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Office of Civilian Radioactive Waste Management

Civilian Radioactive Waste Management System

Preliminary Transportation, Aging and Disposal Canister System Performance Specification Requirements Rationale

Revision B

DOC ID: WMO-TADCS-RR-000001

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REVISION HISTORY

Revision	Change
A	Initial Issue
B	For requirement number (5) and (6) in Section 3.1.1 changed "… or less then 5 years out-of-reactor…" to "…**and no** less than 5 years out-of-reactor…" Made similar revision to the supporting requirements rationale.

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ACRONYMS

ALARA	as low as is reasonably achievable
BSC	Bechtel SAIC Company, LLC
BWR	boiling water reactor
CFR	Code of Federal Regulation
CSNF	commercial spent nuclear fuel
DCRA	disposal control rod assembly
DOE	U.S. Department of Energy
GROA	geologic repository operations area
HLW	high-level radioactive waste
HVAC	heating, ventilation and air-conditioning
ISFSI	independent spent fuel storage installation
ITS	important to safety
MTHM	metric tons of heavy metal
MTIHM	metric tons of initial heavy metal
MTU	metric tons of uranium
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
OCRWM	Office of Civilian Radioactive Waste Management
PWR	pressurized water reactor
SNF	spent nuclear fuel
SSC	structures, systems and components
STC	shielded transfer cask
TAD	transportation, aging and disposal
TEDE	total effective dose equivalent
USL	upper subcritical limit
YMP	Yucca Mountain Project

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ABBREVIATIONS

° C	degrees Centigrade
° F	degrees Fahrenheit
BTU	International Table British thermal unit
BTU/hr-ft^2	British thermal unit per hour-square foot
Bq	becquerel
cm	centimeter
cm^2	square centimeter
dpm	disintegrations per minute
ft	feet
ft/s	feet per second
g	acceleration due to gravity
g/cm^2	grams per square centimeter
GWd	gigawatt-day
h or hr	hour
in.	inches
k_{eff}	effective neutron multiplication factor
kg	kilogram
km	kilometer
km/hr	kilometer/hour
kPa	kilopascal
kW	kilowatt
kW/m^2	kilowatt per square meter
lb	pound(s) (weight; unless otherwise specified)
lb/ft^2	pounds per square foot
lb/in^2	pounds per square inch
lb/in^2/sec	pounds per square inch per second
m	meter
m/s	meter per second
m^2	square meter(s)
mho	Conductance in mho being the reciprocal of resistance in ohms
mm	millimeter
MPa	megapascal
mph	miles per hour

mrem	milli roentgen equivalent man
MT	metric tons
pH	potential of hydrogen
ppm	parts per million
psi, lb/in^2	pounds per square inch
s or sec	second
ton	short ton (2,000 lb weight)
torr	pressure that causes the Hg column to rise 1 millimeter
yr	year

1.0 INTRODUCTION

1.1 Purpose

The purpose of this document is to provide the requirements rationale for the current version of the *Preliminary Transportation, Aging and Disposal Canister System Performance Specification*; WMO-TADCS-000001.

1.2 Definitions

Accident- An undesirable event; especially one that could potentially do damage or harm to a cask or its contents.

Approved Contents- Used in the context of this requirements rationale and the current version of the *Preliminary Transportation, Aging and Disposal Canister System Performance Specification*; WMO-TADCS-000001, the term "approved contents" means one of the following:

> Transportation Overpack: The contents of Type B packaging as discussed in Section 1.3.3 "Package Description" of *The Standard Review Plan for Transportation Packages for Spent Nuclear Fuel* (NUREG-1617) and listed in section 5b "Contents of Packaging" of a Certificates of Compliance issued under 10 CFR part 71.
>
> Storage Overpack: The materials to be stored as discussed in Section 4.4.1 of *Standard Review Plan for Spent Fuel Dry Storage Facilities* (NUREG-1567) and listed in Section 6 "Approved Contents" of Certificates of Compliance issued under 10 CFR part 72.

Normal- A term used to define expected radioactive wastes, operations and/or processes.

Off-normal- A term used to define any combination of radioactive waste, operations or processes that are not expected during normal activities; usually associated with damaged or failed materials, equipment or processes.

Purchaser- Any person, other than a Federal agency, who is licensed by the Nuclear Regulatory Commission to use a utilization or production facility under the authority of sections 103 or 104 of the Atomic Energy Act of 1954 (42 U.S.C. 2133, 2134) or who has title to spent nuclear fuel or high level radioactive waste and who has executed a contract with DOE.

2.0 REFERENCE DOCUMENTATION

Preliminary Transportation, Aging and Disposal Canister System Performance Specification; WMO-TADCS-000001.

Preparation, Review and Approval of Performance Specifications; LP-3.37Q-OCRWM

3.0 REQUIREMENTS ANALYSIS RATIONALE

3.1 TAD Canister Requirements Rationale

3.1.1 General

(1) The TAD canister shall conform to the dimensional envelope (e.g., tolerance stack-up, thermal expansion, etc.) based on a right-circular cylinder with a length of $212.0\ in.\left(\frac{+0.0\ in.}{-0.5\ in.}\right)$ and a diameter of $66.5\ in.\left(\frac{+0.0\ in.}{-0.5\ in.}\right)$.

