October 20, 1995.

Mason, Michael to Frederick Sturz. "Additional information for NRC questions dated September 19, 1995," E-14334, December 1, 1995.

Mason, Michael to Meg Lusardi. "Responses to Request for Additional Information Dated December 22, 1995," E-14501, February 20, 1996.

Mason, Michael to Meg Lusardi. "Modification to Basket Rails," E-14610, March 26, 1996.

Mason, Michael to Meg Lusardi. "Response to Request for Additional Information Dated March 20, 1996," E-14663, April 12, 1996.

Neider, Tara to Mark Delligatti. "Response to Request for Additional Information," E-14735, June 7, 1996.

Mason, Michael, to Meg Lusardi. "Topical Report Revision 7," E-14828, June 19, 1996.

Neider, Tara to Meg Lusardi. "Responses to Request for Additional Information Dated July 19, 1996," E-15011, August 22, 1996.

Neider, Tara to Meg Lusardi. "Revised Pages," E-15065, September 5, 1996.

Neider, Tara to Meg Lusardi. "Request for Additional Information Dated September 16, 1996," E-15120, September 30, 1996.

2. U.S. Nuclear Regulatory Commission. "Standard Format and Content for a Topical Safety Analysis Report for a Spent Fuel Dry Storage Cask," Regulatory Guide 3.61.

3. U.S. Code of Federal Regulations. "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste," Title 10, Part 72.

4. U.S. Nuclear Regulatory Commission. "Safety Evaluation Report for the Prairie Island Independent Spent Fuel Storage Installation," Office of Nuclear Material Safety and Safeguards, July 1993.

Section 1—GENERAL DESCRIPTION

This section evaluates the general description of the TN-32 Dry Storage Cask and its proposed contents. Information concerning the qualifications of the applicant and previous certification actions, if any, are reviewed. A summary assessment of the acceptance criteria applicable to this section under 10 CFR Part 72 is presented.

1.1 Areas of Review

1.1.1 Cask Description and Operational Features

1.1.2 Drawings

1.1.3 Cask Contents

1.1.4 Identification and Qualification of Applicant

1.1.5 Cask Arrays

1.2 Regulatory Requirements

1.2.1 A general description and discussion of the cask must be presented, with special attention to design and operating characteristics, unusual or novel design features, and principal safety considerations. [10 CFR 72.24(b)]

1.2.2 Structures, systems, and components important to safety must be described in sufficient detail to enable an evaluation of their effectiveness. [10 CFR 72.24(c)(3)]

1.2.3 Specifications must be provided for the spent fuel to be stored in the cask, such as, but not limited to, type of spent fuel (i.e., BWR, PWR, or both), maximum allowable enrichment of the fuel prior to any irradiation, burn-up (i.e., megawatt-days/MTU), minimum acceptable cooling time of the spent fuel prior to storage in the cask, maximum heat designed to be dissipated, maximum spent fuel loading limit, condition of the spent fuel (i.e., intact assembly or consolidated fuel rods), and the inerting atmosphere requirements. [10 CFR 72.236(a)]

1.2.4 The technical qualifications, including training and experience, required of the applicant before engaging in the proposed activities, must be included. [10 CFR 72.24(j) and 72.28(a)]

1.2.5 A copy of the Certificate of Compliance issued for the cask under 10 CFR 71, if applicable, and drawings and other documents referenced in the certificate must be included with the application. [10 CFR 72.230(b)]

1.3 Review Procedures

Section 1 of the TSAR was examined to verify that the appropriate information, as listed in the above Areas of Review and Acceptance Criteria, was presented. This information is summarized below.

1.3.1 Cask Description and Operational Features

The TN-32 Dry Storage Cask (see Figure 1.2-1 in the TSAR) was developed by TN to store irradiated spent fuel assemblies at an ISFSI. The cask accommodates 32 intact pressurized water reactor (PWR) fuel assemblies. The TN-32 cask body is a right circular cylinder composed of the following components: containment vessel with bolted lid closure, basket for fuel assemblies, gamma shield, pressure monitoring system, weather cover, trunnions, and neutron shield. A general description of the cask and its operational features are provided in TSAR Sections 1.1 and 1.2.

The containment vessel is made of welded cylindrical carbon steel (SA-203, Gr. A) 38-mm (1.50-in.) thick, with an integrally welded carbon steel bottom closure. A flange forging is welded to the top of the containment vessel to accommodate a flanged and a bolted carbon steel lid closure. The closure lid uses a double-barrier seal system with two metallic O-rings forming the seal. The annular space between the metallic O-rings is connected to a pressure monitoring system (PMS) placed between the lid and the protective cover. Pressure in the tank of the PMS is maintained above the pressure in the cask cavity to prevent either flow of fission gases out, or air into, the cask cavity, which, under normal storage conditions, is pressurized above atmospheric pressure with helium.

Surrounding the outside of the containment vessel wall is a steel gamma shield (SA-516, Grade 70) with a wall thickness of 203 mm (8.0 in.). The bottom end of the gamma shield is made of the same material and has a thickness of 222 mm (8.75 in.). The bolted closure lid provides the gamma shielding at the upper end of the cask body.

Neutron emissions from the stored fuel are attenuated by a borated polyester resin compound neutron shield located on the outside of the gamma shield. The borated polyester is 114-mm (4.50-in.) thick and is encased in aluminum boxes that are 3-mm (0.12-in.) thick, which are held in place by a 13-mm (0.50-in.) thick SA 516 Gr 70 steel shell constructed of two half-cylinders. Neutron emissions from the top of the cask are attenuated by a polypropylene disc 102-mm (4.0-in.) thick and encased in a steel shell 6.35-mm (0.25-in.) thick. There is no neutron shielding provided on the bottom of the cask.

The cask has a cylindrical cavity 1753 mm (69.0 in.) in diameter and 4140-mm (163-in.) long, which holds a fuel basket with 32 compartments, each 221-mm (8.70-in.) square, to hold the fuel bundles. The fuel cavities are formed by a sandwich of aluminum plates, boral plates, and stainless steel boxes. The fuel compartment stainless steel box sections are attached by a series of stainless steel plugs that pass through the aluminum and poison plates

and are fusion-welded to both adjacent stainless steel box sections. The combined wall thickness is 20-mm (0.785-in.) thick. The basket is guided into the cask body and held in place by aluminum rails that run the axial length of the cask body.

A protective cover, 9.5-mm (0.375-in.) thick, is bolted to the top of the cask body to provide weather protection for the lid penetrations. The cask cavity surfaces have a sprayed metallic coating of aluminum for corrosion protection. The external surfaces of the cask are painted for ease of decontamination. The neutron shield, PMS, and shield cap are placed on top of the cask after fuel loading and removal from the spent fuel pool.

The cask body has four trunnions that are welded to the gamma shield. Two of these are located near the top of the cylindrical steel forging, spaced 180 degrees apart, and are used for lifting the cask. The remaining two trunnions are 180 degrees apart and located near the bottom of the cask. The lower trunnions are used to rotate the unloaded cask between vertical and horizontal positions. The lifting trunnions have an effective diameter of 220 mm (8.67 in.) and are hollow to permit installation of neutron shielding material and eliminate a path for neutron streaming.

The cask has two containment penetrations: one cask cavity drain, and one cask cavity vent. Both of these penetrations are in the lid. The drain and vent ports are covered by a double-seal bolted closure. The cavity drain line penetrates the closure lid and terminates in the bottom of the cask cavity. This is used to drain water from the cask cavity after underwater fuel loading. It is also used during the drying and helium back-filling of the cask cavity. The drain valve is of the quick-disconnect type and was not analyzed as part of the primary containment system. The cavity vent valve is identical to the drain valve.

The overall dimensions of the cask are 5131-mm (202-in.) long and 2591-mm (102-in.) in diameter. The cask weighs approximately 115.5 tons (230,990 pounds) when loaded.

The cask is designed to store 32 intact fuel assemblies. Each fuel assembly is assumed to have a maximum initial enrichment not to exceed 3.85 w/o U-235 in uranium. Further assumptions limit the fuel to a maximum of 40,000 MWD/MTU burnup, a minimum decay time of 7 years after reactor discharge and a maximum decay heat load of 0.847 kW per assembly for a total of 27.1 kW for a cask. Additional fuel limitations are discussed in Sections 2 and 12 of this SER.

The heat rejection capability of the cask maintains the maximum fuel rod clad temperature below 348°C (658°F), based on normal operating conditions with a 27.1 kW decay heat load, 38°C (100°F) ambient air, and full insolation. The fuel assemblies are stored in an inert helium gas atmosphere.

The cask shielding features of the cask are designed to maintain the maximum combined gamma and neutron surface dose rate to less than 200 mrem/hr, under normal operating conditions.

The criticality control features of the cask are designed to maintain the neutron multiplication factor (including uncertainties and calculational bias) at less than 0.95, under all conditions.

1.3.2 Drawings

Drawings of the TN-32 cask are presented in Section 1.5 of the TSAR.

1.3.3 Cask Contents

The type of spent fuel to be stored in the TN-32 cask is light water reactor (LWR) fuel of the PWR type. The cask is designed to accommodate a total of 32 assemblies consisting of either 15x15 or 17x17 rod arrays. Additional characteristics and limitations on the spent fuel are presented in Section 1.2.3 of the TSAR, as well as Sections 2 and 12 of the TSAR and SER.

The maximum weight limit of the cask contents, including basket, rails, and fuel assemblies, is 65,960 pounds.

1.3.4 Identification and Qualification of Applicant

As identified in Section 1.3 of the TSAR, TN provides design, engineering, analysis, licensing support, and quality assurance for the cask. TN was incorporated in the State of New York in 1965 and has offices in Hawthorne, New York, and Aiken, South Carolina. TN shares are privately held by Transnucleaire, S.A., of Paris, France.

The cask may be manufactured by one or more qualified organizations. There are no other agents or contractors involved with the cask.

1.3.5 Cask Arrays

The ISFSI may be designed to include one or more casks. The casks will be arranged in a 2 by xx array of casks, free standing in a vertical orientation on a concrete slab. The TSAR provides analyses of this mode of storage. The specific aray will be determined on a site-specific basis.

1.4 Evaluation Findings

A general description and discussion of the cask are presented in Sections 1.1 and 1.2 of the TSAR, with special attention to design and operating characteristics, unusual or novel design features, and principal safety considerations. Drawings are presented in Section 1.5 of the TSAR.

Specifications are provided in Section 1.2.3 for the spent fuel to be stored in the cask. Additional details on these specifications are presented in Section 2 of the TSAR and SER.

The applicant's technical qualifications for performing the proposed activities are described in Section 1.3 of the TSAR.

The staff concludes that the information presented in this section of the TSAR satisfies the requirements of 10 CFR Part 72. This finding is based on a review that considered the regulations, Regulatory Guide 3.61, and accepted practices.

Section 2—PRINCIPAL DESIGN CRITERIA

This section evaluates the principal design criteria and their bases for the TN-32 Dry Storage Cask. Structures, systems, and components important to safety are reviewed to assure that they are designed to provide adequate protection for normal and off-normal operations, accident conditions, and natural phenomena events. A more detailed evaluation of design criteria and the assessment of compliance with these criteria are presented in Sections 3 to 14 of the SER.

2.1 Areas of Review

2.1.1 Spent Fuel Description

2.1.2 Identification of Structures, Systems, and Components Important to Safety

2.1.3 Design Criteria and Bases for Structures, Systems, and Components Important to Safety
—General
—Structural
—Thermal
—Shielding/Confinement/Radiation Protection
—Criticality
—Operating Procedures
—Acceptance Tests and Maintenance
—Decommissioning

2.2 Regulatory Requirements

2.2.1 Spent Fuel Description

Specifications must be provided for the spent fuel to be stored in the cask, such as, but not limited to, type of spent fuel (i.e., BWR, PWR, both), maximum allowable enrichment of the fuel prior to any irradiation, burn-up (i.e., megawatt-days/MTU), minimum acceptable cooling time of the spent fuel prior to storage in the cask, maximum heat designed to be dissipated, maximum spent fuel loading limit, condition of the spent fuel (i.e., intact assembly or consolidated fuel rods), and the inerting atmosphere requirements. [10 CFR 72.236(a)]

2.2.2 Identification of Structures, Systems, and Components Important to Safety

Structures, systems, and components important to safety must be identified. [10 CFR 72.24(c)(3)]

Design criteria and their bases must be provided for structures, systems, and components important to safety. [10 CFR 72.236(b), 72.4(c), 72.120(a)]

2.2.3 Design Criteria and Bases for Structures, Systems, and Components Important to Safety

2.2.3.1 General

The cask must be designed to store the spent fuel safely for a minimum of 20 years and permit maintenance as required. [10 CFR 72.236(g)]

Structures, systems, and components important to safety must be designed, fabricated, erected, and tested to quality standards commensurate with the importance to safety of the function to be performed. [10 CFR 72.122(a) and 72.24(c)(4)]

2.2.3.2 Structural

Structures, systems and components important to safety must be designed to accommodate the combined loads of normal, accident, and natural phenomena events with an adequate margin of safety. [10 CFR 72.24(c)(3) and 72.122(b) and (c)]

The design earthquake must be equivalent to or exceed the safe shutdown earthquake of a nuclear plant at sites evaluated under 10 CFR Part 100. [10 CFR 72.102(f)]

The spent fuel cladding must be protected during storage against degradation that leads to gross ruptures, or the fuel must be otherwise confined such that degradation of the fuel during storage will not pose operational safety problems with respect to its removal from storage. [10 CFR 72.122(h)(1)]

Storage systems must be designed to allow ready retrieval of spent fuel waste for further processing or disposal. [10 CFR 72.122(l)]

The cask must be designed and fabricated so that the spent fuel is maintained in a subcritical condition under credible conditions. [10 CFR 72.236(c) and 72.124(a)]

The cask and its systems important to safety must be evaluated, by appropriate tests or by other means acceptable to the Commission, to demonstrate that they will reasonably maintain confinement of radioactive material under normal, off-normal, and credible accident conditions. [10 CFR 72.236(l)]

2.2.3.3 Thermal

Spent fuel storage or handling systems must be designed with a heat-removal capability having testability and reliability consistent with its importance to safety. [10 CFR 72.128(a)(4)]

The cask must be designed to provide adequate heat removal capacity without active cooling systems. [10 CFR 72.236(f)]

The spent fuel cladding must be protected against degradation that leads to gross ruptures, or the fuel must be otherwise confined such that degradation of the fuel during storage will not pose operational safety problems with respect to its removal from storage. [10 CFR 72.122(h)(1)]

Storage systems must be designed to allow ready retrieval of spent fuel for further processing or disposal. [10 CFR 72.122(l)]

2.2.3.4 Shielding/Confinement/Radiation Protection

Radiation shielding and confinement features must be provided that are sufficient to meet the requirements of 10 CFR 72.104 and 72.106. [10 CFR 72.236(d), 72.128(a)(2) and (3), and 72.126(a)]

During normal operations and anticipated occurrences, the annual dose equivalent to any real individual who is located beyond the controlled area must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as a result of exposure to: (1) planned discharges of radioactive materials (radon and its decay products excepted) to the general environment, (2) direct radiation from ISFSI or MRS operations, and (3) any other radiation from uranium fuel cycle operations within the region. [10 CFR 72.104(a), 72.236(d), and 72.24(d)]

Any individual located on or beyond the nearest boundary of the controlled area shall not receive a dose greater than 5 rem to the whole body or any organ from any design basis accident. The minimum distance from the spent fuel or high-level radioactive waste handling and storage facilities to the nearest boundary of the controlled area shall be at least 100 meters. [10 CFR 72.106(b), 72.236(d), and 72.24(m) and (d)]

The cask must be designed to provide redundant sealing of confinement systems. [10 CFR 72.236(e)]

Storage confinement systems must have the capability for continuous monitoring in a manner such that the licensee will be able to determine when corrective action needs to be taken to maintain safe storage conditions. [10 CFR 72.122(h)(4) and 72.128(a)(1)]

Instrumentation and control systems must be provided to monitor systems that are important to safety over anticipated ranges for normal and off-normal operations. Those control systems that must remain operational under accident conditions must be identified. [10 CFR 72.122(i)]

The spent fuel cladding must be protected against degradation that leads to gross ruptures, or the fuel must be otherwise confined such that degradation of the fuel during storage will not pose operational safety problems with respect to its removal from storage. [10 CFR 72.122(h)(1)]

2.2.3.5 Criticality

Spent fuel transfer and storage systems must be designed to be subcritical under all credible conditions. [10 CFR 72.124(a) and 72.236(c)]

When practicable, the design must be based on favorable geometry, permanently fixed neutron absorbing materials (poisons), or both. Where solid neutron absorbing materials are used, the design shall provide for positive means to verify their continued efficacy. [10 CFR 72.124(b)]

2.2.3.6 Operating Procedures

The cask must be compatible with wet or dry spent fuel loading and unloading procedures. [10 CFR 72.236(h)]

Storage systems must be designed to allow ready retrieval of spent fuel for further processing or disposal. [10 CFR 72.122(l)]

The cask must be designed to minimize the quantity of radioactive waste generated. [10 CFR 72.128(a)(5) and 72.24(f)]

The equipment and processes used to maintain control of radioactive effluents must be described. [10 CFR 72.24(l)(2)]

The cask must be designed to facilitate decontamination to the extent practicable. [10 CFR 72.236(i)]

Operational restrictions must be established to as low as is reasonably achievable objectives for radioactive materials in effluents and direct radiation levels associated with ISFSI operations. [10 CFR 72.104(b) and 72.24(e)]

2.2.3.7 Acceptance Tests and Maintenance

The cask must permit testing and maintenance as required. [10 CFR 72.236(g)]

Structures, systems, and components important to safety must be designed, fabricated, erected, tested, and maintained to quality standards commensurate with the importance to safety of the function to be performed. [10 CFR 72.122(a) and (f), 72.128(a)(1), and 72.24(c)]

2.2.3.8 Decommissioning

The cask must be compatible with wet or dry unloading facilities. [10 CFR 72.236(h)]

The cask must be designed for decommissioning. Provisions must be made to facilitate decontamination of structures and equipment and minimize the quantity of radioactive wastes, contaminated equipment, and contaminated materials at the time the ISFSI is permanently decommissioned. [10 CFR 72.130, 72.24(f), and 72.236(i)]

Information on proposed practices and procedures for the decontamination of the site and facilities and for disposal of residual radioactive materials after all spent fuel has been removed must be described to provide reasonable assurance that decontamination and decommissioning will provide adequate protection to public health and safety. [10 CFR 72.30(a) and 72.24(q)]

2.3 Review Procedures

The principal design criteria presented in Section 2 of the TSAR were examined to evaluate their compliance with 10 CFR Part 72. These criteria are discussed in the following sections of the SER.