Rationale: Requiring the TAD to conform to the envelope limitations above ensures it will fit into a waste package configuration similar to one analyzed and determined to meet repository preclosure and postclosure performance requirements. This specification is based on current operational concepts and technical baseline in *Requirements for the Site-Specific Canister/Basket;* 000-30R-HA00-00400-000-000. This cited source was not developed under the OCRWM QA program. Qualification is not required due to the associated values representing a bounding MGDS operational concept; not a calculations or analyses that need to be preformed under the QARD.

(2) The TAD canister maximum loaded weight shall be 54.25 tons.

Rationale: Limiting the TAD weight to 54.25 tons provides confidence the behavior of the waste package with a TAD canister will respond to structural dynamic event sequences in a manner that meets current repository preclosure and postclosure performance requirements. This specification is based on current operational concepts and technical baseline in *Requirements for the Site-Specific Canister/Basket;* 000-30R-HA00-00400-000-000. This cited source was not developed under the OCRWM QA program. Qualification is not required due to the associated values representing a bounding MGDS operational concept; not a calculations or analyses that need to be preformed under the QARD.

(3) The capacity of the TAD canister shall be either 21 pressurized water reactor (PWR) spent fuel assemblies or 44 boiling water reactor (BWR) spent fuel assemblies.

Rationale: The loaded TAD canister shall be required to meet the approved technical baseline total system performance assessment for source term for waste package loadings. This specification is based on current operational concepts and technical baseline in *Requirements for the Site-Specific Canister/Basket;* 000-30R-HA00-00400-000-000. This cited source was not developed under the OCRWM QA program. Qualification is not required due to the associated values representing a bounding MGDS operational concept; not a calculations or analyses that need to be preformed under the QARD.

(4) The loaded and closed TAD canister shall be capable of being reopened while submerged in an unborated pool. See *Monitored Geologic Repository Systems Requirements Document*; YMP/CM-0026

Rationale: The capability to repackage waste must be maintained in the event that future retrieval is deemed appropriate. The ability to reopen closed TAD canisters will ensure that waste can be repackaged or recovered after off-normal conditions.

(5) A TAD canister for PWR assemblies shall be limited to accepting CSNF with characteristics less then 5% initial enrichment, 80 GWd/MTU burn up and no less than 5 years out-of-reactor cooling time.

Rationale: The maximum design basis source term and heat load for a PWR spent fuel assembly is 5% initial enrichment, 80 GWd/MTU burn up and no less than 5 years out-of-reactor cooling time. See *PWR Source Term Generation and Evaluation.* 000-00C-MGR0-00100-000-00B.

(6) A TAD canister for BWR assemblies shall be limited to accepting CSNF with characteristics less then 5% initial enrichment, 75 GWd/MTU burnup and no less than 5 years out-of-reactor cooling time.

Rationale: The maximum design basis source term and heat load for a BWR spent fuel assembly is 5% initial enrichment, 75 GWd/MTU burn up and no less than 5 years out-of-reactor cooling time. See *BWR Source Term Generation and Evaluation.* 000-00C-MGR0-00200-000-00A.

(7) A TAD canister shall be capable of being loaded with CSNF from one or more facilities that are licensed by the NRC and hold one or more contracts with the DOE for disposal of CSNF.

Rationale: Allowing the contents of a TAD canister to be CSNF generated purchasers will encourage broad use of TAD canisters by reactor operators. See *Civilian Radioactive Waste Management System Requirements Document,* DOE/RW-0406.

(8) All external edges of the TAD canister shall have a minimum radius of curvature of 0.25 in.

Rationale: This requirement helps protect the inner surface of the inner vessel of the waste package will not be gouged or otherwise damaged that could adversely affect the performance of the corrosion barrier.

(9) To the extent practicable, projections or protuberances from reasonably smooth adjacent surfaces shall be avoided or smoothly blended into the adjacent smooth surfaces.

Rationale: This requirement ensures minimization of stress risers and line-stress loads on the inner surface of the inner vessel of the waste package of the outer corrosion barrier.

(10) The TAD canister shall be designed to store vendor defined design basis CSNF at a purchaser site in accordance with 10 CFR part 72 in either a horizontal or vertical orientation.

Rationale: Purchaser engineering, design and operational decisions are to be determined solely by the purchasers.

(11) A TAD canister shall be designed to transport vendor defined design basis CSNF to the GROA in a horizontal configuration.

Rationale: This requirement is 1) in accordance with standard industry practice for the movement of spent nuclear fuel; and, 2) to meet requirements of the OCRWM Transportation Project.

(12) A TAD canister shall be designed to dispose of vendor defined design basis CSNF in waste package in a horizontal configuration.

Rationale: The current technical baseline (and supporting analyses) assumes the disposition of CSNF in a horizontal orientation in a waste package. See *Project Design Criteria Document*; 000-3DR-MGR0-00100-000 REV 005.

(13) A TAD canister shall be designed to be handled at the GROA loaded with vendor defined design basis CSNF in a vertical configuration.