2.3.1 <u>Spent Fuel Description</u>

The TN-32 is designed to store, under dry conditions, irradiated PWR fuel from nuclear power reactors. The design basis fuel for the thermal, radiological, and criticality characteristics is the Westinghouse 17x17 PWR assembly. For the confinement analyses, the 15x15 assembly was used. The maximum enrichment for criticality considerations is 3.85 weight per cent (w/o) U-235. The design basis fuel is assumed to have a maximum initial enrichment not to exceed 3.85 w/o U-235 in uranium and a maximum burnup of 40,000 MWD/MTU, a minimum decay time of 7 years after reactor discharge, and a decay heat load of 0.847 kW per assembly for a total of 27.1 kW for a TN-32 cask. Tables 2.1-1 and 2.1-2 of the TSAR describe the physical, nuclear, and thermal parameters defined as the bounding cases. These limits are included in Section 12 of this SER.

2.3.2 Identification of Structures, Systems, and Components Important to Safety

Section 2.2 of the TSAR notes that the TN-32 is a self-contained, passive spent fuel storage system with multiple layers of protection. A listing of structures, systems, and components important to safety are presented in Table 2.3-1 of the TSAR. The only instrumentation is a pressure monitoring system (PMS) designed to provide assurance that confinement is maintained throughout its 20-year lifetime. The PMS is not considered important to safety. However, the TSAR commits to a monitoring system that will alarm if the system fails.

Although the concrete storage pad that the cask will be stored on is not considered important to safety, the tipover and bottom-end drop analyses in Section 3 of the SER assumes certain parameters about the pad. The analyses account for a varied soil modulus of elasticity and are based on a reinforced concrete storage pad thickness of 3 feet and concrete strength of 4000 psi.

2.3.3 Design Criteria and Bases for Structures, Systems, and Components Important to Safety

2.3.3.1 General

Section 1.1 of the TSAR indicates that the TN-32 is designed to meet all design requirements of 10 CFR Part 72. This includes the top-level requirement that the cask must be designed to store spent fuel safely for a minimum of 20 years and permit maintenance as required.

Principal design criteria and their bases, including quality standards, are presented in Section 2 and summarized in Table 2.5-1 of the TSAR. Additional detail is provided in the following sections of this SER.

2.3.3.2 Structural

Structural design criteria are presented in Section 2.2 and summarized in Tables 2.2-1 to 2.2-7 of the TSAR.

The components important to safety are identified in Table 2.3-1 of the TSAR. Criteria for the design, fabrication, examination, and acceptance of these components in accordance with the ASME Boiler and Pressure Vessel Code (B&PVC) [1] are summarized as follows:

- Containment Vessel: B&PVC, Section III, Subsection NB
- Basket Assembly: B&PVC, Section III, Subsection NF and American Welding Society (AWS) Structural Welding Codes
- Other Safety-Related Components (trunnions, neutron shielding, protective cover): B&PVC, Section III, Subsection NF, AWS Structural Welding codes.

Combined Load Criteria - Each normal and accident condition has a combination of load cases that defines the total combined loadings for that condition. The individual load cases considered include thermal, seismic, external and internal pressure, missile impacts, drops,

snow and ice loads, and/or flood water forces. Loading combinations for Normal Conditions (Design Conditions and Levels A) are given in Table 2.2-8, and loading combinations for Accident Condition (Level D) are given in Table 2.2-9 of the TSAR. A summary of the allowable stress intensity criteria for confinement structures, bolt stress, non-confinement structures, and basket stress is presented in Tables 3.1-2 to 3.1-5 of the TSAR, respectively. These stress limits are consistent with Regulatory Guide 7.6 [2] and the applicable parts of Subsection NB-3000 and Appendix F of the ASME Boiler and Pressure Vessel Code (confinement structures) and Section III, Subsection NG (non-confinement structures, bolts, and basket).

Tornado and Wind Loading - Section 2.2.1 of the TSAR establishes the design basis tornado wind loadings and missile impacts in accordance with Regulatory Guide 1.76 [3] and NUREG-0800 [4]. The design basis wind loadings include a maximum rotational wind speed of 465 km/h (290 mph), a translational wind speed of 112 km/h (70 mph), a combined maximum wind speed of 577 km/h (360 mph), and a pressure drop of 2 psia/second for 1.5 seconds. The design basis missile impacts include a 1800-kg (3960-pound) deformable massive missile, a 125-kg (275-pound) penetration missile, and a small rigid steel sphere 2.54-cm (1-in.) diameter missile. Criteria are established that the cask shall not tip-over and that the stresses for the three design basis missiles must not exceed the allowable stress limits of the applicable sections of the ASME Code, as summarized in Tables 3.1-2 to 3.1-5 of the TSAR.

Flood - Section 2.2.2 of the TSAR defines the source and magnitude of flooding as site-specific conditions. An evaluation of the maximum current velocity and the maximum depth of flood water for which the cask confinement system is maintained is presented in Section 2.2.2.1 of the TSAR and reviewed in Section 3 of this SER. A site limitation on flooding is presented in Section 12 of the SER.

Seismic - Section 2.2.3 of the TSAR defines an earthquake as a site-specific condition. A determination of the minimum horizontal acceleration that will result in a tip-over is presented in Section 2.2.3.2 of the TSAR and reviewed in Section 3 of the SER.

Snow and Ice Loading - As discussed in Section 2.2.4 of the TSAR, for any credible snowfall event, the snow/ice would melt soon after contact with the surface of the TN-32 because of the decay heat generated by the stored fuel. The thermal effects from exposure to snow and ice are bounded by the environmental conditions analyzed in Section 3.4.4 (Hot) and 3.4.5 (Cold) of the TSAR. Furthermore, the torispherical steel head protective cover attached to the top of the cask above the lid can sustain pressure loading in excess of that which would result from any credible snowfall. Therefore, snow and ice loadings are not deemed significant.

Fire and Explosions - The design basis thermal evaluation for the TN-32 cask is based on a cask engulfed in a fuel fire caused by 200 gallons of fuel carried in a tow vehicle which transports the cask to the storage pad.

The pressure generated by a credible industrial-type explosion in the general vicinity of the cask is compared with the cask design external pressure of 25 psi. The analysis of an explosion is presented in Section 11.2.4 of the TSAR.

Retrievability. Section 2.2.5.4.2 of the TSAR specifies that the basket shall be designed so that the fuel can be removed from the cask with minimum difficulty in the event of a cask bottom-end drop or tip-over accident. Maximum design basis decelerations are 50g and 88g, respectively, for the cask bottom-end drop accident and a side-drop equivalent tip-over accident.

2.3.3.3 Thermal

The TN-32 design provides passive heat removal from the spent fuel. The cask cavity is filled with helium to assist in heat transfer to the cask wall and to provide an inerting environment for the fuel. The design ambient temperature range is -29°C (-20°F) to 46°C (115°F), as indicated in Table 2.5-1 of the TSAR.

Section 2.3.2.2 of the TSAR addresses the issue of maintaining fuel cladding integrity during storage by establishing a temperature limit for the cladding. The design criterion for the TN-32 maximum initial storage fuel cladding temperature criterion is determined using the guidelines provided by the Commercial Spent Fuel Management Program (CSFM) [5]. This approach is substantially in accordance with the UCID-21181 [6] criterion adopted by the staff to ensure that degradation and gross rupture do not occur over the design life of the ISFSI.

The limiting clad temperature is established to be 348°C (658°F) for 7-year cooled fuel and 342°C (648°F) for 10-year cooled fuel, respectively.

The design basis fire has been discussed in Section 2.3.3.2 and is reviewed in Section 4 of this SER.

2.3.3.4 Shielding

Shielding design criteria are specified in Section 2.3.5.2 of the TSAR. The maximum dose rate at the cask surface must be less than 2 msv/hour (200 mrem/hour). Dose rates at the ISFSI site boundary should be in accordance with applicable regulatory requirements of 10 CFR 20.1301.

2.3.3.5 Confinement Barriers and Systems

The Helicoflex seals (double metallic o-rings) of the TN-32 primary confinement boundary are specified to have a maximum temperature limit of 299°C (570°F). The cumulative leak rate for all seals shall not exceed $1x10^{-5}$ std cc/sec of helium at 1 atm pressure. Demonstration of this limit satisfying the requirements of 10 CFR Part 72 is discussed in Section 7 of this SER.

As discussed in Section 2.3.2.1 of the TSAR, the TN-32 design also provides the capability to detect seal failure through a pressure monitoring system (PMS). The interlid region is filled with helium gas to 5.5 atm. In the event of a seal failure of either the inner lid or outer lid, this gas will leak either into the cask cavity or to the atmosphere, respectively, and an alarm will indicate a drop in pressure. No single seal failure can result in a leak of cavity gas to the atmosphere. Except for the PMS, no other instrumentation or control systems are applicable to the TN-32.

2.3.3.6 Radiation Protection

Section 2.3.5 of the TSAR addresses radiological protection. The principal design features of the TN-32 for exposure control are the inherent shielding capability of the cask and the integrity of the seals at the closure joints. Radiological alarm systems and systems for monitoring effluents and direct radiation are not applicable to the design of the storage cask. In addition to the provisions of ALARA, the use of the TN-32 at an ISFSI must comply with the total dose limits at the site boundary as specified in 10 CFR 72.104(a) and 72.106(b). Because these dose limits depend on site-specific parameters (e.g., total number of casks, cask-array configuration, distance to the site boundary, and radiation from other fuel cycle operations), demonstration of compliance with these requirements is the responsibility of the site licensee. A detailed analysis to illustrate that such compliance can be achieved in principle is presented in Sections 5, 7, and 10 of the TSAR and is discussed in the corresponding sections of this SER.

2.3.3.7 Criticality

Section 2.3.4 of the TSAR establishes a maximum effective multiplication factor of 0.95, including uncertainties and biases, for all credible configurations and environments for the prevention of criticality. A k_{eff} less than 0.95 is achieved by use of geometry and fixed Boral poisons. Fresh fuel composition and 2000 ppm borated water in the cavity are assumed for criticality analysis.

2.3.3.8 Operating Procedures

The TN-32 is designed to be loaded and unloaded in a fuel storage pool. Dry loading and unloading are not addressed in the TSAR. General operating procedures are addressed in Section 8 of the TSAR.

Operational features of the cask to minimize radioactive wastes and facilitate decommissioning are also presented in Sections 1.2.2 and 2.4 of the TSAR.

2.3.3.9 Acceptance Tests and Maintenance

Section 9 of the TSAR addresses testing and maintenance requirements for the TN-32. The evaluation of these requirements is presented in the corresponding section of the SER.

2.3.3.10 Decommissioning

Decommissioning considerations are addressed in Section 2.4 of the TSAR. Although no specific criteria are established, the analysis indicates that activation of cask components is minimal. The appropriateness of decommissioning considerations is evaluated in Section 14 of this SER.

2.4 Evaluation Findings

The staff concludes that the principal design criteria for the TN-32 are in compliance with 10 CFR Part 72. The evaluation provides reasonable assurance that the TN-32 will enable safe storage of spent fuel. This finding is based on a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices. A more detailed evaluation of design criteria and the assessment of compliance with these criteria are presented in Sections 3 to 14 of this SER.

2.5 References

1. American Society of Mechanical Engineers, "ASME Boiler And Pressure Vessel Code," Section III, Division 1—Subsection NB, 1992.

2. U.S. Nuclear Regulatory Commission. "Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels," Regulatory Guide 7.6.

3. U.S. Nuclear Regulatory Commission. "Design Basis Tornado for Nuclear Power Plants," Regulatory Guide 1.76.

4. U.S. Nuclear Regulatory Commission. "Standard Review Plan, Missiles Generated by Natural Phenomena," Section 3.5.1.4, NUREG-0800, Rev. 2, July 1981.

5. Levy, et al. "Recommended Temperature Limits for Dry Storage of Spent Light Water Reactor Zircaloy - Clad Fuel Rods in Inert Gas," Pacific Northwest Laboratory, PNL-6189, 1987.

6. Schwartz, M.W. and M.C. Witte. "Spent Fuel Cladding Integrity During Dry Storage," UCID-21181, Lawrence Livermore National Laboratory, September 1987.

Section 3—STRUCTURAL EVALUATION

This section evaluates the structural design of the TN-32 Dry Storage Cask. Design features and design criteria are reviewed, and the structural responses of the cask to normal, accident, and natural phenomena events are evaluated.

3.1 Areas of Review

3.1.1 Structural Design
—Structural Design Features
—Structural Design Criteria
—Weights and Center of Gravity
—Mechanical Properties of Materials
—General Standards for Casks
—Supplemental Data

3.1.2 Normal Operating and Design Conditions
—Lifting Devices Analysis
—Temperature
—Fuel Basket Analysis
—Lid Bolt Analyses

3.1.3 Accident Conditions
—Cask Tip-over
—Cask Bottom-end Drop
—Lid Bolt and the Top Neutron Shield Bolt Analyses

3.1.4 Natural Phenomena Events
—Flood
—Tornado Winds
—Tornado Missiles
—Earthquake

3.2 Regulatory Requirements

3.2.1 Structural systems and components important to safety must be described in sufficient detail to enable an evaluation of their structural effectiveness. [10 CFR 72.24(c)(3)]

3.2.2 Structures, systems, and components important to safety must be designed to accommodate the combined loads of normal, accident, and natural phenomena events with an adequate margin of safety. [10 CFR 72.122(b) and (c)]

3.2.3 The spent fuel cladding must be protected during storage against degradation that leads to gross ruptures, or the fuel must be otherwise confined such that degradation of the fuel during storage will not pose operational safety problems with respect to its removal from storage. [10 CFR 72.122(h)(1)]

3.2.4 Storage systems must be designed to allow ready retrieval of spent fuel waste for further processing or disposal. [10 CFR 72.122(l)]

3.2.5 The cask must be designed and fabricated so that the spent fuel is maintained in a subcritical condition under all credible conditions. [10 CFR 72.236(c) and 72.124(a)]

3.2.6 The cask and its systems important to safety must be evaluated, by appropriate tests or by other means acceptable to the Commission, to demonstrate that they will reasonably maintain confinement of radioactive material under normal, off-normal, and credible accident conditions. [10 CFR 72.236(l)]

3.2.7 Structural systems and components important to safety must be analyzed and evaluated to assess their adequacy for protecting the health and safety of the public. [10 CFR 72.24(d)]

3.3 Review Procedures

3.3.1 Structural Design

3.3.1.1 Structural Design Features

Section 1 of this SER provides a complete description of the cask. The structural components of the TN-32, as discussed in Section 3.1.1 of the TSAR, include: cask body consisting of a containment vessel and gamma shielding, the basket, the trunnions, and the neutron shield outer shell. All drawings, figures, and tables describing structural features are sufficiently detailed.

3.3.1.2 Structural Design Criteria

Section 3.1.2 of the TSAR provides a discussion of the TN-32 structural design criteria, which supplements information presented in Section 2. These criteria can be divided into several categories: load conditions, stress categorization, allowable stress limits for ductile failure, and buckling.

Section 3.1.1 of the TSAR specifies that the TN-32 cask body is designed, fabricated, examined, and tested in accordance with the requirements of Section III, Subsection NB of the ASME Boiler and Pressure Vessel Code (B&PVC) [1]. The containment boundary consists of the inner shell and bottom plate, shell flange, lid outer plate, lid bolts, penetration cover plates, and bolts. The containment boundary welds are full penetration welds examined volumetrically by radiograph. These welds are also liquid penetrant examined.

Gamma shield welds are examined in accordance with Section III, Subsection NF. Seal welds are examined in accordance with Section V of the ASME Code. Stainless steel overlay welds are also examined per Section V of the ASME Code. Lifting devices are designed in accordance with ANSI N14.6 [2] requirements for lifting operations. In addition, a principal structural design criterion is established that confinement must be maintained under accident conditions.

All metals used in the primary confinement boundary are Class 1 metals and comply with specifications listed in the B&PVC Section II, Part D, Table 2A. These metals are weldable as required in the B&PVC, Section IX. Metals for bolts comply with the requirements of specifications listed in the B&PVC Section II, Part D, Subpart 1, Table 4. Other metals for components important to safety comply with the requirements of specifications in Section II, Part A or B.

The staff agrees with the use of the provisions of Section III of the ASME Boiler and Pressure Vessel Code for stress categorization and for the determination of allowable stress limits for ductile failure. Section III specifies requirements for nuclear power plant components and its use is consistent with Regulatory Guides 3.60 [3] and 7.6 [4]. Tables 3.1-2 to 3.1-5 of the TSAR list the allowable stress limits for TN-32 containment vessel, containment bolt, non-containment structure, and basket stress limits.

Section 3.1.2.3 of the TSAR discusses the fuel basket structure design criteria under both Level A and Level D service conditions. Individual fuel compartment wall panels are evaluated against buckling load using the provisions of both the ASME Code rules for component supports and B96.1 [5].

3.3.1.3 Weights and Center of Gravity

Section 3.2 and Table 3.2-1 of the TSAR summarize the weights and centers of gravity of the TN-32. The cask weight on the storage pad loaded with fuel is 230,990 pounds. Many of the structural analyses use a cask design weight of 235,000 pounds, which exceeds the loaded cask weight. In the analysis of the stability of the cask, however, a low weight of 228,000 pounds is used. The center of gravity is 92.09 in. above the bottom surface of the cask body.

3.3.1.4 Mechanical Properties of Materials

Table 3.3-1 of the TSAR provides mechanical properties for the cask materials used in the structural evaluation. Table 3.3-2 reports the temperature dependency of the material properties.

The properties of the basket materials (ASME SA-240, Type 304, as well as SB 209, 6061-T6 aluminum), along with their temperature dependencies, are listed in Tables 3.3-4 and 3.3-5.

3.3.1.5 General Standards for Casks

Sections 3.4.1 and 3.4.2 of the TSAR discuss the general standards for chemical or galvanic reactions and positive closure for the TN-32. Supplemental information presented during the review provided an evaluation of the TN-32 cask materials, including coatings, lubricants, and cleaning agents to determine whether chemical, galvanic, or other reactions among the materials, cask contents, and environment could occur during any phase of loading, unloading, handling, and storage. All environments that could be encountered during normal, off-normal, or accident conditions were considered.

No significant reactions were identified which could reduce the overall integrity of the cask or its contents during storage operations. Insignificant amounts of hydrogen may be generated from the flame-sprayed aluminum coating and the aluminum components in the cask cavity reacting with the spent fuel pool water, but this small amount is significantly less than the lower ignition limit for hydrogen and would not result in a flammable gas mixture within the cask or any other safety hazard. The TN-32 has a bolted closure and, unlike welded closures, has no source of ignition to result in an explosion or fire. No chemical, galvanic, or other reactions were identified. [6]

3.3.1.6 Supplemental Data

The computer program used for the structural evaluation of the cask is ANSYS [7]. ANSYS is a general purpose, finite element program that is well benchmarked and widely used for many types of structural analyses. The staff concurs that ANSYS is an appropriate tool for the detailed design evaluations of the TN-32.

3.3.2 Normal Operating and Design Conditions

3.3.2.1 Lifting Devices Analysis

Section 3.4.3 of the TSAR summarizes the evaluations of the lifting devices. The staff concurs with the TSAR evaluations, which demonstrate that two lifting trunnions are capable of supporting loads of 3 times and 5 times the design loaded lift weight of the cask, without producing stresses anywhere in the cask in excess of the material minimum yield strength and ultimate tensile strength, respectively. The cask body outer gamma shielding at the trunnion locations are evaluated with local stress calculations. A summary of the trunnion loads is provided in Tables 3.4-2 and 3.4-3. Lifting of the cask in the spent fuel pool building must be evaluated and conducted in accordance with 10 CFR Part 50 requirements.

3.3.2.2 Temperature

Section 3.4.4 of the TSAR summarizes the structural evaluation for the heat condition, while Section 3.4.5 of the TSAR summarizes the evaluation for the cold condition. The analyses presented are reasonable, and the staff accepts Sections 3.4.4 and 3.4.5 of the TSAR without further evaluation.

3.3.2.3 Fuel Basket Analysis

Table 3.4-8 of the TSAR summarizes the stresses imposed by thermal expansion and gravity. The staff concurs with the TSAR conclusion that the structural adequacy of the TN-32 fuel basket design for the normal operations condition is demonstrated.

3.3.2.4 Lid Bolt Analyses

The staff concurs with Section 3.4.4.3.3 of the TSAR, which concludes that the lid bolts are structurally adequate for the storage cask normal and off-normal operating conditions. The analyses examine the stress intensity in the lid bolts resulting from the tensile, tensile plus bending, shear, as well as the combined stress intensities. Results of the evaluation of the bolts are summarized in Table 3.4-7 of the TSAR.

3.3.3 Accident Conditions

3.3.3.1 Cask Tip-over

Section 3A.2 of the TSAR contains an evaluation of the performance of the cask subjected to a 50-g side impact to envelop the tip-over accident. The 50-g deceleration was selected based on the methodology of EPRI NP-4830 [8] and a scale factor to account for dynamic load effects. A 50-g cask side impact structural analysis was performed for the cask body using the static results for a side load of 1-g for the normal conditions (Section 3A.2.3.1). The stresses for the 50-g load case were obtained by taking 50 times the 1-g load case results. Section 3A.2.4.3 evaluates a 50-g side impact onto the trunnion.

Section 3B.4.2 evaluates structural performance of the basket for a quasi-static lateral load of 50 g. Using the ANSYS computer code, the analysis was performed by three-dimensional finite element modeling of a cross-sectional slice of the basket consisting of an assembly of stainless steel compartments joined by welded steel plugs and separated by aluminum conductor plates. Section 3B.4.3 presents the basket design criteria, including those for stresses, in accordance with Section III, Appendix F of the ASME Boiler and Pressure Vessel Code. The structural performance of the basket was evaluated in Section 3B.4.4 for the stainless steel plates, plug welds, and aluminum conductor plates and in Section 3B.4.5 for the aluminum basket support rails.

The staff concurs with the TSAR results that, for a 50-g side impact, the cask stresses are within the stress intensity limits in the cask body and its components, including the basket.

However, the methodology of EPRI NP-4830 has not been benchmarked against any cask side drop tests and the staff, therefore, has not endorsed the EPRI report. Based on side drop and tip-over steel billet test results [9] and confirmatory analysis, the staff determined that the tip-over accident will cause local plastic deformation of the neutron shield and will result in the cask body experiencing a maximum deceleration of 63 g at the top of the cask. The staff also determined that after considering dynamic load factors, the fuel compartments will experience a maximum quasi-static force of 82 g at the top of the basket and 51 g at the

cross section of the basket that will experience the highest temperatures. These analyses account for a varied soil modulus of elasticity and are based on a reinforced concrete storage pad thickness of 3 feet and concrete strength of 4,000 psi.

The staff determines that the TSAR analysis for the 50-g side impact of the cask body, including the trunnions and lid bolts, contains sufficient design margins to assure confinement with a potential maximum side impact of 63 g on the cask body in association with a tip-over handling accident. However, additional analysis of the basket was required.

At the request of the staff, TN performed additional analysis of the basket and evaluated the basket and its support rails subject to a lateral quasi-static force of 88 g. Appendix 3C to the TSAR contains this analysis. In a response to the staff's request for additional information on Appendix 3C, TN modified its modeling assumptions and analyzed two bounding cases for the basket and support rails assembly, considering inelastic material properties at applicable temperatures for both aluminum and steel plates. For the case applicable to the top of the basket which will experience the highest deceleration, the basket was analyzed for a quasi-static load of 88 g. For the cross section of the basket that will experience the highest temperatures, the basket was analyzed for 52 g. The inelastic analyses were performed for a basket impact orientation of 90°, based on the results of quasi-static analyses conducted in Appendix 3B which shows that this orientation yields the highest stresses. The staff evaluated TN's modeling approach and its bases and concurs with the analysis results that the basket structural performance meets the design criteria at elevated temperatures. The staff also concurs with the conclusion that the maximum deformations in the basket are small enough to maintain a subcritical configuration of the fuel and allow for removal of the fuel assemblies after a tip-over accident.

On the basis of TN's analysis and use of the lateral inertia loads which envelop the quasi-static lateral forces associated with a TN-32 cask tip-over handling accident, the staff concludes that the TN-32 cask will perform adequately after a tip-over accident. Cask confinement and spent fuel retrievability from the basket will be assured if the concrete storage pad 1) is not more than 3 ft thick, 2) the concrete strength is not greater than 4,000 psi and 3) the soil modulus of elasticity is not greater than 40 ksi. If the cask were to be located at an ISFSI that exceeds these site conditions, further analysis and staff review would be required.

3.3.3.2 Cask Bottom-end Drop

Section 3A.2.3.2 of the TSAR selects a 50-g deceleration for evaluating the bottom-end drop accident. The 50-g deceleration was higher than that determined with the EPRI NP-4830 methodology for drop heights of both 18 and 60 in. The staff has not endorsed the EPRI NP-4830 methodology for computing bottom-drop cask decelerations. Staff review experience has shown, however, that a 50 g deceleration is adequate for cask analysis of an end-drop accident of 18 in. onto a concrete pad 3 ft thick and concrete strength of 4,000 psi. The 50-g bottom-end drop analysis was based on the 1-g static load results for the normal condition. The stresses for the 50-g load case were obtained by taking 50 times the 1-g load case results.

On the basis of the above, the staff concludes that the TN-32 cask will perform adequately after a bottom-end drop accident. Cask confinement and spent fuel retrievability from the basket will be assured if the cask is not lifted more than 18 in. above the concrete storage pad and if the pad 1) is not more than 3 ft thick, 2) the concrete strength is not greater than 4,000 psi, and 3) the soil modulus of elasticity is not greater than 40 ksi.

3.3.3.3 Lid Bolt and the Top Neutron Shield Bolt Analyses

Section 3A.3 of the TSAR evaluates the lid bolts under a 50-g cask bottom-end drop and a tip-over accident onto the concrete storage pad. The evaluation of the lid bolts considers the inertial loads from the end drop and tip-over accident conditions as well as loads from internal pressure and bolt preload. The results of Section 3A.3.2 of the TSAR demonstrate sufficient design margins to resist the inertia loads discussed in Sections 3.3.3.1 and 3.3.3.2 above. Therefore, the staff concludes that the lid bolts are structurally adequate for the cask handling accident conditions.

The dose rate at the top of the lid without the neutron shield is below the acceptable accident dose limit. As a result, the staff concurs with the TSAR conclusion that no accident condition analysis of the top neutron shield bolts is required.

3.3.4 Natural Phenomena Events

3.3.4.1 Flood

Section 2.2.2 of the TSAR summarizes the evaluation of the TN-32 for the flood event due to a natural event (high water, a broken dam, a seismic event, or a hurricane). The evaluation considers hydrostatic effects and dynamic phenomena such as momentum and drag imposed on the cask if the water velocity or the hydrostatic pressure is too high. The cask has been evaluated for a water level of 56 ft and a water drag force of 45,600 pounds. Assuming a friction coefficient of 0.25, this force is equivalent to a stream of water flowing past the cask at 18.5 ft/sec. The staff agrees with the analysis of this section and that the cask is acceptable for these conditions. Section 12 of the SER includes the condition that the cask cannot be used when flooding exceeding these assumptions is credible.

3.3.4.2 Tornado Winds

Section 2.2.1.2.1 of the TSAR summarizes the evaluation of the TN-32 for extreme tornado winds. The staff accepts the conclusion that a wind velocity of 403 mph is required to cause the cask to slide (with a coefficient of friction being 0.25), and a wind speed of 532 mph is required to tip the cask. Therefore, the design is acceptable for meeting the requirements of 10 CFR 72 with respect to tornado and wind loadings.

3.3.4.3 Tornado Missiles

Section 2.2.1.2 of the TSAR summarizes the evaluation of the TN-32 for three types of tornado missiles, including a massive high kinetic energy missile, a rigid missile, and a missile produced by a small, rigid steel sphere of 1-in. diameter. The staff concurs with the conclusions in the TSAR that none of the missiles can puncture the outer shell and that only localized penetration or crushing of the neutron shielding material may occur. The staff further agrees that these missiles will not result in a cask tip-over.

3.3.4.4 Earthquake

Section 2.2.3 of the TSAR summarizes the evaluation of the TN-32 for a seismic event and determines that a horizontal acceleration of 0.36 g is needed to cause a tip-over. The staff accepts the analysis in this section.

3.4 Evaluation Findings

Structures, systems, and components important to safety are described in sufficient detail to enable an evaluation of their structural effectiveness, and are designed to accommodate the combined loads of normal, accident, and natural phenomena events.

Storage systems are designed to allow ready retrieval of spent fuel waste for further processing or disposal. No accident or natural phenomena events analyzed will result in damage that will prevent retrieval of the fuel.

The cask is designed and fabricated so that the spent fuel is maintained in a subcritical condition under credible conditions. The configuration of the fuel is unchanged. Additional criticality evaluation is discussed in Section 6 of the SER.

The cask and its systems important to safety are evaluated to demonstrate that they will reasonably maintain confinement of radioactive material under normal, off-normal, and credible accident conditions.

The staff concludes that the structural design of the TN-32 is in compliance with 10 CFR Part 72 and that the applicable design and acceptance criteria have been satisfied. The structural evaluation provides reasonable assurance that the TN-32 will enable safe storage of spent fuel. This finding is based on a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, accepted practices, and staff confirmatory analysis.

3.5 References

1. American Society of Mechanical Engineers. "ASME Boiler and Pressure Vessel Code," Section III, 1992.

2. American National Standards Institute. "American National Standard for Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4,500 kg) or More for Nuclear Materials," ANSI N14.6, New York.

3. U.S. Nuclear Regulatory Commission. "Content of Technical Specifications for Fuel Reprocessing Plants," Regulatory Guide 3.6

4. U.S. Nuclear Regulatory Commission. "Design Criteria for the Structural Analysis of Shipping Cask Containment Vessels," Regulatory Guide 7.6.

5. American Society of Mechanical Engineers. "Welded Aluminum Alloy Storage Tanks," ASME B96.1, 1989.

6. Lusardi, Meg to William Travers. "Safety Evlauation of Transnuclear Inc.'s Response to NRC Bulletin 96-04 for the TN-32," November 1, 1996.

7. De Salvo, G.J. and J.A. Swanson. "ANSYS Engineering Analysis System, Users Manual for ANSYS Rev. 4.4," Swanson Analysis Systems, Inc., Houston, PA, June 1989.

8. Electric Power Research Institute. "The Effects of Target Hardness on the Structural Design of Concrete Storage Pads for Spent-Fuel Casks," Report No. NP-4830, October 1986.

9. Lawrence Livermore National Laboratory. "Low Velocity Impact Testing of Solid Steel Billet onto Concrete Pads: A Summary of Twelve Drop Tests Conducted February 1996 at the Lawrence Livermore National Laboratory," Draft, March 1, 1996.

Section 4—THERMAL EVALUATION

This section evaluates the thermal performance of the TN-32 Dry Storage Cask. Design criteria and their bases, initially presented in Section 2, are reviewed for additional detail. Heat loads from both content and external sources are assessed, and models used by the applicant for thermal analyses are examined. Temperatures and pressures calculated by the applicant are confirmed, and compliance with design and acceptance criteria is evaluated.

One of the most important functions of the thermal evaluation is the confirmation that the fuel clad temperatures are below the threshold at which unacceptable degradation of the clad will occur over 20 years of storage. The temperature and pressure information evaluated in this section is further used in the review of other sections of the TSAR, such as structural and confinement.

The thermal performance of the TN-32 dry storage cask under accident conditions, as evaluated in this section, is also addressed as appropriate in the overall accident analyses presented in Section 11.

4.1 Areas of Review

4.1.1 Thermal Design Criteria and Design Features
- Design Criteria
- Design Features

4.1.2 Thermal Load Specification
- Normal Storage Conditions
- Accident Conditions

4.1.3 Model Specification
- Configuration
- Material Properties
- Boundary Conditions

4.1.4 Thermal Analyses
- Computer Programs/Analytical Solutions
- Temperatures
- Pressures
- Confirmatory Analysis

4.2 Regulatory Requirements

4.2.1 Thermal structures, systems, and components important to safety must be described in sufficient detail to enable an evaluation of their effectiveness. [10 CFR 72.24(c)(3)]

4.2.2 Spent fuel storage or handling systems must be designed with a heat-removal capability having testability and reliability consistent with its importance to safety. [10 CFR 72.128(a)(4)]

4.2.3 The cask must be designed to provide adequate heat removal capacity without active cooling systems. [10 CFR 72.236(f)]

4.2.4 The spent fuel cladding must be protected against degradation that leads to gross ruptures, or the fuel must be otherwise confined such that degradation of the fuel during storage will not pose operational safety problems with respect to its removal from storage. [10 CFR 72.122(h)(1)]

4.2.5 Storage systems must be designed to allow ready retrieval of spent fuel for further processing or disposal. [10 CFR 72.122(1)]

4.2.6 The analysis and evaluation of the thermal design and performance must demonstrate that the cask is able to store spent fuel safely for a minimum of 20 years with an adequate margin of safety. [10 CFR 72.24(d) and 72.236(g)]

4.3 Review Procedures

4.3.1 <u>Thermal Design Criteria and Design Features</u>

4.3.1.1 Design Criteria

Design criteria for the TN-32 dry storage cask have been formulated by the applicant to ensure that public health and safety will be protected during the period that spent fuel is stored in the cask. The design criteria cover both the normal storage conditions which may exceed a minimum of 20 years and accident incidents that last a short time, such as a fire.

4.3.1.1.1 Normal Storage Conditions

Section 2.3.2.2 of the TSAR defines four primary design criteria for the TN-32 cask. First, the seal temperatures must not exceed the allowable seal temperature to ensure the confinement of radioactive material and gases. The maximum temperature limit of the metallic o-ring seals in the confinement vessel closure lid is 570°F. Second, the stability of the neutron shield resin must be maintained. The maximum temperature limit of the neutron shield material is 300°F during normal storage conditions. Third, the maximum

temperatures of the confinement structural components must not adversely affect the confinement function. The temperature limit, below which the allowable stresses in these components remains invariant with temperature, is 500°F. Fourth, the maximum fuel clad temperature must not exceed the limit that will cause unacceptable degradation of the clad during 20 years of storage. Based on references [1] and [2], the maximum clad temperature limits for fuel cooled a maximum of 7 and 10 years are 658°F (348°C) and 648°F (342°C), respectively, as given in Section 3.5 of the TSAR.

4.3.1.1.2 Accident Conditions

The design criteria for accident conditions given in Section 11.2.5.2 of the TSAR are based on preserving the confinement integrity of the TN-32 storage cask. The maximum temperature limit of the metallic o-ring seals in the confinement vessel closure lid of 570°F must not be exceeded. The maximum cavity pressure must not exceed 100 psig. Based on shielding calculations, the loss of the resin in the neutron shield during a fire does not lead to unacceptable consequences.

4.3.1.2 Design Features

The heat removal system of the TN-32 storage cask is totally passive. No coolants or active cooling systems are utilized. The cask cavity is filled with helium to provide a chemically inert atmosphere as well as to aid in the transport of decay heat from the fuel assemblies to the cask inner wall. The decay heat is transferred from the fuel assemblies to the outer environment by conduction, convection, and radiation.

As discussed in Section 1.2.1 of the TSAR, 32 PWR fuel assemblies are supported in a basket assembly of 304 stainless steel cells separated by 0.5-in. thick 6061-T6 aluminum alloy and 0.040-in. thick borated aluminum plates. The cells are joined by a series of stainless steel plugs that pass through the aluminum plates and are fusion-welded to the stainless steel to form 8.7-in. square compartments for the spent fuel assemblies. The aluminum plate provides the conduction paths for the removal of the decay heat from the assemblies to the cask inner surface. The borated plate provides the necessary criticality control.

The cask body consists of concentric shells. The inner shell, fabricated from ASME SA-203, Grade A ferritic steel, is the confinement boundary. The second shell, fabricated from ASME SA-105, SA-560, Gr. 70 or SA-266, Cl. 2 ferritic steel, is a gamma shield. The third shell, that consists of a borated polyester resin compound cast into long slender 6063-T5 aluminum alloy containers, is the neutron shield. The fourth shell, fabricated from ASME SA-516, Grade 70, ferritic steel, encloses the neutron shield. The bottom shield and the bottom confinement plate are made from the same material as the second shell and the inner shell, respectively. The lid is fabricated from ASME SA-350, Gr. LF3 or SA-203, Gr. A or D ferritic steel. The top shield plate is fabricated from ASME SA-105 or SA-560, Gr. 70 ferritic steel.