Rationale: The current technical baseline and concept of operations assumes handling TAD canisters in a vertical configuration. See *Project Design Criteria Document*; 000-3DR-MGR0-00100-000 REV 005.

(14) A TAD canister shall be designed to age vendor defined design basis CSNF in a vertical configuration.

Rationale: The current technical baseline and concept of operations excludes the ability to transfer TAD canisters outside licensed structures (i.e., buildings) at the GROA. The conceptual design of the site transporter only allows for handling in a vertical configuration. See *Project Design Criteria Document*; 000-3DR-MGR0-00100-000 REV 005.

(15) Prior to emplacement for disposal, the service lifetime of the TAD canister shall be a minimum of 100 years without maintenance.

Rationale: This requirement is based on engineering judgment intended to envelope storage and aging requirements (purchaser and GROA sites, respectively) prior to emplacement.

(16) The service lifetime environmental conditions shall be an unprotected "harsh marine environment."

Rationale: This is intended to allow for extended storage at purchaser locations that have ambient conditions that will cause maximum environmental insult to the TAD canister prior to receipt at the GROA.

3.1.2 Structural

(1) The TAD canister inside a transportation or aging overpack shall meet following temperature and leak tight standards for 2,000-year and 10,000-year design basis seismic events.

a. Following a 2,000-year seismic return period event, a TAD canister in an aging overpack or transportation overpack with impact limiters, shall maintain a maximum leakage rate of 1.5×10^{-12} fraction of canister free volume per second (normal) and maximum cladding temperature of 752° F (normal).

b. Following a 10,000-year seismic return period event, a TAD canister in an aging overpack or transportation overpack with impact limiters shall maintain a maximum leakage rate of 1.5×10^{-12} fraction of canister free volume per second (normal) and cladding temperature limit of 1,058° F (off-normal) following a seismic event defined by the 10,000-year seismic return period.

Rationale: 10 CFR part 63 provides repository performance objectives in terms of annual dose limits for workers and public and requires that 10 CFR part 20 be met. An acceptable leakage rate was established to meet both the acceptance criterion of 10% of the annual TEDE and the acceptance criterion that ensures that oxygen concentration inside the TAD canister remains below 0.25% by volume to preclude fuel oxidation. Because a seismic event would affect all TADs located on the surface of the GROA, the TAD system must maintain confinement within the normal acceptance leakage rate specified in PCSA-1 during and after the seismic event. The TAD can be in any configuration, including on a site transporter. See *Determination of Leakage Rate Requirements for Transportation, Aging and Disposal (TAD) Canisters and Transportation and Aging Casks,* 000-00C-WHS0-01300-000-000.

(2) A TAD canister in an aging overpack or transportation overpack with impact limiters, shall maintain a maximum leakage rate of 1.5×10^{-12} fraction of canister free volume per second and the specified cladding temperature limits during and exposure to the environmental conditions.

a. These environmental conditions are not cumulative but occur independently:

- Outdoor average daily temperature range of 2º F to 116º F with insolation as specified in 10 CFR part 71 (normal)
- Extreme wind gust of 90 mph for 3-sec (normal)

- Tornado wind speed of 189 mph with a corresponding pressure drop of 0.81 lb/in^2 and a rate of pressure drop of 0.30 lb/in^2/sec (off-normal) with the listed spectrum of missiles (off-normal).

b. Annual precipitation of 20 inches/year (normal) and the specified spectrum of rainfall.

c. Maximum daily snowfall of 6.0 in. (normal)

d. Maximum monthly snowfall of 6.6 in. (normal)

e. A lightning strike with a peak current of 250 kiloamps over a period of 260 microseconds and continuous current of 2 kiloamps for 2 seconds (off-normal).

Rationale: This requirement is consistent with specifications in *Project Design Criteria Document*, 000-3DR-MGR0-00100-000 REV 005.

(3) The TAD canister shall have a flat bottom.

Rationale: OCRWM requirement to ensure the empty or loaded TAD canister will remain upright and freestanding.

3.1.3 Thermal

(1) For normal operations, CSNF cladding temperature in TAD canisters shall not exceed 752° F. Normal operations include storage at purchaser sites, transportation from purchasers to the GROA and handling at the GROA (e.g., aging, storage, onsite transfer, etc).

Rationale: NRC Interim Staff Guidance (ISG-11) for storage and transport of CSNF.

(2) TAD canister cooling features and mechanisms shall be passive.

Rationale: OCRWM requirement that will simplify the GROA design, license application and future maintenance.

(3) For normal operations in the repository emplacement drifts, the CSNF cladding temperature contained in a TAD canister shall not exceed 662° F. This includes both preclosure and postclosure time periods.

Rationale: The 662° F limit during emplacement is imposed per DOE direction.

3.1.4 Dose and Shielding

(1) For GROA operations, the combined neutron and gamma integrated average dose rate over the top surface of a loaded TAD canister shall not exceed 800 mrem/hr on contact.

Rationale: This requirement allows for TAD operations in GROA facilities which have limited shielding and access capability.

(2) For GROA operations, the combined contact neutron and gamma maximum dose rate at any point on the top surface of the TAD canister shall not exceed 1,000 mrem/hr.

Rationale: This requirement allows for TAD operations in GROA facilities which have limited shielding and access capability.

(3) The TAD canister shall be designed such that accessible external surfaces contamination shall be removable to:

a. 1,000 dpm/100 cm^2 - beta-gamma with a wipe efficiency of 0.1.

b. 20 dpm/100 cm^2 - alpha with a wipe efficiency of 0.1.

Rationale: Control of surface contamination on the TAD canister supports the design of a radiologically clean facility. Such controls mitigate the potential for onsite and offsite releases of radioactive material. See "*Control of Radioactively Contaminated Material,*" IE Circular No. 81-07.

3.1.5 Criticality

(1) Preclosure Criticality - The maximum calculated effective neutron multiplication factor (k_{eff})[1] (assuming same burnup credit currently given under 10 CFR 71, which requires demonstrating criticality safety under fully flooded conditions with unborated water) for a TAD canister containing the most reactive CSNF for which the design is approved shall not exceed the upper subcritical limit (USL)[2] for three archetypical preclosure proxy configurations. The three archetypical preclosure proxy configurations are defined as:

a. Nominal fully loaded TAD configurations that are open and fully flooded in the Wet Handling Facility pool with no soluble neutron absorber present in the pool water;

b. Off-normal TAD configurations where a fuel assembly, normal or deformed, are lying across an open, fully loaded, TAD in the Wet Handling Facility pool with no soluble neutron absorber present in the pool water;

c. Off-normal configurations where the TAD shell, TAD internals and CSNF assemblies are reconfigured in accordance with a 50g impact in the orientation that would result in the greatest force transfer to the TAD and its contents while inside the transfer cask and in the Wet Handling Facility pool (i.e., the TAD is fully flooded with no soluble neutron absorber present in the pool water).

Rationale: These configurations should ensure that the possibility of a criticality event in a TAD canister is a "beyond Category 2" event sequence. See *Criticality Input to Canister Based System Performance Specification for Disposal,* TDR-DS0-NU-000002 REV 00.

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1 The maximum k_{eff} for a configuration is the value at the upper limit of a two-sided 95% confidence interval.

2 The USL is a value of k_{eff} that accounts for biases and uncertainties for the configurations and includes an administrative margin to provide added assurance of subcriticality.

(2) Postclosure Criticality control shall be maintained by employing either the items in (a) or the analysis in (b), as follows:

a. Include the following features in the TAD internals:

- Neutron absorber plates or tubes made from borated stainless steel produced by powder metallurgy and meeting ASTM A887-89 Grade “A” alloys.
- Minimum thickness of neutron absorber plates shall be 0.433 inches. Maximum and nominal thickness can be based on structural requirements.
- The neutron absorber plate shall have a boron content of 1.1 wt % to 1.2 wt %, a range that falls within the specification for 304B4 UNS S30464 as described in ASTM A887-89.
- Neutron absorber plates or tubes must extend the full axial length (+0”/-½”) of the canister internals at room temperature.
- Neutron absorber plates or tubes must cover all four longitudinal sides of each fuel assembly.
- TAD canister designs for PWR fuel assemblies shall accommodate assemblies loaded with a disposal control rod assembly (DCRA[3]). A DCRA is intended for acceptance of PWR CSNF with characteristics outside limits set in the postclosure criticality loading curves. Examples (i.e., illustrative purposes only) of postclosure criticality loading curves are shown in Attachment B of the current version of the *Preliminary Transportation, Aging and Disposal Canister System Performance Specification*; WMO-TADCS-000001.

b. Perform analyses of TAD systems to ensure the maximum calculated effective neutron multiplication factor (k_{eff})[4] for a TAD containing the most reactive CSNF for which the design is approved shall **not** exceed the critical limit[5] for four postclosure archetypical proxy configurations.[6,7]

Rationale: These features will ensure postclosure criticality control to extent reasonably possible without a fully detailed postclosure criticality evaluation of a specific design using the methods described in the topical report and Input document.

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[3] DCRA is similar to control rod assemblies, reactivity control assemblies, reactivity control cluster assemblies or burnable poison rod assemblies placed in fuel assemblies during irradiation in reactors. A primary difference is extra thick zircaloy cladding, absorber materials that extend beyond the active fuel length and spiders that hold rods have thick zircaloy or titanium locking mechanism(s).

[4] The maximum k_{eff} for a configuration is the value at the upper limit of a two-sided 95% confidence interval.

[5] The critical limit is the value of k_{eff} at which a configuration is considered potentially critical including biases and uncertainties (BSC 2004, Section 6.3.1).

[6] The *Criticality Input to Canister Based System Performance Specification for Disposal* (BSC 2006, Section 3.1) provides a set of considerations for determining the proxy configurations based upon analyses of different, but similar, waste package designs. A list of the four proxy configuration cases are:

a. Nominal case, basket assembly degraded, CSNF intact.

b. Seismic case-I, basket assembly intact, CSNF degraded.

c. Seismic case-II, basket assembly degraded, CSNF degraded.

d. Igneous intrusion case, basket assembly degraded, CSNF degraded, waste package and TAD structural deformation.