4.3.2 Thermal Load Specification

The design basis fuel to be stored in the TN-32 cask is described in Section 2.1 of the TSAR. The initial maximum average decay heat per spent fuel assembly is 0.847 kW for 7-year-cooled fuel, which is consistent with an initial enrichment of 3.85% and a maximum burnup of 40,000 MWD/MTU. The axial power profile of the design basis spent fuel assembly is shown in Section 4.4.1.1 of the TSAR. The peak power in a spent fuel assembly is 1.2 times the average power. The decay heat load will decrease with time over the storage period.

Thermal loads will be different for normal storage conditions than for accident conditions, such as a fire. The difference in the thermal loads will occur at the surface of the cask. The application of the surface thermal loads will be for a short time during an accident, while the surface thermal loads are applied continuously during normal storage conditions. The decay heat load during an accident will be the same as for the normal storage condition at the time of the accident.

4.3.2.1 Normal Storage Conditions

The external environment conditions for normal storage conditions are described in Section 2.1 (Table 2.5-1) of the TSAR. The applicant evaluates the cask for conditions with an ambient temperature of 100°F and an insolation for a 12-hour period of 2950 BTU/ft^2 and 1475 BTU/ft^2 for horizontal flat and curved surfaces, respectively. The results of these evaluations are reviewed in Section 4.3.4 below.

4.3.2.2 Accident Conditions

A thermal accident postulated for the TN-32 storage cask is described in Section 11.2.5 of the TSAR. A fire with an average flame temperature of 1550°F and an emissivity of 0.9 engulfs a TN-32 storage cask with an initial temperature distribution based on the normal storage conditions given in Section 4.3.2.1, above. In addition to the radiant energy absorbed on the cask surface with an emissivity of 0.8, flame energy is convected to the cask surface with a convection heat transfer coefficient of 4.5 BTU/hr-ft^2-F. Following the 15-minute fire, the cask is cooled by radiation and natural convection to an ambient temperature of 100°F.

4.3.3 Model Specification

4.3.3.1 Configuration

The model used for the analysis of the thermal performance of the TN-32 storage cask consists of three primary components: the spent fuel assemblies, the basket, and the cask body. In addition to these components, the concrete storage pad is also modeled. The three-dimensional finite element mesh for the storage cask system is generated using ANSYS.

4.3.3.1.1 Fuel Assembly

The TN-32 storage cask is designed to store 32 15x15 or 17x17 Westinghouse spent fuel assemblies. The fuel assembly parameters are given in Table 2.1-1 of Section 2.1 of the TSAR. The spent fuel pin decay heat is assumed to be transferred by conduction through the fuel clad and through the helium between the fuel rods in parallel with the thermal radiation between the rods.

The decay heat is transferred from the fuel assembly to the basket assembly tube by conduction through the helium and thermal radiation from the assembly pins to the interior of the basket assembly tube.

4.3.3.1.2 Fuel Basket

The basket is comprised of 32 stainless steel boxes with typically one 0.5-in. thick aluminum and one 0.04-in. thick poison plate placed between boxes. The boxes are held together by stainless steel plugs which pass through the aluminum and poison plates and are welded to the stainless steel.

The fuel basket is modeled as a square grid of orthogonal 0.5-in. thick aluminum alloy plates on 9.45-in. centers. Some of the aluminum alloy plates are interrupted to allow orthogonal plates a direct conduction path to the basket periphery. A 0.02-in. helium gap is assumed between the interrupted plates and the continuous plates. The thermal conductivity of the aluminum alloy plate material is reduced by 10% in the model to compensate for the loss of material at the plug weld holes. The heat flux from the spent fuel assemblies is applied directly to the aluminum alloy plates to determine the temperature distribution in the basket. The basket temperature distribution is then used as boundary conditions to determine the fuel pin temperatures.

The model assumes a 0.188-in. helium gap between the periphery of the basket and the basket rails. The rails provide structural support for the basket and increase the surface area for heat dissipation. Although the rails are bolted to the cask cavity inner surface, a 0.01-in. gap is assumed between these surfaces in the thermal model.

4.3.3.1.3 Cask Body

The cask body portion of the model consists of the cask bottom and the concentric cylindrical shells. The cask components above the cask body, including the lid, are not modeled. An adiabatic surface is assumed at the plane defined by the top of the cask cavity.

The cask body consists of a multi-walled hollow cylinder of concentric shells. The containment vessel and the gamma shield are assembled with an interference fit. A contact conductance of 200 BTU/hr-ft^2 is assumed for the interface between these two surfaces. The neutron shielding consists of aluminum containers filled with resin and placed between the

gamma shield and the outer shell. Although the aluminum containers butt against the gamma shield and outer shell, an air gap of 0.01 in. is used between the components in the model. The two steel cask bottom plates are assumed to be separated by a 0.125-in. air gap in the model.

4.3.3.1.4 Storage Pad

The concrete storage pad is modeled as a 36-in. thick cylinder extending radially 36 in. beyond the outer diameter of the bottom of the cask. The bottom of the pad is in contact with the soil and is assumed to be isothermal.

4.3.3.2 Material Properties

The material properties used in the thermal analysis of the storage cask system are given in Section 4.2 of the TSAR. The material properties given reflect the accepted values of the thermal properties of the materials specified for the construction of the cask.

4.3.3.3 Boundary Conditions

The boundary conditions include the decay heat load from each of the fuel assemblies and the external conditions on the cask surface. The peak power per fuel assembly is 1.2 times the average power of 0.847 kW per assembly. For an active fuel length of 144 in., the peak linear power is 7.06 watts/in. The peak decay heat flux on a basket surface, based on 8.7-in. square compartments, is 0.203 watts/in.^{2}. As noted in Section 4.3.3.1.2 above, the spent fuel decay heat flux is applied to the aluminum alloy plates to determine the boundary conditions for determining the fuel pin temperatures.

The boundary conditions depend on the environment surrounding the cask. Two cases are considered for the TN-32 storage cask. The first case includes several variants of normal storage conditions. The second is a fire accident case. For both cases, the decay heat load boundary condition is applied as described above.

4.3.3.3.1 Normal Storage Conditions

The energy on the surface boundaries of the cask includes both the decay heat from the 32 spent fuel assemblies and the absorbed insolation. The absorbed insolation is the insolation from Section 4.3.2.1 above, multiplied by the absorptivity of thermal radiation with the solar spectrum by the cask surface material.

The energy is transferred from the outer cask surface to the environment and, through the storage pad, to the ground. The heat transferred to the environment is by natural convection and thermal radiation. The models used for the thermal convection and thermal radiation given in Section 4.4.1 of the TSAR are appropriate models for a storage cask in an array of casks. Heat is also conducted from the bottom of the storage cask through the concrete

storage pad to the soil underlying the pad. The bottom of the storage cask is assumed to be in perfect contact with the concrete storage pad. The interface between the bottom of the storage pad and the soil is assumed to be isothermal at the specified soil temperature.

The applicant considers both a short-term and a long-term environment for storage. The short-term environment assumes a 100°F ambient temperature and an incident solar heat flux based on the prescribed insolation averaged over a 12-hour period. The soil temperature is assumed to be 70°F. The long-term environment assumes a 60°F ambient temperature and an incident solar heat flux based on the prescribed insolation values averaged over a 24-hour period. The soil temperature is assumed to be 60°F.

4.3.3.3.2 Accident Conditions

The accident condition consists of the 15-minute fire with a flame temperature of 1550°F on a cask with an initial temperature distribution based on the short-term normal storage condition of 100°F ambient temperature with an incident solar heat flux based on the specified insolation averaged over 12 hours. The emissivities of the flames and the package surface during the fire are 0.9 and 0.8, respectively. The flame energy is also assumed to be convected to the package surface with a convection heat transfer coefficient of 4.5 BTU/hr-ft^2-°F. Following the termination of the 15-minute fire, the cask is cooled by thermal radiation and natural convection from the surface to the environment, with an ambient temperature of 100°F.

4.3.4 Thermal Analyses

The thermal analysis for normal storage conditions is performed in Section 4.3.4 of the TSAR. A thermal accident scenario is presented in Section 11.2.5 of the TSAR. Reviews for both cases are discussed in this section of the SER.

4.3.4.1 Computer Programs/Analytical Solutions

A detailed thermal analysis of the TN-32 storage cask system is performed by TN using the finite element code ANSYS [3]. The model, material properties, and the boundary conditions discussed in Section 4.3.3 above are used in the ANSYS analysis. Based on the use of the model, properties, and boundary conditions, the temperature distributions in the aluminum alloy basket elements are determined.

4.3.4.1.1 Normal Storage Conditions

A three-dimensional version of ANSYS is used to determine the steady-state temperature distribution of the TN-32 storage cask standing vertically on the concrete pad. The cask components include the basket, the basket rails, the cask shells, the neutron shielding, the outer shell, and the concrete pad. Because of symmetry, a quadrant slice of the radial cross-section is analyzed in the three-dimensional model.

As noted in Section 4.3.3.1.2 above, the fuel assembly decay heat is applied as a uniform flux to the aluminum alloy basket plates to determine the temperature distribution in the basket. The maximum fuel pin temperature is then calculated from the temperature distribution in the plates surrounding the hottest basket compartment using a modified Wooton-Epstein correlation [4,5,6]. The use of the modified Wooten-Epstein model assumed 0.075-in. helium gaps between the aluminum alloy plates and the outer surfaces of the spent fuel assembly in lieu of the borated aluminum poison plates that are in the basket. Helium gaps were also assumed between the fuel pins in the spent fuel assembly. The calculation was based on the energy transferred by thermal radiation through, and conduction across, the helium between the fuel pins.

4.3.4.1.2 Accident Conditions

The hottest section of the TN-32 cask during normal storage is used as the initial condition for the fire accident. ANSYS is used to perform the analysis of the transient response of the cask to the fire and subsequent cooldown. This essentially two-dimensional analysis evaluated the components at the location on the cask elevation where the maximum temperatures were experienced during normal storage conditions. These maximum temperatures served as the initial temperatures for the accident analysis. The peak fuel pin temperature is not explicitly determined.

The response of the lip-seal region to a fire is determined using a two-dimensional axisymmetric ANSYS model. The model includes the lid, a resin disk, protective cover, and the upper region of the cask body shells. Air is assumed to conduct heat from the lid to the protective cover in the seal region where a small gap exists. The heat in the remainder of the enclosure under the protective cover is assumed to be transferred only by thermal radiation between the surfaces with emissivity of 0.9. The initial temperature of this region is assumed to be the seal/lip region temperature from the short-term normal storage conditions. The heat flux from the fire is incident on the outer surfaces of the protective cover and the cask body. Following the 15-minute fire, during cooldown, the heat is transferred from these surfaces to the ambient environment temperature of 100°F.

4.3.4.2 Temperatures

4.3.4.2.1 Normal Storage Conditions

A comparison of the temperatures of several critical components for a 27.1 kW decay heat load of 7-year cooled fuel with the design criteria is shown below. The temperatures given in the TSAR are calculated based on the short-term normal storage conditions. These temperatures are less than the maximum allowable temperatures based on the design criteria given in Section 4.3.1.1 above.

Component	Maximum Temperatures*	
	Calculated in TSAR	Design Criterion
Neutron Shield (resin/aluminum)	276°F (136°C)	300°F (149°C)
Seal/lid	239°F (115°C)	570°F (300°C)
Fuel Clad	595°F (313°C)	658°F (348°C)
Basket Plate	531°F (277°C)	

* 100°F ambient temperature and an incident solar heat flux based on the prescribed insolation averaged over 12 hours.

The maximum temperature in the aluminum alloy plate for conducting the decay heat from the fuel assemblies to the cask interior surface is approximately 531°F. The melting point of the aluminum alloy is 1080°F [7].

4.3.4.2.2 Accident Conditions

Peak transient temperatures of several critical components due to a 15-minute, 1550°F flame temperature fire for the TN-32 storage cask with a 27.1 kW decay heat is shown in the table below. The initial temperatures are based on the short-term normal storage conditions of 100°F ambient temperature and an incident solar heat flux based on the specified insolation averaged over 12 hours.

Component	Temperatures (°F)			
	Initial	Peak Transient	Design Criterion	Time to Reach Peak Temp After Start of Fire (min.)
Outer Shell	242	1080		15
Neutron Shield (resin)	276	836		17
Seal/lid	239	327	570	60
Cavity Wall	301	355	500	190
Basket Rail	327	378		241
Basket Plate	531	576		495

These temperatures, taken from Section 11.2.5 of the TSAR, demonstrate that melting of the metallic cask components will not occur as a result of the fire. The structural integrity of the confinement vessel will be maintained because the peak temperature of 355°F experienced by the cavity wall is lower than 500°F, the temperature below which the allowable stressses in

the confinement components remains invariant with temperature. The melting point of the basket aluminum alloy plates that conduct the spent fuel decay heat to the cask inner surface is 1080°F. Thus, the confinement and its ability to remove the decay heat are not impaired by the effects of the fire on the TN-32 storage cask. The maximum outer shell temperature of 1080°F does not exceed the eutectoid temperature (1330°F) of iron-carbon steel. The neutron shield material will off-gas (primarily water vapor) during the specified fire. A pressure relief valve on the outer shell will prevent pressurization of the shell. The loss of the neutron shield during the fire accident will not result in the dose rates exceeding the regulatory limits at the site boundary. The peak fuel clad temperature is about 640°F based on adding the difference of 64°F between the peak fuel clad and the basket plate temperatures during the short-term, normal storage conditions to the maximum basket plate temperature resulting from an accident. This value is less than the NRC acceptance criteria of 1058°F for the short-term accident condition.

4.3.4.3 Pressures

4.3.4.3.1 Normal Conditions of Storage

The pressure in the cask cavity is determined in Section 7.2.2 of the TSAR based on the average cavity gas temperature of 417°F and the short-term normal storage conditions of 100°F ambient temperature. The cask is assumed to be closed and sealed at 77°F and 1.35 atmospheres of dry helium. The calculation considers pressure increases due to ideal gas heating and the partial pressure of the released fission gases, assuming 10 percent of the available free gases in the spent fuel assemblies released into the cavity. The maximum internal pressure during normal conditions of storage is determined to be 35 psia. This pressure is less than the design pressure of 100 psig specified in Section 2.2.5.3.3 of the TSAR. The incident solar heat flux is based on the specified insolation averaged over 12 hours.

4.3.4.3.2 Accident Conditions

The peak average cavity gas temperature during the prescribed fire increases about 54°F above the 417°F during the short-term normal condition of storage. This increase in temperature will result in an increase of the cavity pressure during normal conditions of storage described in Section 4.3.4.3.1 above, to a peak cavity pressure of 63.1 psia from the prescribed fire, assuming 100% fuel rod failure. This pressure is less than the design pressure of 100 psig specified in the TSAR.

4.3.4.4 Confirmatory Analysis

The confirmatory analysis of the TN-32 storage cask TSAR can be divided into six categories: (1) review the models used in the analyses, (2) review the material properties used in the analyses, (3) review the boundary conditions and the models used for calculations of the surface heat transfer coefficients, (4) perform independent analyses to confirm the

applicant's analyses, (5) compare the results of the analyses with the applicant's design criteria, and (6) assure that the applicant's design criteria will satisfy the regulatory acceptance criteria.

The models generated using ANSYS adequately described the TN-32 Dry Storage Cask system. The neglect of the content decay heat transfer through the top of the cask is balanced in part by the neglect of the absorbed insolation at the horizontal surface. The thermal properties of the materials used in the storage cask as given in the TSAR are an acceptable representation of the material properties. The boundary conditions for the short-term normal storage represent a reasonable upper bound storage environment. The boundary conditions for a thermal accident are similar to those used for packaging of greater than Type A quantities of radioactive materials as prescribed by the NRC in 10 CFR Part 71. The difference between the specified thermal accident for the TN-32 storage cask and the prescribed accident for transportation packages is the flame temperature and duration of the application of the boundary conditions: 15 minutes of a 1550°F fire for the TN-32 versus 30 minutes of a 1475°F environment for transportation packages. The models presented in the TSAR to calculate the heat transfer coefficients at the surfaces of the TN-32 storage cask are well documented in the literature and are appropriately applied to the surfaces.

The review confirms the results of the applicant's thermal analyses. A one-dimensional thermal analysis was performed for short-term normal storage conditions. The one-dimensional analysis of the cask which assumed a power peaking factor of 1.2 was performed in two parts. The first part consisted of a one-dimensional analysis through the cask. An effective thermal conductivity of the neutron shield region was determined based on creating an electrical circuit analog of the parallel flow of the decay heat through the resin and the aluminum alloy. The second part consisted of a one-dimensional treatment of the basket by isolating the heat flow along a single aluminum alloy element extending from the center of the basket to the outer rail attached to the cavity surface of the cask. The maximum fuel clad temperature was determined by treating the fuel assembly region with the highest temperature boundary as a square "log" with an effective thermal conductivity of 0.5 BTU/hr-ft-°F. The review calculations were in substantial agreement with the results presented in the TSAR.

An independent analysis was also performed to confirm the results of the applicant's thermal analysis of the response of the TN-32 storage cask to a 15-minute engulfing 1550°F fire. The independent analysis assumed the cask material had an infinite thermal conductivity. The independent calculation was in substantial agreement with the result presented in the TSAR.

The two limiting thermal conditions on the TN-32 storage cask are the short-term normal storage and the postulated 15-minute fire. The temperatures of the various TN-32 cask components, as well as the maximum temperature of the spent fuel clad (as calculated by the applicant using ANSYS and independently confirmed by the reviewer) for the two limiting thermal conditions, are less than the applicant's design criteria presented in the TSAR. The

cask cavity gas pressure resulting from the average cavity temperature, coupled with the failure of all of the spent fuel rods for either limiting thermal condition, is less than the design criteria presented in the TSAR.

4.4 Evaluation Findings

Thermal structures, systems, and components important to safety are described in sufficient detail in Sections 1.2 and 2.3 of the TSAR to enable an evaluation of their effectiveness. The TN-32 is designed with a heat removal capability having testability and reliability consistent with its importance to safety. The acceptance as described in Section 9.1.6 of the TSAR is performed by analysis.

The TN-32 is designed to provide adequate heat removal capacity without active cooling systems.

The spent fuel clad is protected against degradation that leads to gross ruptures by maintaining the clad temperature below maximum allowable limits and by providing an inert environment in the cask cavity. These measures, along with the basket structural design discussed in Section 3 of the TSAR and SER, will assure that the fuel can be retrieved for further processing or disposal.

Thermal systems and components important to safety have been analyzed and evaluated to assess their adequacy for protecting the health and safety of the public. The cask is able to store spent fuel safely for a minimum of 20 years with an adequate margin of safety.

The staff concludes that the design of the heat removal system of the TN-32 Dry Storage Cask is in compliance with 10 CFR 72 and that the applicable design and acceptance criteria have been satisfied. The evaluation of the thermal system design provides reasonable assurance that the TN-32 will enable safe storage of spent fuel. This finding is based on a review which considered the requirements of 10 CFR 72, appropriate regulatory guides, applicable codes and standards, and accepted practices.

4.5 References

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2. Levy, I.S., et al. "Recommended Temperature Limits for Dry Storage of Spent Light Water Zircaloy Clad Fuel Rods in Inert Gas," PNL-6189, Pacific Northwest Laboratory, May 1987.

3. Swanson Analysis Systems, Inc. "ANSYS Computer Code for Large Scale General Purpose Engineering Analysis," Houston, PA.

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Section 5—SHIELDING EVALUATION

This section evaluates the design and analysis of the shielding system of the TN-32 cask for normal, off-normal, and accident conditions. Design features and design criteria, initially presented in Sections 1 and 2 of the TSAR, are reviewed for additional detail related to the shielding safety function. Gamma and neutron source terms are assessed, and models used by the applicant for shielding analyses are examined. Dose rates calculated in the TSAR are confirmed, and compliance with design criteria is evaluated.

The shielding review focuses on the applicant's calculation of the dose rates from gamma and neutron radiation at locations near the cask (for occupational exposure) and at an assumed site boundary (for public exposure). Because 10 CFR Part 72 acceptance criteria for doses at the site boundary include both the direct dose and that from release of radionuclides to the atmosphere, an overall assessment of the compliance with these regulatory limits is deferred until Section 10 (Radiation Protection) of the SER. Occupational doses for those cask operations described in Section 8 of the TSAR are evaluated in Section 10 of the TSAR and SER.

The performance of the cask shielding under accident conditions, as evaluated in this section, is also addressed as appropriate in the overall accident analyses presented in Section 11.

5.1 Areas of Review

5.1.1 Shielding Design Features and Design Criteria

5.1.2 Source Specifications
- —Gamma Source
- —Neutron Source

5.1.3 Model Specifications
- —Configuration of Shielding and Source
- —Material Properties

5.1.4 Shielding Analyses
- —Computer Programs
- —Flux-to-Dose Rate Conversion
- —Dose Rates
- —Confirmatory Analysis

5.1.5 Supplemental Information

5.2 Regulatory Requirements

5.2.1 Shielding structures, systems, and components important to safety must be described in sufficient detail to enable an evaluation of their effectiveness. [10 CFR 72.24(c)(3)]

5.2.2 Shielding structures, systems and components important to safety must be evaluated with the objective of assessing the impact of health and safety resulting from the operation of the ISFSI. [10 CFR 72.24(d)]

5.3 Review Procedures

5.3.1 Shielding Design Features and Design Criteria

The TN-32 is designed to provide both gamma and neutron shielding. As discussed in Sections 1.1, 1.2, and 5.1 of the TSAR, the principal components of the radial gamma shielding are the 1.5-in. thick steel confinement shell, the 8.0-in. thick steel outer shell, and the 0.5-in. thick steel neutron-shield shell. Gamma shielding at the bottom of the cask is provided by the confinement shell and a 8.75-in. thick bottom plate that is welded to the closure flange. The gamma shielding in the top of the cask consists primarily of the 10.5-in. lid and the 0.25-in. shell which encases a neutron shield.

In addition to the steel components discussed above, neutron shielding is provided by a 4.5-in. thick polyester resin compound that surrounds the radial cask body and by a 4.0-in. polypropylene disk attached to the cask lid.

Sections 1.2.2.1, 2.3.5.2, and 12.1.2.1 of the TSAR specify a design criterion which stipulates that the maximum dose rate at the accessible surfaces (top, side) of the cask on a storage pad does not exceed 2 msv/h (200 mrem/h). The criterion is applicant-imposed, not a specific requirement of 10 CFR Part 72. It is, however, consistent with surface dose rate limits allowed under Part 71 for transportation on public highways and is considered acceptable by the staff. Personnel exposures during operational activities are discussed in Section 10.3 of the TSAR. Such activities must comply with the site radiation protection program in accordance with 10 CFR Part 20.

The Part 72 requirements for the doses to an individual at the site boundary are specified in §72.104(a) and §72.106(b). These allowed doses include direct radiation (including skyshine), atmospheric release, and other sources of radiation from fuel cycle operations. Because doses at the site boundary, as well as those at the restricted area boundaries, depend on site-specific information, each licensee must demonstrate that its site complies with these limits.

5.3.2 Source Specifications

The gamma and neutron source specifications, generated by the ORIGEN2 computer code [1] are presented in Section 5.2 of the TSAR. Calculations are performed using a Westinghouse

17x17 fuel assembly as described in Section 2.1 for a 40,000-Mwd/MTU burnup, 7-year cooling time, and an initial 3.85% enrichment.

Table 5.2-2 of the TSAR lists the gamma source terms for the fuel zone, plenum zone, and top and bottom end-fitting zones. Fission product activities are indicated in Table 5.2-3 and activation activities in Table 5.2-4. The neutron source term for the fuel zone from spontaneous fission and alpha-n reactions is also listed in Table 5.2-2.

Confirmatory analysis of the gamma source terms was performed using the DOE Characteristics Data Base [2]. The staff recognizes that activation activities depend on details of impurities and flux spectra for different fuel assemblies and that variations in the calculation of these gamma source terms is to be expected. Differences between gamma source terms presented in the TSAR and those estimated by the reviewer do not significantly affect the shielding analyses, discussed in Section 5.3.4 below.

Confirmatory analysis of the neutron source term was also performed using the DOE Characteristics Data Base [2]. The ORIGEN2 code used by the applicant is not intended for burnups that exceed 35,000 MWd/MTU and, therefore, results in an underestimate of the neutron source. The difference between the source term presented in the TSAR and that estimated by the reviewer does not significantly affect the shielding analysis. The staff also notes that fuel enriched to less than 3.85% (but otherwise having the same characteristics as the design-basis fuel) will result in a neutron source term exceeding the design-basis source term specified in Table 2.1-2. Under conservative assumptions, the neutron source term could double. However, the neutron contribution to the total dose for the cask is minimal. Based on confirmatory analysis, the increased neutron source term will not significantly affect the dose rates for the cask, remaining well below the design criterion of 2msv/h (200 mrem/h). This potential incremental increase would result in a negligible increase in the dose rate at the site boundary.

5.3.3 Model Specifications

The model specifications for shielding are presented in Section 5.3.1 of the TSAR. Shield regional densities are provided in Section 5.3.2.

The model used for calculations of dose-rates from the primary gamma source at the top, bottom, and side of the cask is depicted in Figure 5.3-1. The source region is divided into four separate zones (fuel, plenum, top fitting, and bottom fitting). Sources are assumed to be uniform both axially and radially. Shield regional densities are listed in Table 5.3-1.

The model used for calculations of dose-rates from the neutron and capture gamma sources at the side of the cask is depicted in Figure 5.3-3 of the TSAR. The central fuel region is considered to consist of uranium dioxide homogenized with the cladding and basket. The models for the ends of the cask are shown in Figure 5.3-2. The fuel region is treated in the same manner as in the side calculation. The model for the top includes the plenum and top-end fitting homogenized with basket material. The model for the bottom is similar. Shield regional densities are listed in Table 5.3-2.

For postulated accident conditions, the models are the same as those described above, except that the neutron shield and its outer shell are removed.

5.3.4 Shielding Analyses

The shielding analyses are presented in Section 5.4 of the TSAR. A summary of dose rates at the radial mid-plane and center of the top and bottom of the cask are listed in Table 5.1-2.

The three-dimensional (3-D) point-kernel code QAD-CGGP [3] is used to calculate the primary gamma dose rates. Neutron and capture gamma dose rates are calculated with the 1-D SAS1 module of SCALE-4 [4] using the 27n-18g group cross-section library. As discussed in Section 5.3.3 above, the neutron source is assumed to be uniform over the active fuel region. This assumption will result in a conservatively high calculation of the dose rate at the ends of the cask, since the actual neutron source will be relatively low near the top and bottom of the fuel. Flux-to-dose rates are calculated using ANSI/ANS 6.1.1-1977 [5].

Dose rates at the cask surface and at one meter from the surface under normal conditions are presented in Table 5.1-2 of the TSAR. As shown in the table, the maximum dose rate on the accessible cask surface is approximately 0.9 msv/h (90 mrem/h), substantially less than the design criterion of 2 msv/h (200 mrem/h). These dose rates are used in Section 10 of the TSAR to determine the occupational doses during operational procedures with the cask.

The analysis of dose rates under accident conditions considers the very conservative case of the total loss of the neutron shield and its shell. Dose rates at the cask surface and at one meter from the surface under these accident conditions are also presented in Tables 5.1-2 of the TSAR. The maximum dose rate is approximately 8.7 msv/h (870 mrem/h), which is less than the allowable dose rate under accident conditions for transportation on public highway under 10 CFR Part 71. Consideration of accident conditions is further discussed in Section 11 of the SER.

In addition to the dose rates near the cask surface, Table 5.1-3 of the TSAR lists representative doses rates from direct radiation from a single cask at postulated site boundaries, calculated with SAS1 using a 1-D spherical model. These calculations are consistent with those for other casks with similar surface dose rates. The actual dose at a site boundary, however, depends on many site-specific conditions (e.g., number of casks, distance from ISFSI to boundary, array configuration, actual fuel loading, presence of a berm, etc.) and must be evaluated by the site licensee. Furthermore, the licensee also needs such a site-specific evaluation to assess compliance with the 10 CFR Part 20 requirements for doses received by the public in unrestricted areas within the site boundary. A comparison of representative total dose (direct radiation, including skyshine, and release of radionuclides) with the regulatory limits at the site boundary is further discussed in Sections 10 and 11 of the SER.

The confirmatory evaluation of the shielding analysis consisted of the comparison between the dose rates from the TN-32 with those of the TN-40, which had been evaluated earlier and

reported earlier in a separate SER [6]. The reviewer notes that more detailed 3-D calculations of the TN-32 may yield somewhat higher dose rates at small localized areas of the cask surface due to streaming and other 3-D effects, but such areas would have negligible contribution to the dose rates at the site boundary. Furthermore, the dose rates calculated in the TSAR are significantly below the acceptable design criteria, and, as specified in Section 12.1.2.1, the actual dose rates on the surface of the cask must be confirmed by measurement to be less than 2 msv/h (200 mrem/h) prior to movement of the casks to the ISFSI.

5.3.5 Supplemental Information

Section 5.5 of the TSAR presents selected input files for the QAD and SAS1 computer analyses. Additional supplemental information presented during the review process is referenced in Section 1 of the SER.

5.4 Evaluation Findings

Shielding structures, systems, and components important to safety are described in sufficient detail to enable an evaluation of their effectiveness.

Shielding structures, systems, and components important to safety are evaluated with the objective of assessing the impact of health and safety resulting from the operation of the ISFSI. A more detailed evaluation against specific acceptance criteria is presented in Sections 10 and 11 of the SER.

The staff concludes that the design of the shielding system of the TN-32 is in compliance with 10 CFR Part 72 and that the applicable design and acceptance criteria have been satisfied. The evaluation of the shielding system design provides reasonable assurance that the TN-32 will enable safe storage of spent fuel. This finding is based on a review which considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

5.5 References

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Section 6—CRITICALITY EVALUATION

This section evaluates the criticality design of the TN-32 Dry Storage Cask for normal and accident conditions. Design features and design criteria, initially presented in Sections 1 and 2 of the TSAR, are reviewed for additional detail. The fuel specification is examined, the model specification is assessed, and the criticality analyses are confirmed.

6.1 Areas of Review

6.1.1 Criticality Design Features and Design Criteria

6.1.2 Fuel Specification

6.1.3 Model Specification

6.1.4 Criticality Analysis

6.2 Regulatory Requirements

6.2.1 Criticality structures, systems, and components important to safety must be described in sufficient detail to enable an evaluation of their effectiveness. [10 CFR 72.24(c)(3)]

6.2.2 Spent fuel transfer and storage systems must be designed to be subcritical under all credible conditions. [10 CFR 72.124(a) and 72.236(c)]

6.2.3 When practicable, the design must be based on favorable geometry, permanently fixed neutron absorbing materials (poisons), or both. Where solid neutron absorbing materials are used, the design shall provide for positive means to verify their continued efficacy. [10 CFR 72.124(b)]

6.2.4 The analysis and evaluation of the criticality design and performance must demonstrate that the cask will enable the storage of spent fuel for a minimum of 20 years with an adequate margin of safety. [10 CFR 72.24(d) and 72.236(g)]

6.3 Review Procedures

6.3.1 Criticality Design and Design Criteria Features

The applicant discusses design criteria and design features in Sections 2.3.4 and 6.1 of the TSAR. The design criterion for criticality is that the effective neutron multiplication factor, k_{eff}, including statistical uncertainties, shall be less than 0.95 for all postulated arrangements of fuel within the cask. The design incorporates solid neutron poisons in the basket in the form of borated aluminum and requires that irradiated fuel assemblies be loaded in a fuel pool containing at least 2000 ppm boron. The cask is designed to assure an adequate margin of safety for fresh fuel.

The borated aluminum is an alloyed material and is sandwiched between stainless steel boxes in the basket design. The material is held in place by stainless steel plugs that pass through the poison and are welded to the stainless steel boxes. The dry, inert environment of the cask ensures the long term integrity of the borated aluminum and the welds. The brief exposure of these materials to the spent fuel pool water will not lead to any serious degradation. In addition, depletion of the borated aluminum is negligible over the license period. Since the fast neutrons emitted will not become thermalized in the dry environment, their reaction probability with the boron poison will be low.

6.3.2 Fuel Specification

The TN-32 dry storage cask is designed to store up to 32 intact Westinghouse 15x15 or 17x17 PWR spent fuel assemblies. The initial enrichment on both types of fuel assemblies is taken to be 3.85% wt. The applicant gives a description of the fuel assemblies in Section 2.1 of the TSAR. Chapter 6 of the TSAR covers the criticality safety of the TN-32 cask and its contents, listing material densities, moderator ratios, and geometric configurations.

6.3.3 Model Specification

The Model Specification is presented in Section 6.4 of the TSAR. The applicant makes the following assumptions in constructing a three-dimensional model in which the fuel assembly, basket, and cask wall are modeled explicitly:

- Borated water fills the void spaces in the cask cavity
- The end fittings and plenum are represented by fresh water
- The B-Al plate is present only in the active fuel region
- The Al rails are not modeled explicitly but are homogenized with borated cavity water

6.3.4 Criticality Analysis

The applicant presents the criticality analysis in Section 6.4 of the TSAR, which was performed with the SCALE-4 code system [1] using 27 neutron group cross sections. The applicant demonstrates that for both the 15x15 and 17x17 PWR spent fuel assemblies, loading of the cask, with borated water and B-Al plates present, results in values of the effective neutron multiplication factor, k_{eff}, including statistical uncertainties and bias, that are less than 0.95.

Table 6.1 TSAR's 2000 ppm Borated Water Analyses

Case Description	$k_{eff} \pm \sigma$	$k_{eff} + 2\sigma$
15x15 3.85% wt ^{235}U	0.9183 ± 0.0029	0.9241
17x17 OFA 3.85% wt ^{235}U	0.9010 ± 0.0036	0.9082

The reviewer used the MCNP code [2] to confirm these results. Confirmatory calculations also indicated that both the borated water and B-Al plates are necessary to assure an adequate margin of subcriticality.

6.4 Evaluation Findings

Criticality structures, systems, and components important to safety are described in sufficient detail in Sections 1.2, 2.3.4 and 6.1 of the TSAR to enable evaluation of their effectiveness.

The TN-32 dry storage cask and its spent fuel transfer systems are designed to be subcritical under all credible conditions.

The criticality design is based on fixed neutron poisons and soluble poisons of the spent fuel pool. Fixed neutron poisons will remain effective for the 20-year storage period.

The analysis and evaluation of the criticality design and performance has demonstrated that the cask will enable the storage of spent fuel for a minimum of 20 years with an adequate margin of safety.

The staff concludes that the criticality design of the TN-32 dry storage cask is in compliance with 10 CFR Part 72 and that applicable design and acceptance criteria have been satisfied. The evaluation of the criticality design provides reasonable assurance that the TN-32 will enable the storage of spent fuel. This finding is based on a review which considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted practices.

6.5 References

1. U.S. Nuclear Regulatory Commission. "SCALE-4: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation," ORNL/NUREG/CR-0200, Rev. 4, February 1990.

2. Los Alamos National Laboratory. "MCNP 4A, Monte Carlo N-Particle Transport Code System," December 1993.

Section 7—CONFINEMENT EVALUATION

This section evaluates the design and analysis of the confinement system of the TN-32 for normal, off-normal, and accident conditions. Design features and design criteria, initially presented in Sections 1 and 2 of the TSAR, are reviewed for additional detail. The pressure monitoring capability is assessed, and radioactive nuclides present in the spent fuel are reviewed. The analysis of the potential release of radionuclides at the site boundary is confirmed, and compliance with design criteria is evaluated.

Because the 10 CFR Part 72 acceptance criteria for doses at the site boundary include both the direct dose and that from release of radionuclides to the atmosphere, an overall assessment of the compliance with these regulatory limits is included in Section 10 (Radiation Protection) of the SER.

The performance of the cask confinement system under accident conditions, as evaluated in this section, is also addressed as appropriate in the overall accident analyses presented in Section 11.