[7] A system performance assessment is a comprehensive analysis estimating dose incurred by reasonably maximally exposed individual, including associated uncertainties, as a result of repository releases caused by all significant features, events, processes, and sequences of events and processes, weighted by their probability of occurrence (YMP 2003, Appendix B).

See *Criticality Input to Canister Based System Performance Specification for Disposal*, TDR-DS0-NU-000002 REV 00.

3.1.6 Containment

(1) The TAD canister shall be designed to facilitate helium leak testing of closure features using methods that can demonstrate the defined leak-tight requirements have been met. Leak testing shall be performed in accordance with ANSI N14.5-97.

Rationale: NUREG-1536, Section 8.0, Item V, ("Filling and Pressurization") leak testing should be in accordance with ANSI N 14.5-97. The requirement is general and should provide vendor flexibility in selecting the appropriate test method.

(2) Helium shall be the only gas used for final backfill operations.

Rationale: Helium is the assumed inert gas in the Total System Performance Assessment (TSPA).

(3) Closure welds shall be used for TAD canister containment in accordance with standard nuclear industry practice. ASME Boiler and Pressure Vessel Code shall be used for design, procedure and qualification requirements.

Rationale: This requirement obviates the need for active leak monitoring during aging.

By adopting a nationally recognized code for design and construction of pressure vessels, such as *2004 ASME Boiler and Pressure Vessel Code*, acknowledges the guidance provided by NRC in NUREG-1804, *Yucca Mountain Review Plan, Final Report*.

(4) In accordance with industry standards and regulatory guidance, the TAD canister shall be designed to facilitate the following:

a. Draining and vacuum drying to remove water vapor and oxidizing material. The loaded TAD canister shall maintain a 3 torr vacuum for 30 minutes after vacuum pump operation ceases.
b. Filling with helium to atmospheric pressure or greater as required to meet leak test procedural requirements.
c. Sampling of the gas space to verify helium purity.
d. Limiting maximum allowable oxidizing gas concentration within the loaded and sealed TAD canister to 0.20% of the free volume in the TAD canister at atmospheric pressure.

Rationale: Complies with guidance in NUREG-1536 (NRC 1997) related to limits on oxidizing agents and inerting medium for interior environment. The sealed TAD canister must provide conditions necessary to maintain physical integrity and chemical stability of waste form and maintain waste form characteristics that restrict transport of radionuclides to the accessible environment. This requirement maintains consistency with licensing precedents established for commercial canisters that have been previously reviewed and accepted under title 10 CFR part 72.

(5) A loaded TAD canister shall maintain a leakage rate of 1.5×10^{-12} fraction of canister free volume per second (normal) and maintain the cladding temperature below 752° F (normal) following vertical flat-bottom drop of 12 inches onto an unyielding surface.

Rationale: Current GROA concepts of operation require an unprotected transfer of a loaded TAD canister from a transportation overpack to an aging overpack or waste package.

3.1.7 Operations

(1) The TAD canister lid shall be designed for handling under water with the TAD in a vertical orientation.

Rationale: GROA handling concepts are based on a vertical orientation of the TAD canister for fuel assembly loading. See *Project Design Criteria Document*; 000-3DR-MGR0-00100-000 REV 005.

(2) The TAD canister body and lid shall have features to center and seat the lid during submerged installation. The maximum off-center value is ½ in.

Rationale: Industry standard cranes have a positional repeatability of ±¼ in. See *Project Design Criteria Document*; 000-3DR-MGR0-00100-000 REV 005.

(3) An integral feature for lifting a vertically oriented, loaded TAD from the top lid, without requiring manual installation and removal of devices and adapters shall be provided.

Rationale: To facilitate operational, dose and throughput requirements, TAD canisters shall have a common integral lifting feature. See *ALARA Management Commitment and Policy*; POL-MG-007, Rev. 0.

(4) An open, empty and vertically oriented TAD canister shall have integral lifting feature(s) provided to allow lifting by an overhead handling system.

Rationale: To facilitate GROA pool operations TAD canisters shall have an integral lifting feature or features. See *Project Design Criteria Document,* 000-3DR-MGR0-00100-000 REV 005.

3.1.8 Materials

(1) Required Materials- Except for thermal shunts and criticality control materials, the TAD canister and structural internals (i.e., basket) shall be constructed of a Type 300-series stainless steel (UNS S3XXXX, such as UNS S31603, which may also be designated as type 316L) as listed in ASTM A-276-06, *Standard Specification for Stainless Steel Bars and Shapes*.

Rationale: The need for corrosion degradation of TAD canister materials to have minimal impact on the pH of the aqueous solution(s) contacting the TAD canister and waste form after TAD canister is breached and is consistent with the In-Package Chemistry Abstraction AMR.

(2) The TAD canister and basket material designs shall be compatible with repository pool water defined in the current version of the *Preliminary Transportation, Aging and Disposal Canister System Performance Specification*; WMO-TADCS-000001.

Rationale: TAD canister materials must not be adversely affected by pool water chemistry. Pool water chemistry must not be adversely affected by TAD canister materials. See *Behavior of Spent Nuclear Fuel in Water Pool Storage*, BNWL-2256.

(3) Prohibited or Restricted Materials

a. Except for graphite, the TAD canister shall not have organic, hydrocarbon-based materials of construction.

b. All metal surfaces shall meet surface cleanliness classification C requirement defined in ASME NQA-1-2000 Edition, Subpart 2.1 *Quality Assurance Requirements for Cleaning of Fluid Systems and Associated Components for Nuclear Power Plants*.

c. The TAD canister shall not be constructed of pyrophoric materials.

d. The TAD canister, including steel matrix, gaskets, seals, adhesives and solder, shall not be constructed with materials regulated as hazardous wastes under the Resource Conservation and Recovery Act (RCRA) and prohibited from land disposal under RCRA if declared to be waste.

Rationale: The extremely low organic carbon supply in the repository will limit heterotrophic microbial activity, which could otherwise accentuate corrosion or radionuclide transport. See *Evaluation of Potential Impacts of Microbial Activities on Drift Chemistry*; ANL-EBS-MD-000038 REV 01.

A pyrophoric event is defined as ignition, followed by rapid chemical oxidation or self-sustained burning. A constraint on availability of pyrophoric materials for exothermic reaction is used to Exothermic Reactions in the EBS. See *Waste Form Features, Events, and Processes*; ANL-WIS-MD-000009 REV 02.

To avoid the generation, storage, or disposal of hazardous or mixed waste that could subject the CRWMS facility to State of Nevada RCRA permitting requirements and NRC or DOE regulation. See *Civilian Radioactive Waste Management System Requirements Document;* DOE/RW-0406, Rev. 07.

(4) Markings

a. The TAD canister shall be capable of being marked on the lid and body with an identical unique identifier prior to delivery for loading.

b. The unique identifier space shall be of suitable length and height to contain nine (9) alphanumeric and two (2) special characters (e.g., -, /, "space", etc.) to be specified by the DOE.

c. Alphanumeric characters shall have a minimum height of 6 in.

d. The markings shall remain legible without intervention or maintenance during/after any of the following events:

- The entire 100 year service life.
- Normal operations to include loading, closure, storage, transportation, aging and disposal.
- Dose, heat and irradiation associated with the vendor defined design basis PWR or BWR, as applicable.

<u>Rationale</u>: This provides capability to further implement requirement for material control and accountability. See *Material Control and Accounting of Special Nuclear Material*; 10 CFR part 74.

3.2 Transportation Overpack

3.2.1 <u>General</u>

(1) The transportation overpack shall accommodate a TAD canister formed as a right-circular cylinder with a length of 212.0" and diameter of 66.5".

<u>Rationale</u>: The transportation overpack must be capable of containing a loaded TAD canister.

(2) The transportation overpack shall function with a TAD canister that has a maximum loaded weight 54.25 tons.

<u>Rationale</u>: The transportation overpack must be capable of containing a loaded TAD canister.

(3) The loaded transportation overpack (without impact limiters) shall be designed to be lifted in a vertical orientation by an overhead crane.

<u>Rationale</u>: Current GROA facility operations require handling transportation overpacks in a vertical orientation. It is consistent with common industry cask and overpack designs and handling practices.

(4) The loaded transportation overpack (without impact limiters) shall be able to stand upright when set down upon a flat horizontal surface without requiring the use of auxiliary supports.

Rationale: Requiring the transportation overpack stand upright in a vertical orientation facilitates simplified operations and preparations for TAD transfers. It is consistent with common industry cask and overpack designs and handling practices.

(5) The size and weight of the loaded transportation overpack shall be limited to the values listed in Table 3.2-1 of the current version of the *Preliminary Transportation, Aging and Disposal Canister System Performance Specification*; WMO-TADCS-000001.

Rationale: To establish reasonable interface parameters for repository surface facility interfaces such as trolley widths, sizes of shielded canister transfer area openings, crane heights, and crane capacities.

(6) Lifting attachments and appurtenances on transportation overpacks, overpack lids and impact limiters shall be designed, documented and fabricated in accordance with NUREG-0612 *Control of Heavy Loads at Nuclear Power Plants*.

Rationale: Heavy items, as defined in NUREG-0612, need to be safely and securely lifted and moved to handle TAD canisters.

3.2.2 Structural

(1) A loaded TAD canister contained within a transportation overpack assembled with any other components included in the packaging, as defined in 10 CFR part 71, shall meet requirements for a Type B cask as specified in 10 CFR part 71, as evidenced by a valid Certificate of Compliance.

Rationale: A valid Certificate of Compliance under 10 CFR part 71 for contents comprising the TAD system is sufficient to ensure that the transportable function is satisfied.

3.2.3 Thermal

(1) During normal operations, the CSNF cladding temperature in the TAD canister shall not exceed 752° F. Normal operations include transportation from purchaser sites to the GROA and on-site at the GROA.

Rationale: NRC Interim Staff Guidance for storage and transport of CSNF sets guidelines for cladding temperature. See *Cladding Considerations for the Transportation and Storage of Spent Fuel*; Interim Staff Guidance-11, Rev. 3

(2) Transportation overpack cooling features and mechanisms shall be passive.

Rationale: OCRWM requirement that will simplify GROA design, license application and future maintenance.