7.1 Areas of Review

7.1.1 Confinement Design Features and Design Criteria

7.1.2 Confinement Monitoring Capability

7.1.3 Radionuclides Available for Release

7.1.4 Confinement Analyses
—Normal Conditions
—Leakage of One Seal
—Accident Conditions/Natural Phenomena Events

7.1.5 Supplemental Information

7.2 Regulatory Requirements

7.2.1 Confinement structures, systems, and components important to safety must be described in sufficient detail to enable an evaluation of their effectiveness. [10 CFR 72.24(c)(3) and 72.24(l)]

7.2.2 The spent fuel cladding must be protected against degradation that leads to gross ruptures, or the fuel must be otherwise confined such that degradation of the fuel during storage will not pose operational safety problems with respect to its removal from storage. [10 CFR 72.122(h)(1)]

7.2.3 The cask must be designed to provide redundant sealing of confinement systems. [10 CFR 72.236(e)]

7.2.4 Storage confinement systems must have the capability for continuous monitoring in a manner such that the licensee will be able to determine when corrective action needs to be taken to maintain safe storage conditions. [10 CFR 72.122(h)(4) and 72.128(a)(1)]

7.2.5 Instrumentation and control systems must be provided to monitor systems that are important to safety over anticipated ranges for normal and off-normal operation. Those control systems that must remain operational under accident conditions must be identified. [10 CFR 72.122(i)]

7.2.6 The quantity of radionuclides expected to be released annually to the environment must be estimated. [10 CFR 72.24(l)(1)]

7.2.7 The cask and its systems important to safety must be evaluated, by appropriate tests or by other means acceptable to the Commission, to demonstrate that they will reasonably maintain confinement of radioactive material under normal, off-normal, and credible accident conditions. [10 CFR 72.236(l) and 72.24(d)]

7.3 Review Procedures

7.3.1 Confinement Design Features and Design Criteria

The primary confinement boundary of the TN-32 is depicted in Figure 1.2-1 of the TSAR. It includes the inner shell, the shell bottom plate and top flange, the bolted lid assembly outer plate with its inner metallic O-ring, and the bolted vent/drain port covers with their inner O-rings. The confinement vessel is 175.25 inches in length and 1.5 inches in thickness. The cask cavity itself is 68.75 inches in diameter and 163.25 inches in length. Redundant sealing of the confinement boundary is provided by the outer O-rings of the lid and vent/drain port covers.

The inner shell, lid, and bottom closure material are SA-203 Grade A, and the flange is SA-350 Grade LF3. The vent and drain port covers are SA-240, TP 304.

Penetrations in the primary confinement boundary include the opening for the lid assembly and the vent and drain ports. These penetrations are closed by the lid assembly outer plate and the vent/drain port covers, all of which are sealed by two metallic O-rings. The quick-disconnect valve nipples installed in the vent port are not considered to be part of the primary or redundant confinement boundaries.

Welds in the TN-32 are shown in the drawings in Section 1.5 of the TSAR. Confinement boundary welds include the circumferential welds attaching the bottom closure and the top flange to the inner shell and the longitudinal weld(s) on the rolled plate. All confinement boundary welds are full penetration welds examined volumetrically by radiograph. These

welds are also examined either by liquid penetrant or magnetic particle. Acceptance standards are in accordance with Section III, Article NB-5000 of the ASME Code [1]. Electrodes, wire, and fluxes used for fabrication comply with the applicable requirements of Section II, Part C. Welding procedures, welders, and weld operators are qualified in accordance with Section III, Article NB-4300.

Double metallic Helicoflex O-ring seals are utilized on the lid and vent/drain port covers.

The cask is primarily intended for wet loading in the spent fuel pool. After the cask is drained and dried, it is backfilled with helium cover gas at 2.2 atm (at thermal equilibrium) to provide an inerting environment to protect the fuel against degradation during storage.

The functionality of the confinement boundaries are continuously monitored with a pressure monitoring system (PMS), as shown in Figure 2.3-1 in the TSAR. The system consists of an overpressure tank bolted to the cask lid. A quick connect coupling with a diaphragm valve is used to fill the tank. Tubing connects the overpressure tank to the interspace between the inner and outer seals of the lid. Electrical wiring extends from two pressure transducers/switches on the tank to an alarm panel. All connections to the overpressure tank are welded fittings. The PMS is enclosed in a protective cover for weather. Only the electrical wires penetrate the cover.

Section 2.3.2.1 of the TSAR specifies a design criterion leak rate of less than 10^{-5} std cc/s of helium. The inner and outer seals of the lid and vent/drain port covers may be tested either together or independently, but the total leakage of all seals added together, including that of the PMS, is limited to less than 10^{-5} std cc/s of helium [2]. Operating procedures discussed in Section 8.3 of the TSAR require leak tests to meet this criterion, which is also listed as an operating control and limit in Section 12.1.2.4.

Section 7.3 of the TSAR establishes that under accident conditions the requirements of 10 CFR 72.106(b) will be satisfied even if all of the fission product gases in the cask cavity are released (under the assumptions that 100% of the fuel cladding has failed and a simultaneous complete failure of the confinement occurs). Although this is not a credible event, it provides a very conservative upper bound for assessing site suitability.

The dose from radioactive release is discussed in Section 7.3 of the SER; the overall assessment of the total dose (including direct radiation) is further discussed in Sections 10 and 11 of the SER.

7.3.2 Confinement Pressure Monitoring System (PMS) Capability

As discussed in Sections 2.3.2.1 and 7.2 of the TSAR, the region between the inner and outer seals of the cask lid is pressurized with helium to an initial pressure of 5.5 atm by use of a helium tank attached above the lid and under the protective cover. The regions between the inner and outer seals of the vent/drain ports are connected to the region between the lid seals by paths drilled into the cask lid. In the event of an unanticipated failure of any of the primary (inner) confinement seals, helium will leak into the cask cavity (<2.2 atm) or into

the vent port (1 atm), and a pressure transducer/switch will signal an alarm when the inter-lid pressure decreases to 3 atm. Likewise, an alarm will also be signaled if the helium leaks to the atmosphere due to an unanticipated failure of the any of the redundant (outer) confinement seals. Because of the higher pressure in the inter-seal regions, in no case will radioactive gas escape to the atmosphere. A failure of the PMS to alarm will in itself not result in any radioactive release. The PMS is designed to alarm if the electrical system malfunctions.

7.3.3 Radionuclides Available for Release

Table 5.2-8 of the TSAR presents fission products that could be released from the design basis fuel, calculated with ORIGEN2 [3] in a manner similar to that for the gamma and neutron source terms in Section 5. The reviewer concurs that the majority of the release potential is from the gaseous/volatile ^{3}H, ^{85}Kr, and ^{129}I. Activities of these nuclides are in agreement with calculations by the reviewer using the DOE Characteristics Data Base [4].

7.3.4 Confinement Analyses

As discussed above, under normal conditions the TN-32 provides a primary and redundant sealing confinement boundary, with seals having a total leakage rate less than 10^{-5} std cc/s helium. The increased helium pressure in the inter-seal regions will prevent release of radioactive material from the cask cavity through these seals to the atmosphere.

To provide a conservative upper bound (and assess the importance of the pressure monitoring system), supplemental information presented during the review process also analyzes the very conservative case in which one set of seals totally fails, and no alarm is signaled by the pressure monitoring system. This analysis assumes 10% fuel failure, 30% release of the ^{85}Kr and 10% for ^{129}I and ^{3}H from the fuel matrix, a χ/Q of 8.65×10^{-3} s/m^3 from Regulatory Guide 1.145 [5], the methodology of Regulatory Guide 1.109 [6], and dose conversion factors from EPA Report No. 11 [7] and No. 12 [8]. An individual is also conservatively assumed to remain outdoors at the site boundary (100 m from the cask) for an entire year. The results of these calculations indicate such an individual would receive a negligible whole body dose of approximately 6×10^{-5} msv (6×10^{-3} mrem). The reviewer notes that typically the release fraction of ^{3}H assumed is 30%. In addition, actual cask pressures and temperatures, rather than standard conditions, should be used in the analysis. Nevertheless, calculations by the reviewer indicate that the dose at the site boundary is negligible compared with the regulatory limits in 10 CFR 72.104(a) of 2.5×10^{-1} msv (25 mrem) and 7.5×10^{-1} msv (75 mrem), respectively, even for these very conservative assumptions.

Section 7.3 of the TSAR calculates the dose at the site boundary for the non-credible case of a release of radionuclides to the atmosphere resulting from a failure of the cask confinement and 100% rupture of the fuel rods. Other assumptions are the same as those discussed above for normal conditions. Under this assumed, but non-credible, accident sequence, an individual would receive a whole body dose of approximately 3.6 msv (360 mrem) and a thyroid dose of about 6.9 msv (690 mrem). For additional conservatism, the reviewer

assumes 30% release of ^3H (as in the off-normal case) and further neglects plume meandering from Regulatory Guide 1.145. With these added conservatisms, the result is 2500 mrem, still below the regulatory limit in 10 CFR 72.106(b) of 50 msv (5000 mrem). Accident analyses are further discussed in Section 11 of the TSAR and in Sections 10 and 11 of the SER.

7.3.5 Supplemental Information

Supplemental information presented during the review process is referenced in Section 1 of the SER.

7.4 Evaluation Findings

Confinement structures, systems, and components important to safety are described in sufficient detail to enable an evaluation of their effectiveness in Sections 2.3.2.1 and 7.1 of the TSAR, as discussed in Section 7.3.1 of the SER.

The spent fuel cladding is protected against degradation that leads to gross ruptures by placing it in a basket structure and maintaining helium as an inert cover gas. Temperature considerations are discussed in Section 4 of the SER.

Redundant sealing of the confinement system is provided by an outer set of O-rings for the cask lid and the vent/drain port covers.

The confinement system is monitored with a pressure monitoring system as discussed in Section 7.3.2 above and is acceptable for determining when corrective actions need to be taken to maintain safe storage conditions. Testing is discussed in Sections 8 and 9 of the SER.

A pressure switch on the PMS provides monitoring capability of confinement over anticipated ranges for normal and off-normal operations. Although there is no requirement for this instrumentation to remain operational under accident conditions, its anticipated functioning will enable an assessment that confinement is maintained.

The quantity of radioactive nuclides expected to be released to the environment has been assessed and is discussed in Sections 7.3.3 and 7.3.4 of the SER.

The cask confinement system has been evaluated to demonstrate that it will reasonably maintain confinement of radioactive material under normal, off-normal, and accident conditions.

The staff concludes that the design of the confinement system of the TN-32 is in compliance with 10 CFR Part 72 and that the applicable design and acceptance criteria have been satisfied. The evaluation of the confinement system design provides reasonable assurance that the TN-32 will enable safe storage of spent fuel. This finding is based on a review

which considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted practices.

7.5 References

1. ASME Boiler and Pressure Vessel Code (ASME B&PV Code), Section III, Article NB-5000, 1992.

2. Mason, Michael to Frederick Sturz. "Responses to Questions Dated September 19, 1995," E-14266, October 20, 1995.

3. Croft, A.G. et al. "Revised Uranium-Plutonium Cycle PWR and BWR Models for the ORIGEN Computer Code," ORNL/TM-6051, Oak Ridge National Laboratory, Oak Ridge, Tennessee, September 1978.

4. TRW Environmental Safety Systems, Inc. "User Manual for the CDB-R, CSCI ID A00020002-AAX01.0, DOE Characteristics DATA Base," November 16, 1990.

5. U.S. Nuclear Regulatory Commission. "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants," Regulatory Guide 1.145.

6. U.S. Nuclear Regulatory Commission. "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I," Regulatory Guide 1.109.

7. U.S. Environmental Protection Agency. "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," Federal Guidance Report No. 11. 1988.

8. U.S. Environmental Protection Agency. "External Exposure to Radionuclides in Air, Water, and Soil," Federal Guidance Report No. 12. 1993.

Section 8—OPERATING PROCEDURES

This section evaluates the sequence of operations for developing operating procedures for loading the TN-32 (including leak testing after closure), transferring the cask from the fuel handling building to the ISFSI, and, if necessary, unloading the cask.

8.1 Areas of Review

8.1.1 Loading the Cask

8.1.2 Transferring the Cask to the ISFSI

8.1.3 Unloading the Cask

8.1.4 Personnel Operations

8.2 Regulatory Requirements

8.2.1 The cask must be compatible with wet or dry spent fuel loading and unloading procedures. [10 CFR 72.236(h)]

8.2.2 The cask must be designed to facilitate decontamination to the extent practicable. [10 CFR 72.236(i)]

8.2.3 Operational restrictions must be established to meet Part 20 limits, and as low as is reasonably achievable (ALARA) objectives for radioactive materials in effluents and direct radiation levels associated with ISFSI operations. [10 CFR 72.104(b) and 72.24(e)]

8.3 Review Procedures

A sequence of operations is outlined in Sections 8.1 and 8.2 of the TSAR and in Table 8.1-1 of the TSAR. Based on this information, detailed site-specific operating procedures will be developed by each licensee and cask user for loading, testing, storing, unloading, and maintaining the TN-32 cask.

8.3.1 <u>Loading the Cask</u>

The loading operations for the TN-32 are described in Section 8.1.1 and Table 8.1-1 of the TSAR. The use of the cask for storage is based on the receipt of an uncontaminated cask from the fabricator, and hence, no decontamination procedures are necessary prior to spent fuel operations. The external surfaces of the cask are painted, providing for ease of decontamination after loading the cask in the spent fuel pool.

Prior to being placed in storage, leak testing of the primary and redundant confinement boundaries will be performed. As described in Section 7 of the SER, the total leakage from all confinement seals (i.e., the O-rings of the lid and vent and drain port covers and the PMS) must be less than 1.0 $\times 10^{-5}$ std cc/sec of helium. Detailed leak testing procedures will be developed by the cask user.

8.3.2 Transferring the Cask to the ISFSI

The cask will be transferred to the ISFSI in a vertical position. The cask will be transported to the ISFSI site by a transport vehicle that limits the height of the cask above the ground to 18 inches to bound the cask end-drop analysis. Operations for movement of the cask to the ISFSI are presented in Section 8.1.1 of the TSAR. The pressure monitoring system will be activated at the ISFSI.

8.3.3 Unloading the Cask

Operations for unloading the cask are described in Section 8.2 of the TSAR. These processes assume wet unloading and no further use of the cask for storage. The cask will be removed from the ISFSI back into the spent fuel pool building using the transport vehicle. The weather cover will be unbolted and removed. The PMS will then be removed and the cavity gas sampled through the vent port.

After moving the cask into the fuel pool area, the cavity will be depressurized through the vent coupling and the cask lowered into the spent fuel pool. With the cask lid at the pool surface, fill and drain lines will be connected to the lid drain and vent ports. Borated water will be slowly added to fill the cask and to gradually cool the fuel in the cask. When the cask is full, the fill and drain lines will be removed. The cask will then be lowered to the pool bottom where the lid would be removed making the fuel accessible for transfer.

Detailed unloading procedures will be developed by the cask user.

8.3.4 Personnel Operations

Table 8.1-2 in the TSAR provides detailed numbers for the personnel and estimated time required for the various operations. These values are used to determine the occupational radiation exposures in Section 10 of the TSAR. The data is based on the vendor's experience with transport cask operations.

8.4 Evaluation Findings

The TN-32 is compatible with wet loading and unloading. General steps for these operations are summarized in Sections 8.1 and 8.2 of the TSAR. Detailed procedures will need to be developed on a site-specific basis.

No significant radioactive effluents are produced. Any radioactive solutions generated from routine decontamination of the cask inside the fuel building after the cask is removed from

the spent fuel pool will be governed under the 10 CFR Part 50 license conditions. The smooth surface of the cask is designed to facilitate decontamination.

Operational restrictions to meet Part 20 limits are further evaluated in Section 10 of the TSAR. Additional site-specific restrictions may also be established by the user. The limited time spent on cask loading and transfer operations, the heavy cask shielding, the passive nature of the design, and the limited repair and maintenance anticipated will provide for ALARA direct radiation levels associated with ISFSI operations.

The staff concludes that the sequence of operations for the TN-32 described in the TSAR provide enough information for the development of detailed operating procedures by the cask user to ensure compliance with 10 CFR Part 72. The evaluation of the sequence of operations provides reasonable assurance that the TN-32 will enable safe storage of spent fuel. This finding is based on a review which considered the regulations, appropriate regulatory guides, applicable codes and standards, and accepted practices.

Section 9—ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

This section evaluates the acceptance tests and maintenance program required for the TN-32.

9.1 Areas of Review

9.1.1 Fabrication Requirements and Acceptance Tests
- —Visual Inspections
- —Structural/Pressure Tests
- —Leak Tests
- —Component Testing
- —Shielding Tests
- —Thermal Acceptance

9.1.2 Maintenance Program

9.2 Regulatory Requirements

9.2.1 The program covering preoperational testing and initial operations must be described. [10 CFR 72.24(p)]

9.2.2 The cask must permit testing and maintenance as required. [10 CFR 72.236(g)]

9.2.3 Structures, systems, and components important to safety must be designed, fabricated, erected, tested, and maintained to quality standards commensurate with the importance to safety of the function to be performed. [10 CFR 72.122(a), 72.122(f), 72.128(a)(1), and 72.24(c)]

9.2.4 The cask must be inspected to ascertain that there are no cracks, pinholes, uncontrolled voids, or other defects that could significantly reduce its confinement effectiveness. [10 CFR 72.236(j)]

9.2.5 Structures, systems, or components important to safety whose functional adequacy or reliability have not been demonstrated by prior use for that purpose, or which cannot be demonstrated by reference to performance data in related applications or by reference to widely accepted engineering principles, must be identified and a schedule included showing how safety questions will be resolved prior to the initial receipt of spent fuel. [10 CFR 72.24(i)]

9.2.6 The cask must be conspicuously and durably marked with a model number, unique identification number, and an empty weight. [10 CFR 72.236(k)]

9.3 Review Procedures

The acceptance tests and maintenance program are summarized in Sections 9.1 and 9.2 of the TSAR, respectively. Specific procedures for inspection, special processes, and testing will be developed as required by quality assurance programs.

9.3.1 Acceptance Criteria

The Acceptance Criteria for the TN-32 have been subdivided into six major subsections: Visual Inspections, Structural/Pressure Tests, Leak Tests, Component Testing, Shielding Tests, and Thermal Acceptance.

9.3.1.1 Visual Inspections

Visual inspections will be performed at the fabricator's facilities to ensure that the casks conform to the drawings and specifications. These visual inspections will include verifying that all specified coatings have been applied and that the casks are clean and free of defects. Upon arrival at the loading facility, the casks will be reinspected to ensure that they have not been damaged during shipment.

9.3.1.2 Structural/Pressure Tests

To ensure that the casks will perform their intended design functions, all structural materials will be chemically and physically tested to ensure that the required properties have been met. All welding will be performed using qualified processes and qualified personnel according to the ASME Boiler and Pressure Vessel Code [1]. Base materials and welds will be examined in accordance with the Code.