3.2.4 Dose and Shielding

(1) The transportation overpack impact limiters shall include design and handling features that use standardized tools and features that simplify removal operations.

Rationale: Supports DOE ALARA policy and design goals. This specification is currently an operational concept required under the current draft version of the *U.S. Department of Energy Spent Nuclear Fuel and High-Level Radioactive Waste to the Monitored Geologic Repository*; Integrated Interface Control Document, Volume 2, DOE/RW-0572, Rev. 0. The performance specification shall be updated as required upon release of the approved version.

(2) Transportation overpack shall be designed such that accessible external surfaces contamination shall be removable to:

a. 1,000 dpm/100 cm^2 - beta-gamma with a wipe efficiency of 0.1.
b. 20 dpm/100 cm^2 - alpha with a wipe efficiency of 0.1.

Rationale: Control of surface contamination on transportation overpacks supports the design of a radiologically clean facility. Such controls mitigate the potential for onsite and offsite releases of radioactive material. See "*Control of Radioactively Contaminated Material,*" IE Circular No. 81-07.

3.2.5 Criticality

No specific requirements beyond those of 10 CFR part 71.

Rationale: Transportation overpack must be transportable with a TAD canister loaded with vendor defined CSNF.

3.2.6 Containment

The loaded transportation overpack shall have a tamper indicting device (TID) that meets requirements of 10 CFR part 73 *Physical Protection of Plants and Materials*.

Rationale: Transportation overpack must be transportable with a TAD canister loaded with vendor defined CSNF.

3.2.7 Operations

(1) Normal operational procedures shall **not** require submergence of transportation overpacks into a CSNF handling pool water at either the repository or loading site.

Rationale: This specification is intended to mitigate spread of radioactive contamination of the exterior surfaces of the transportation overpack and mitigating potential for decontamination upon receipt. See "*Control of Radioactively Contaminated Material,*" IE Circular No. 81-07.

(2) Transportation overpacks shall have closures that can be bolted and unbolted using standard tools. Standard tools are those that can be found in industrial tool catalogs.

Rationale: This specification is currently an operational concept required under the current draft version of the *U.S. Department of Energy Spent Nuclear Fuel and High-Level Radioactive Waste to the Monitored Geologic Repository*; Integrated Interface Control Document, Volume 2, DOE/RW-0572, Rev. 0.

The performance specification shall be updated as required upon release of the approved version.

(3) The transportation overpack shall have two (2) upper and two (2) lower trunnions located between 44 in. and 51 in. from each end.

Rationale: The requirement allows use of a standard yoke for all transportation overpacks and allows for proper clearance to interface with GROA facilities.

(4) The transportation overpack shall be designed to permit the transportation overpack, without impact limiters, to be upended by rotation about its lower trunnions and removed in a vertical orientation via overhead crane.

Rationale: Facilitates preparation of the transportation overpack to remove a TAD canister. Ensures the transportation overpack will not require removal from conveyance in a horizontal orientation prior to upending.

(5) The transportation overpack shall have upper lifting trunnions with dual seats and lower turning trunnions.

Rationale: Facilitates preparation of the transportation overpack to remove a TAD canister. Ensures the transportation overpack will not require removal from conveyance in a horizontal orientation prior to upending.

(6) Trunnions shall remain attached to the transportation overpack body during transport.

Rationale: Installing and removing lifting trunnions on a loaded cask is an activity that requires exposure to ionizing radiation. This feature results in increased facility throughput.

(7) The transportation overpack lid shall have lift(ing) feature(s) (either fixed or removable) such that it can be lifted via the same grapple used to lift a vertically oriented, loaded TAD canister.

Rationale: Current GROA design concepts require removal of the loaded transportation cask lid using remote systems. In order to facilitate safer and more efficient unloading of transportation overpacks a common lifting tool concept is being required.

3.2.8 Materials

Materials selections shall be as required to meet requirements of 10 CFR part 71 and other requirements of this specification.

Rationale: Transportation overpack requires certification under 10 CFR part 71.

3.3 Aging Overpack

3.3.1 General

(1) The aging overpack shall accommodate a TAD canister that is based on a right-circular cylinder with a length of 212.0” and diameter of 66.5”.

Rationale: The aging overpack shall be capable of containing a loaded TAD canister.

(2) The aging overpack shall function with a loaded TAD canister having a maximum gross weight of 54.25 tons.

Rationale: The aging overpack shall be capable of containing a loaded TAD canister.

(3) The combined size and weight of the loaded TAD aging overpack shall be limited to the values listed the current version of the *Preliminary Transportation, Aging and Disposal Canister System Performance Specification*; WMO-TADCS-000001.

Rationale: To establish reasonable interface parameters for GROA facility interfaces such as trolley widths, sizes of transfer area openings, crane heights and capacities. See *Integrated Interface Control Document*; Volume 1 of *High-Level Radioactive Waste to the Monitored Geologic Repository*, DOE/RW-0511, Rev. 2.

(4) The loaded aging overpack shall meet the operational requirements detailed in sketch presented in the current version of the *Preliminary Transportation, Aging and Disposal Canister System Performance Specification*; WMO-TADCS-000001.