Pressure testing (hydrostatic testing) will be performed on each cask assembly at a test pressure of 44 psi, which is 1.25 times the normal operating pressure of 35 psi [2]. These tests will be performed in accordance with Section III, Subsection NB, Paragraph NB-6200 or NB-6300 of the Code. Accessible joints will be visually examined for possible leakage after the completion of each test.

9.3.1.3 Leak Tests

Leak tests will be performed on the lid seals for the confinement system and the overpressure system for each cask assembly at the fabricator's facilities. Leak tests will be performed using standard helium mass spectrometer methods, and the maximum allowable total leak for the TN-32 confinement boundary will be 1×10^{-5} std cc/sec of helium. All leak testing will be performed in accordance with the provisions set forth in ANSI N14.5 [3], the sensitivity for all leak testing will be 5×10^{-6} std cc/sec helium or better, and all personnel performing the leak tests will be qualified in accordance with SNT-TC-1A [4].

9.3.1.4 Component Testing

Component testing for the TN-32 consists of testing of the double metallic O-ring seals on the cask lid and all confinement penetrations. The inside metallic O-Ring forms part of the confinement boundary. Upon completion of cask loading, the seals will be leak tested as described in Section 9.3.1.3 above, and/or as described in Section 12.1.2.5 of the TSAR.

There are no valves that perform a safety-related function on the TN-32. The TN-32 design incorporates quick-disconnect couplings for ease of draining and venting. These quick-disconnect couplings do not perform a safety-related function nor are they part of the confinement boundary.

9.3.1.5 Shielding Tests

The acceptance criteria for shielding integrity includes qualification testing of the personnel and procedures used for the mixing and pouring of the polyester resin used for neutron shielding. Qualification testing further includes verification that the required chemical composition and densities are achieved and that the processes are performed in a manner that will prevent the inclusion of voids.

Additional surveillances will be performed after loading to ensure that the radiation dose limits will not be exceeded for each cask.

9.3.1.6 Thermal Acceptance

The analyses performed to ensure that the casks are capable of performing their heat transfer functions are presented in Chapter 4 of the TSAR. The analyses were performed using conservative assumptions for the design basis fuel. Staff accepts this analysis and no thermal tests are required.

9.3.2 Maintenance Program

The TN-32 does not require routine or periodic maintenance during normal storage operations at an ISFSI. The valves and seals selected for use will not require inspection or replacement during normal fuel storage operations.

The pressure transducers/switches used to monitor the confinement seals will be inspected according to site-specific procedures. Two identical pressure transducers/switches are used to assure a functional system through redundancy. The switches are not replaced unless they are malfunctioning.

All the gaskets are designed to maintain their sealing capability until the cask is reopened. If a leak is detected by a drop in pressure in the PMS, the cask would be returned to the spent fuel pool and all gaskets would be replaced.

Maintenance actions following off-normal, accident, or natural phenomena events are discussed in Section 11 of the SER.

9.4 Evaluation Findings

The program covering preoperational testing and initial operations of the TN-32 is described in Section 9.1 of the TSAR. The maintenance program is discussed in Section 9.2.

Structures, systems, and components important to safety will be designed, fabricated, erected, tested, and maintained to quality standards commensurate with the importance to safety of the function to be performed. The safety importance of structures, systems, and components is identified in Section 2.0 of the TSAR. Standards for design, fabrication, and testing are presented in Sections 2 and 9 of the TSAR.

The TN-32 is inspected and tested to ensure that there are no defects that could significantly reduce its confinement effectiveness. This inspection and testing is described in Section 9.1 of the TSAR.

Section 1.2.1 of the TSAR specifies that each cask shall be identified by a Mark Number, TN-32-XX, where XX is a sequential number corresponding to a specific cask.

The staff concludes that the acceptance tests and maintenance program for the TN-32 are in compliance with 10 CFR Part 72 and that the applicable acceptance criteria have been satisfied. The evaluation of the acceptance tests and maintenance program provides reasonable assurance that the TN-32 will enable safe storage of spent fuel. This finding is based on a review which considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted practices.

9.5 References

1. ASME Boiler and Pressure Vessel Code (ASME B&PV Code), Section III, 1992.

2. Mason, Michael to Frederick Sturz. "Docket No. M-56, Additional Information for NRC Questions dated September 19, 1995," December 1, 1995.

3. ANSI N14.5. "American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials," New York, 1987.

4. SNT-TC-1A. "American Society for Nondestructive Testing, Personnel Qualification and Certification in Nondestructive Testing," 1984.

Section 10—RADIATION PROTECTION

This section evaluates the radiation protection aspects of the TN-32 cask. The assessment of radiation protection examines those design features and operating procedures that affect radiation doses to both the occupational worker and the public.

Occupational exposures are based on the direct radiation doses presented in Section 5 of the TSAR and operating procedures discussed in Section 8. Doses to the public are determined from the direct doses in Section 5 and doses from release of radionuclides to the atmosphere in Section 7.

10.1 Areas of Review

10.1.1 Radiation Protection Design Features and Design Criteria

10.1.2 ALARA

10.1.3 Occupational Exposures

10.1.4 Public Exposures
—Normal Conditions
—Accidents/Natural Phenomena Events

10.1.5 Supplemental Information

10.2 Regulatory Requirements

10.2.1 Radiation shielding and confinement features must be sufficient to meet the requirements of 10 CFR 72.104 and 72.106. [10 CFR 72.236(d), 72.128(a)(2), 72.128(a)(3), and 72.126(a)]

10.2.2 The means for controlling and limiting occupational radiation exposures within the limits given in 10 CFR Part 20 and for meeting the objective of maintaining exposures as low as is reasonably achievable (ALARA) must be described in sufficient detail to enable an evaluation of their effectiveness. [10 CFR 72.24(e), 72.104(b), and 72.126(a)]

10.2.3 During normal operations and anticipated occurrences, the annual dose equivalent to any real individual located beyond the controlled area must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as a result of exposure to: (1) planned discharges of radioactive materials, radon and its decay products excepted, to the general environment; (2) direct radiation from ISFSI operations; and (3) any other radiation from uranium fuel cycle operations within the region. [10 CFR 72.104(a), 72.236(d), and 72.24(d)]

10.2.4 Any individual located on or beyond the nearest boundary of the controlled area shall not receive a dose greater than 5 rem to the whole body or any organ from any design basis accident. The minimum distance from the spent fuel or high-level radioactive waste handling and storage facilities to the nearest boundary of the controlled area shall be at least 100 meters. [10 CFR 72.106(b), 72.236(d), 72.24(m), and 72.24(d)]

10.3 Review Procedures

10.3.1 Radiation Protection Design Features and Design Criteria

The TN-32 includes a number of design features that provide radiation protection to both the occupational worker and the public. As discussed in Section 10.1 of the TSAR, the steel body of the cask and its neutron shielding result in low dose-rate levels from direct radiation, both in the vicinity of the cask and at the site boundary. The redundant sealing and the pressure monitoring system ensure negligible leakage of potentially radioactive gas from the cask cavity to the atmosphere during storage operations. The cask will not be opened at the ISFSI. Quick-disconnect valves minimize exposure during loading procedures. The passive, essentially maintenance-free design reduces occupational radiation exposure during storage conditions. Finally, the rugged steel body of the cask maintains confinement of the fuel and cavity gases even under accident conditions.

As defined in Sections 2.3.5, 5.1, 7.2, and 7.3 of the TSAR, top-level design criteria for radiation protection includes the maximum allowed dose at the site boundary during normal and accident conditions, as specified in 10 CFR Part 72.104(a) and 72.106(b), respectively. Criteria for occupation workers are established by 10 CFR Part 20 limits. The ISFSI licensee will implement a radiological protection program in accordance with 10 CFR 72.126. In addition, the applicant has imposed both a limit and design goal for the direct radiation dose on the cask surface, as discussed in Section 5 of this SER.

10.3.2 ALARA

The TN-32 has been designed to meet ALARA considerations. Section 10.1.2 of the TSAR addresses these issues in terms of Regulatory Position 2 (Facility and Equipment Design Features) of Regulatory Guide 8.8 [1]. Operational matters, as described in Regulatory Guide 8.10 [2], are primarily the responsibility of the ISFSI operator, although the TN-32 has been designed to consider operational requirements, as discussed above.

10.3.3 Occupational Exposures

Section 8 of the TSAR identifies personnel operations required during receipt of the TN-32 at the ISFSI site, fuel loading operations, preparation and transfer of the cask to the ISFSI, storage, and maintenance. The time required for each of these tasks, the number of personnel needed, and the dose rates to which these personnel would be exposed in performing these tasks are estimated in Tables 10.3-1 and 10.3-2 of the TSAR. These calculations indicate that the total occupational dose in loading, transfer, and emplacement of a TN-32 is approximately 3.06 man-rem. Actual occupational doses will depend on site-specific parameters, including special measures taken to maintain ALARA. Limits for occupational doses, including those for personnel not directly involved in ISFSI operations, must comply with the requirements of 10 CFR Part 20 and other site-specific requirements imposed under the site's 10 CFR Part 50 license.

10.3.4 Public Exposures

10.3.4.1 Normal Conditions

The dose rates from atmospheric release, as discussed in Section 7.3.4 of the SER, are negligible (even if it is assumed that only one of the confinement boundaries is functional). Consequently, the total annual dose from a TN-32 at a site boundary is the same as that from direct radiation alone, including skyshine. Table 5.1-3 of the TSAR estimates the dose rates at the site boundary from a single cask as a function of the distance of the cask from the site boundary. As shown in this table, the annual dose at distances exceeding approximately 200 meters satisfies the requirements of 10 CFR 72.104(a), even if it is conservatively assumed that an individual remains outdoors at the site boundary for the full year. The reviewer notes that these estimates should be considered only as guidance and that actual rates will depend on site-specific information. This includes, for example, number of casks, activity of the actual spent fuel, array configuration, distance from the ISFSI to the site boundary, and any special measures (e.g., berm), as appropriate. In addition, the dose limits of 10 CFR 72.104(a) include doses from any other fuel cycle activities, including reactor operation. Consequently, final determination that the 10 CFR 72.104(a) limits are satisfied is the responsibility of the site licensee.

Site-specific analysis is also required to assess the dose rates for non-occupational personnel in unrestricted areas within the controlled boundary of the site to comply with the requirements of 10 CFR 20.1301.

10.3.4.2 Accidents/Natural Phenomena Events

As discussed in Section 5.3.4 of the SER, Table 5.1-2 of the TSAR presents the maximum dose rates from direct radiation on the cask surface and at one meter from the cask under a worse-case assumed accident (total loss of neutron shielding). The dose at the site boundary would be insignificant. As discussed in Section 7.3 of the TSAR and Section 7.3.4 of the SER, the whole body dose even from a non-credible atmospheric release with failure of

100% of the fuel is less than 0.05 Sv (5 rem). Consequently, the total dose to an individual at the site boundary under accident conditions would be significantly less than the limits of 10 CFR 72.106(b).

10.4 Evaluation Findings

Shielding and confinement design features are discussed in Sections 5 and 7 of the TSAR, respectively. Their suitability is based on compliance with exposure limits of 10 CFR 72.104 and 72.106.

The means for controlling and limiting occupational radiation exposures within the limits of 10 CFR Part 20 and for meeting the objective of maintaining exposures as low as is reasonably achievable are described in sufficient detail to enable an evaluation of their effectiveness. Operational restrictions to meet ALARA objectives are the responsibility of the site licensee. The TN-32 is designed to assist in meeting those objectives.

Radiation shielding and confinement features are sufficient to meet the requirements in 10 CFR 72.104(a) and 72.106(b). Site-specific details must be evaluated by the site licensee. These limits are defined in Section 10.2.3 and 10.2.4 above.

The staff concludes that the radiological protection design criteria for the TN-32 are in compliance with 10 CFR Part 72 and that the radiological protection design and acceptance criteria have been satisfied. The radiation protection evaluation of the TN-32 demonstrates that the TN-32 will provide for safe storage of spent fuel. This finding is based on a review which considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted practices.

10.5 References

1. U.S. Nuclear Regulatory Commission. "Information Relevant to Ensuring that Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Is Reasonably Achievable." Regulatory Guide 8.8.

2. U.S. Nuclear Regulatory Commission. "Operating Philosophy for Maintaining Occupational Radiation Exposures at Nuclear Power Stations As Low As Is Reasonably Achievable." Regulatory Guide 8.10.

Section 11—ACCIDENT ANALYSES

This section evaluates the design of the TN-32 Dry Storage Cask for off-normal conditions, accidents, and natural phenomena events. Because these events have generally been addressed by individual functional area in earlier sections of the SER, this section presents a summary of their consequences and courses of action that could be initiated in response to these events.

A primary difference between off-normal conditions, accidents, and natural phenomena events is the appropriate regulatory and design limits that must be satisfied in each case. In particular, the radiation dose from an off-normal event must not exceed the limits specified in 10 CFR 72.104(a), while an accident or natural phenomena event must not exceed the specifications of 72.106(b). Because of the common regulatory and design limits for both accidents and natural phenomena events, these scenarios are sometimes referred to in the following sections as "accident conditions."

11.1 Areas of Review

11.1.1 Off-normal Conditions
—Loss of electric power
—Loss of seal and failure of pressure monitoring system alarm

11.1.2 Accident Events
—Bottom-end Drop
—Tip-over
—Fire
—Explosion
—Non-mechanistic leakage
—Inadvertent loading of a newly discharged fuel assembly

11.1.3 Natural Phenomena Events
—Tornado Winds and Missiles
—Earthquake
—Flood

11.2 Regulatory Requirements

11.2.1 The adequacy of structures, systems, and components provided for the prevention of accidents and the mitigation of the consequences of off-normal conditions, accidents, and natural phenomena events must be demonstrated. [10 CFR 72.24(d), 72.122(b), and 72.122(c)]

11.2.2 The cask and its systems important to safety must be evaluated, by appropriate tests or by other means acceptable to the Commission, to demonstrate that they will reasonably maintain confinement of radioactive material under credible accident conditions. [10 CFR 72.236(l)]

11.2.3 During normal operations and anticipated occurrences, the annual dose equivalent to any real individual who is located beyond the controlled area must not exceed 25 mrem to the whole body, 75 mrem to the thyroid, and 25 mrem to any other organ as a result of exposure to: (1) planned discharges of radioactive materials, radon and its decay products excepted, to the general environment; (2) direct radiation from ISFSI or MRS operations; and (3) any other radiation from uranium fuel cycle operations within the region. [10 CFR 72.104(a), 72.236(d), and 72.24(d)]

11.2.4 Any individual located on or beyond the nearest boundary of the controlled area must not receive a dose greater than 5 rem to the whole body or any organ from any design basis accident. [10 CFR 72.106(b), 72.236(d), 72.24(m), and 72.24(d)]

11.2.5 Storage systems must allow ready retrieval of spent fuel for further processing or disposal. [10 CFR 72.122(l)]

11.2.6 The spent fuel must be maintained in a subcritical condition under credible conditions. [10 CFR 72.236(c), and 72.124(a)]

11.2.7 Structures, systems, and components important to safety must be designed for emergencies. The design must provide for accessibility to the equipment of onsite and available offsite emergency facilities and services. [10 CFR 72.122(g)]

11.2.8 Instruments and control systems that must remain operational under accident conditions must be identified in the Safety Analysis Report. [10 CFR 72.122(i)]

11.3 Review Procedures

11.3.1 Off-normal Conditions

Section 11.1 of the TSAR analyzes a single off-normal condition considered to be applicable and credible to ISFSI operations. The event is the loss of external electric power supply for a limited duration and its consequences are summarized in this section of the SER.

11.3.1.1 Loss of electric power

A loss of power at the ISFSI would render the area lighting and the cask pressure monitoring instrumentation nonfunctional. This would be detected during periodic surveillance by noting that area lighting is not operational. The loss-of-power event has no safety or radiological consequences. Following a loss of electric power to the ISFSI, maintenance personnel would

be informed and would isolate the fault and restore service. No integrity of the storage casks nor the safe storage of the fuel would be affected.

11.3.1.2 Loss of Seal and Failure of Pressure Monitoring System Alarm

As discussed in Section 7.3.4 of the SER, supplemental information presented by TN during the review process also analyzes the very conservative case in which one set of seals totally fails and no alarm is signaled by the pressure monitoring system. Even for this case, the dose at the site boundary is negligible compared with the regulatory limits of 10 CFR 72.104(a).

11.3.2 Accident Events

Section 11.2 of the TSAR addresses several credible accidents involving the TN-32 cask during storage or movement to an ISFSI. In each case, the accident would be obvious from routine surveillance of ISFSI operations.

11.3.2.1 Bottom-end Drop

Because the cask is both transported to the ISFSI and stored in a vertical position, a bottom-end drop is a credible, although remote, accident event analyzed in Section 11.2.8 of the TSAR.

Section 3.3.3.2 of the SER discusses the structural effects of a bottom-end drop with a 50-g maximum deceleration of the cask and the basket structure. Section 3.3.3.2 concludes that a 50-g bottom-end drop does not compromise the confinement system of the cask. That section also concludes that the fuel basket does not buckle and that the fuel can be retrieved from the TN-32 following such a drop.

In the event of an end drop, site personnel would assess the damage that may have occurred to the TN-32. If significant damage is noted or suspected (including increased radiation levels), the cask would be returned to the fuel building and unloaded. Minor damage might be repaired at the ISFSI site or in the fuel building, without unloading the cask.

11.3.2.2 Tip-over

Because the cask is transported to the ISFSI in a heavy haul vehicle that supports the cask at only a small distance above the ground, a tip-over accident is very unlikely. Nevertheless, Section 11.2.8 of the TSAR analyzes a tip-over accident resulting from severe natural phenomena and man-induced, low-probability events.

Section 3.3.3.1 of the SER discusses the structural effects of a tip-over accident with a 88-g maximum deceleration of the cask and the basket structure. Section 3.3.3.1 concludes that a 88-g tip-over does not compromise the confinement system of the cask. That section also concludes that the fuel basket does not buckle and that the fuel can be retrieved from the TN-32 following such a drop. These analyses account for a varied soil modulus of elasticity and are based on a tipover on a reinforced concrete pad thickness of 3 feet and concrete strength of 4,000 psi.

A tip-over accident would likely result in localized damage to the neutron shield. Table 5.1-2 shows the calculated dose rate assuming the neutron shield and outer shell are removed. The staff agrees with the TSAR conclusion that the increased dose rate at the site boundary is below the requirements of 10 CFR 72.106(b), even if total loss of the neutron shielding is assumed.

In the event of a tip-over, site personnel would initiate specific procedures to upright the cask and assess the damage. If significant damage is noted or suspected (including increased radiation levels), the cask would be returned to the fuel building and unloaded.

11.3.2.3 Fire

Because an ISFSI does not contain a substantial quantity of flammable material, a major fire is not considered to be a credible event. Nevertheless, Section 11.2.5 of the TSAR analyzes the hypothetical fire based on a fuel fire, the source of fuel being that from a ruptured fuel tank of the cask transporter tow vehicle. The bounding capacity of the fuel tank is 200 gallons, and the bounding hypothetical fire is an engulfing fire around the cask.

The staff agrees with the TSAR conclusion that the TN-32 packaging can withstand the hypothetical fire accident event without compromising its containment integrity. Peak seal temperature remains below 570°F and the cavity pressure below 100 psig. Shielding analyses have been performed showing acceptable consequences even if all the resin disappears.

In the event of a fire, site personnel would assess the damage. If significant damage is noted or suspected (including increased radiation levels), the cask would be returned to the fuel building and unloaded.

11.3.2.4 Explosion

As discussed in Section 11.2.4 of the TSAR, the effect of an industrial-type explosion in the general vicinity of the cask is expected to generate pressure on the order of a few psi. Since the cask is designed to withstand 25 psi external pressure, any credible explosion in the general vicinity of the cask is negligible.

11.3.2.5 Non-mechanistic leakage

Section 11.2.9 of the TSAR considers a cask leakage accident in which simultaneous failure of all cask seals occurs, all fuel rods rupture, and all free fission product/gases are released to the atmosphere. Even though no such accident is credible, it serves as a bounding case to evaluate release of radionuclides. As discussed in Section 7.3 of the SER, the dose that would be received by an individual at the site boundary is below the regulatory limits of 5 rem as defined in 10 CFR 72.106(b).

11.3.2.6 Inadvertent loading of a newly discharged fuel assembly

Section 11.2.6 of the TSAR considers the possibility of a spent fuel assembly, with a heat generation rate greater than 0.85 kW, being erroneously selected for storage. To preclude this accident from going undetected, and to ensure that appropriate corrective actions can be taken prior to the sealing of the casks, a final verification of the assemblies loaded into the casks and a comparison with fuel management records will assure that the correct assemblies are loaded. Radiation dose measurements will also provide final verification of the assemblies loaded.

11.3.3 Natural Phenomena Events

Section 11.2 of the TSAR addresses several natural phenomena events that could result during ISFSI operations. As with the accidents discussed above, the occurrence of these natural phenomena events would be obvious.

11.3.3.1 Tornado Winds and Missiles

Section 11.2.2 of the TSAR examines the effects of tornado winds and missiles on the TN-32. As discussed in Sections 3.3.4.2 and 3.3.4.3 of the SER, the effect of tornado winds is negligible, and tornado missiles could result in only minor damage to the outside structure of the cask. The staff concurs with the conclusion of this analysis.

In the event that a tornado missile strikes a TN-32, site personnel would assess the damage, which in most cases is expected to be minor. In the very unlikely situation in which significant damage is noted or suspected (including increased radiation levels), the cask would be returned to the fuel building and unloaded.

11.3.3.2 Earthquake

Section 11.2.1 of the TSAR and Section 3.3.4.4 of the SER examine the effect of an earthquake on the TN-32. The only significant effect of an earthquake results from a large ground acceleration (exceeding 0.36-g horizontal design value) that causes the cask to tip-over. The tip-over accident is evaluated in Section 11.2.8 of the TSAR.

11.3.3.3 Flood

Section 11.2.3 of the TSAR and Section 3.3.4.1 of the SER examine the effect of a flood on the TN-32. The staff concurs that no credible flood at an ISFSI site could result in significant damage to the TN-32. Section 12 of the SER establishes as an operating control and limit that the cask must be located such that the site conditions are bounded by the TSAR analysis for flooding.

11.4 Evaluation Findings

Structures, systems, and components of the TN-32 are adequate for the prevention of accidents and the mitigation of the consequences of accidents and natural phenomena events.

The TN-32 has been evaluated to demonstrate that it will reasonably maintain confinement of radioactive material under credible accident conditions.

Off-normal and accident conditions will not result in a dose to an individual outside the controlled area which exceeds the limits of 10 CFR 72.104(a) or 72.106(b), respectively.

An accident or natural phenomena event will not preclude the ready retrieval of spent fuel for further processing or disposal.

The spent fuel will be maintained in a subcritical condition under accident conditions.

The spacing of TN-32 casks, discussed in Section 1.3.1 of the SER and included as an operating limit in Section 12, will provide for accessibility to the equipment at onsite and available offsite emergency facilities and services, as required.

No instruments or control systems must remain operational under accident conditions.

The staff concludes that the accident design criteria for the TN-32 are in compliance with 10 CFR Part 72 and that the accident design and acceptance criteria have been satisfied. The accident evaluation of the TN-32 demonstrates that the TN-32 will provide for safe storage of spent fuel. This finding is based on a review which considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

Section 12—OPERATING CONTROLS AND LIMITS

This section summarizes the operating controls and limits set by the TN-32 Dry Storage Cask TSAR. It is developed from information presented in Section 12 of the TSAR, commitments of the applicant discussed in other sections of the TSAR, and accepted practices.

The controls and limits listed in this section are intended to highlight significant areas and provide a useful listing of key requirements. The absence of a particular commitment in this section of the SER that is otherwise present in the TSAR or other applicant correspondence, or is required by the regulations or site license conditions, does not negate the requirement to comply with that commitment.

12.1 Areas of Review

12.1.1 Functional/Operating Limits and Monitoring Limits/Limited Control Settings

12.1.2 Limiting Conditions

12.1.3 Surveillance Requirements

12.1.4 Design Features

12.1.5 Administrative Controls

12.2 Regulatory Requirements

12.2.1 Specifications must be provided for the spent fuel to be stored in the cask, such as, but not limited to, type of spent fuel (i.e., BWR, PWR, both), maximum allowable enrichment of the fuel prior to any irradiation, burn-up (i.e., megawatt-days/MTU), minimum acceptable cooling time of the spent fuel prior to storage in the cask, maximum heat designed to be dissipated, maximum spent fuel loading limit, condition of the spent fuel (i.e., intact assembly or consolidated fuel rods), and the inerting atmospheric requirements. [10 CFR 72.236(a)]

12.2.2 Technical specifications must be proposed. These specifications must include: (1) functional and operating limits and monitoring instruments and limiting control settings, (2) limiting conditions, (3) surveillance requirements, (4) design features, and (5) administrative controls. [10 CFR 72.44(c), 72.24(g), and 72.26]

12.2.3 Instrumentation and control systems must be provided to monitor systems that are important to safety over anticipated ranges for normal and off-normal operations. Those instruments and control systems that must remain operational under accident conditions must be identified in the Safety Analysis Report. [10 CFR 72.122(i)]

12.3 Review Procedures

The following drawings were used in the review:

1. TN-32 Dry Storage Cask, Assembly & Parts List, Drawing No. 1049-70-1 (Rev. 2)
2. TN-32 Dry Storage Cask, Cross Section, Drawing No. 1049-70-2 (Rev. 2)
3. TN-32 Dry Storage Cask, Lid Assembly & Details, Drawing No. 1049-70-3 (Rev. 2)
4. TN-32 Dry Storage Cask, Protective Cover, Drawing No. 1049-70-4 (Rev. 0)
5. TN-32 Dry Storage Cask, Basket, General Arrangement, Drawing No. 1049-70-5 (Rev. 0)
6. TN-32 Dry Storage Cask, Basket, Typical Cross Section, Drawing No. 1049-70-6 (Rev. 3)

Section 12 of the TSAR presents the proposed operating controls and limits. These conditions have been assessed by the staff. The controls and limits listed below have been identified for inclusion in this section of the SER based on this review, consideration of information presented in other sections of the TSAR, and accepted practices. For convenience and consistency with 10 CFR 72.44, these controls and limits are separated into five categories in the SER.

12.3.1 Functional/Operating Limits and Monitoring Limits/Limited Control Settings

12.3.1.1 Fuel Characteristics

The TN-32 shall be limited to the storage of 32 PWR fuel elements that satisfy the thermal, shielding, and radiological design limits of Section 2.1 of the TSAR, which is repeated below:

Thermal, Gamma and Neutron Sources for the Design Basis 17x17
Westinghouse Fuel Assembly (without control components)

U^{235} Enrichment (%wt)	3.85
Burnup (MWD/MTU)	40,000
Specific Power (MW/MTU)	37.5
Cooling Time (year)	7 (minimum)
Decay Heat (kw/assembly)	0.85
Gamma Source (photons/sec)	7.23E15
Neutron Source (neutrons/sec)	1.51E8

Known or suspected failed fuel or fuel with cladding defects greater than pin holes and hairline cracks is not authorized for storage in the TN-32.

Fuel rods that have been removed from fuel assemblies must be replaced with dummy rods before loading in the TN-32.

The maximum weight of the fuel shall be such that the total payload weight (fuel, basket, and the rail) does not exceed 66,000 pounds.

12.3.1.2 Radiation Protection

Dose rates on the accessible surfaces (top, sides) of the cask shall not exceed 200 mrem/hr., and shall be compared to the values in Table 5.1-2 of the TSAR to verify proper loading of the fuel and assure the ISFSI site's compliance with 10 CFR 72.104 and 10 CFR Part 20.

Removable contamination on the cask shall not exceed 1000 dis/min/100 cm^2.

The total leak rate of all confinement seals shall not exceed $1x10^{-5}$ std cc/s helium. (See Section 7.3.1 for a description of these three sets of seals.)

A pressure-monitoring system shall be installed on each cask to monitor the pressure of helium in the inter-seal regions. The monitoring system shall be set to alarm if the pressure decreases to 3.2 atm or if the pressure switch fails.

12.3.1.3 Acceptance Testing

Each cask shall be fabricated, tested, and maintained in accordance with the specifications of Section 9 of the TSAR.

12.3.1.4 Operating Procedures

The water in the spent fuel pool shall contain at least 2000 ppm boron during cask loading and unloading operations. Steps shall be taken before loading or unloading the cask to verify the boron concentration.

Before moving the cask to the pad, the cask shall be vacuum dried and successfully dryness tested. Chapter 8 of the TSAR specifies a dryness test of evacuating the cask to a vacuum of 10 mbar or less. The pressure change shall not exceed 3 mbar in less than 10 minutes.

The cask cavity shall be backfilled to an equilibrium pressure of 2.2 atm with helium.

The TN-32 shall not be lifted more than 18 inches when outside the spent fuel pool building.

For use at a reactor site, all operations, including maintenance of the TN-32, shall also be conducted in accordance with the 10 CFR Part 50 license, technical specifications, programs, and procedures for the site.

12.3.1.6 Site Conditions

Design-basis conditions assumed for TN-32 analysis are summarized below. Further analysis and review would be required to locate the cask at a site that exceeds these conditions.

Characteristic	Limit
Maximum average daily ambient temperature, °F	100
Maximum annual average ambient temperature, °F	60
Minimum ambient temperature, °F	-20
Maximum insolance (solar heat load), BTU/ft^2-hr:	
Flat horizontal surfaces	2950
Curved surfaces	1475
Maximum tornado wind, mph	
Rotational	290
Translational	70
Maximum horizontal earthquake acceleration to preclude tip-over, g	0.36

Radiation doses at the site boundary shall be in compliance with 10 CFR 72.104(a) and 72.106(b).

Radiation doses in unrestricted areas within the controlled boundary shall be in compliance with 10 CFR Part 20.

The cask shall be stored in a location such that significant cask burial as the result of an earthquake, tornado, explosion, or other accident or natural phenomena event shall not occur.

The cask shall be located such that a flooding event would not exceed a water level of 56 ft. and a drag force of 45,600 pounds while assuming a friction coefficient of 0.25.

A minimum spacing of 4.88 meters (16 feet) shall be maintained between cask centers to permit observation and maintenance.

The cask shall be located on a reinforced concrete storage pad with the following characteristics: 1) ≤3 feet thick, 2) ≤4000 psi, and 3) a soil modulus of elasticity ≤40 ksi.

12.3.2. Limiting Conditions

The pressure in the inter-seal regions of the TN-32 shall be maintained at 3.2 atm ±5%.

12.3.3. Surveillance Requirements

Surveillance requirements for use of the TN-32 shall be established by the ISFSI operator. These requirements shall include a means to assess the functionality of the pressure monitoring system (PMS).

12.3.4. Design Features

Design features described in the text and license drawings of the TSAR shall not be modified except as permitted by 10 CFR 72.48.

12.3.5. Administrative Controls

Administrative controls shall be established by the ISFSI licensee in accordance with 10 CFR 72.42(c)(5).

12.4 Evaluation Findings

The staff concludes that the operating controls and limits for the TN-32 are in compliance with 10 CFR Part 72 and that the applicable acceptance criteria have been satisfied. The evaluation of the operating controls and limits provides reasonable assurance that the TN-32 will enable safe storage of spent fuel. This finding is based on a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted practices.

Section 13—QUALITY ASSURANCE

The staff has reviewed TN's commitments for quality assurance given in the TSAR. As indicated in Chapter 13 of the TSAR, the NRC has issued a Quality Assurance Program Approval for activities conducted under Subpart H of 10 CFR Part 71. The staff found that the TN TSAR commitments for quality assurance meets the requirements of Subpart G of 10 CFR Part 72. The TSAR can be referenced without further quality assurance review in a license application to receive and store spent fuel under 10 CFR Part 72, provided that the applicant applies its NRC-approved quality assurance program that meets the requirements of Appendix B to 10 CFR Part 50 to the design, construction, and use of the spent fuel storage installation.

Section 14—DECOMMISSIONING

This section evaluates the decommissioning aspects of the TN-32 design. Because the actual decommissioning will occur at a future date (perhaps more than 20 years after first use of the cask) and will employ site-specific procedures available at that time, 10 CFR Part 72 does not require the development of detailed plans or procedures. As a result, the cask is acceptable if decommissioning has been considered in the design and if proposed practices and procedures provide reasonable assurance that it can be unloaded, decontaminated, and decommissioned with adequate protection to public health and safety.

14.1 Areas of Review

14.1.1 Unloading Procedures

14.1.2 Decommissioning and Decontamination Design Features and Procedures

14.1.3 Activated Material and Other Radioactive Wastes

14.2 Regulatory Requirements

14.2.1 The cask must be compatible with wet or dry unloading facilities. [10 CFR 72.236(h)]

14.2.2 The cask must be designed for decommissioning. Provisions must be made to facilitate decontamination of structures and equipment and minimize the quantity of radioactive wastes, contaminated equipment, and contaminated materials at the time the ISFSI is permanently decommissioned. [10 CFR 72.130, 72.24(f), and 72.236(i)]

14.2.3 Information on proposed practices and procedures for the decontamination of the site and facilities and for disposal of residual radioactive materials after all spent fuel has been removed must be described to provide reasonable assurance that decontamination and decommissioning will provide adequate protection to public health and safety. [10 CFR 72.30(a) and 72.24(q)]

14.3 Review Procedures

Design criteria for decommissioning and analysis of activated material resulting from spent fuel storage in the TN-32 are presented in Section 2.4 of the TSAR.

14.3.1 Unloading Procedures

Unloading procedures are described in Section 8.2 of the TSAR. As reviewed in Section 8.3.3 of the SER, these procedures assume wet unloading in the spent fuel pool and consider venting of radioactive gases that may have built up in the cavity during storage. These gases and contaminated water that may result from the unloading process will be handled in accordance with the 10 CFR Part 50 license for the specific site.

14.3.2 Decommissioning and Decontamination Design Features and Procedures

The TN-32 is designed with a smooth steel exterior and sealed neutron shield that are physically separated from radioactive material. After the TN-32 is loaded with spent fuel and removed from the pool, the exterior surface is decontaminated prior to transport to the ISFSI. Consequently, end-of-life decontamination effort for the ISFSI itself will be minimal.

Minor contamination of the cask surfaces resulting from unloading the fuel in the pool can be removed in a manner analogous to that employed during loading procedures. The fuel basket and interior cask surfaces can also be readily decontaminated using conventional mechanical or chemical methods.

14.3.3 Activated Material and Other Radioactive Wastes

After decontamination of the cask and basket surfaces, the only radioactive material will be that resulting from neutron activation of the fuel basket and cask body. Section 2.4 of the TSAR calculates radioactive nuclides produced in the cask during a 20-year storage period using the ORIGEN2 computer code [1]. Based on the shielding calculations described in Section 5 of the TSAR, the neutron fluxes at the cask centerline, cavity wall, neutron shield, and outer shell are used to irradiate the respective cask components. Table 2.4-1 depicts the material compositions, masses of irradiated material, and fluxes; the latter conservatively assumed to remain constant during the storage period. The results of these calculations, presented in Table 2.4-2 of the TSAR, indicate a minimum total activity of approximately 2.6×10^9 Bq (0.07 Ci) at 30 days after cask unloading. Table 2.4-3 compares the specific activities of each radionuclide to the respective limits for Class A radioactive waste, as defined by 10 CFR 61.55. The staff concurs that the quantities of activated materials from the TN-32 are comparable to that of other dry storage casks and agrees that these quantities are a negligible fraction of the limits of Class A waste.

14.4 Evaluation Findings

The TN-32 is compatible with wet unloading procedures. While dry loading may be possible, it was not evaluated.

The TN-32 has been designed for decommissioning. The cask can be readily decontaminated by conventional methods. The quantities of activated materials and other radioactive waste are significantly below the limits of Class A waste, as defined by 10 CFR Part 61.

Information on the proposed practices and procedures for the decontamination of the TN-32 and disposal of radioactive materials after removal of spent fuel have been presented and provide reasonable assurance that decontamination and decommissioning will adequately protect public health and safety.

The staff concludes that the decommissioning considerations for the TN-32 are in compliance with 10 CFR Part 72 and provide reasonable assurance that the cask can be decontaminated and decommissioned in a manner that will adequately protect public health and safety. This finding is based on a review which considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted practices.

14.5 References

1. Croft, A.G. et al. "Revised Uranium-Plutonium Cycle PWR and BWR Models for the ORIGEN Computer Code," ORNL/TM-6051, Oak Ridge National Laboratory, Oak Ridge, Tennessee, September 1978.