Rationale: To establish reasonable interface parameters for GROA facility interfaces such as trolley widths, sizes of transfer area openings, crane heights and capacities.

(5) The aging overpack shall be designed to be moved in a vertical orientation.

Rationale: Repository handling concepts are based on handling transportable aging overpacks with both an overhead crane and site transporter. This specification is based on current operational concepts and technical baseline in the *Yucca Mountain Project Conceptual Design Report.* TDR-MGR-MD-000014, Rev. 05. This cited source was not developed under the OCRWM QA program. Qualification is not required due to the associated values representing a bounding MGDS operational concept; not a calculations or analyses that need to be preformed under the QARD.

(6) The aging overpack lid shall have a permanent lifting ring compatible with the TAD canister grapple.

Rationale: OCRWM requirement.

(7) The designed maintainable service lifetime of the aging overpack shall be a minimum of 100 years.

Rationale: Doubling the anticipated allowable time frame provide design margin.

3.3.2 Structural

(1) See Section 3.1.2 (1) for the requirement and rationale.

(2) See Section 3.1.2 (2) for the requirement and rationale.

(3) Following an impact (with resultant fire) from an F-15 military aircraft into an aging overpack, the TAD canister shall maintain a maximum leak rate of 9.3×10^{-10} fraction of canister free volume per second (off-normal) and maximum cladding temperature 1,058° F (off-normal). The analysis shall assume the following:

a. The crash speed is assumed to be 500 ft/sec.

b. Impact orientation analyzed shall be that which results in maximum damage.

c. 12,000 lbs of JP-8 fuel.

d. F-15 airframe.

e. Two engine components of 3,740 lbs. and dimensions of 46.5 inches D × 191 inches each spaced 96 inches apart.

f. One (1) M61A1 20-mm cannon mounted internally just off center of axis.

g. 1,000 lbs of inert armaments (i.e., dummy bombs) located between the engines.

Rationale: Maintain TEDE limits and cladding integrity following the unlikely event of an impact of an F-15 with the aging overpack on the aging pad.

(4) See Section 3.2.2 (3) for requirements and rationale.

3.3.3 Thermal

(1) Aging overpack cooling features and mechanisms shall be passive.

Rationale: OCRWM requirement that will simplify the GROA design, license application and future maintenance.

(2) A loaded aging overpack shall be capable of withstanding a fully engulfing fire without the TAD canister exceeding a leakage rate of 9.3×10^{-10} fraction of canister free volume per second (off-normal) and maximum fuel cladding temperature of 1,058° F (off-normal) under the conditions below.

a. The resulting fire described by an aircraft impact.

b. The fire described in 10 CFR 71.73.c (4) *Hypothetical Accident Condition* requirements as modified below.

- The 30-minute period shall be replaced by a period to be determined by calculation of a pool spill fire formed by 100 gallons of diesel fuel.
- Additionally, a surrogate fully engulfing fire of duration twice the duration of the pool fire which starts simultaneously with the pool fire and with a steady-state

heat release rate of 10 MW shall be used to model the burning rate of all other solid and liquid combustible materials. For this purpose, assume the heat transfer conditions specified in 10 CFR 71.73.c (4). Temperature conditions from this fire shall be consistent with a totally engulfing black body emitting from the 10 MW requirement.

c. A loaded aging overpack shall withstand a deflagration blast wave, fuel tank projectiles and incident thermal radiation resulting from the worst case engulfing fire[8] determined in the previous fire protection requirement without the TAD canister exceeding a leakage rate of 9.3×10^{-10} fraction of canister free volume per second (off-normal) and maximum fuel cladding temperature of 1,058° F (off-normal).

Rationale: This fire protection standard should envelope any possible causality and allow for safe recovery.

3.3.4 Dose and Shielding

The loaded aging overpack combined neutron and gamma dose rate shall not exceed 40 mrem/hr on contact at any location on the exterior surface.

Rationale: 40 mrem/hr on contact is approximately 10 mrem/hr at 2 m from overpack surface, which is consistent with OCRWM ALARA program goals and specifications of several NRC-issued Certificates of Compliance.

3.3.5 Criticality

The aging overpack must be designed, fabricated and operated to support the design basis for the TAD for nuclear criticality mitigation.

Rationale: OCRWM requirement.

3.3.6 Containment

The aging overpack shall be designed such that following a 3-ft vertical drop or tip over from a 3-ft high site transporter, the TAD canister maximum leak rate is 9.3×10^{-10} fraction of canister free volume per second (off-normal) under applicable repository environmental conditions.

Rationale: To meet performance objectives for the GROA in terms of dose limits for workers and public. This specification is based on current operational concepts and technical baseline in the *Yucca Mountain Project Conceptual Design Report.* TDR-MGR-MD-000014, Rev. 05. This cited source was not developed under the OCRWM QA program. Qualification is not required due to the associated values representing a bounding MGDS operational concept; not a calculations or analyses that need to be preformed under the QARD.

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8 For this analysis, assume the total quantity of fuel shall vaporize into an efficient fuel-air mixture producing an explosive event. Effects of heat generation, fuel tank projectiles and blast wave propagation shall be considered.

3.3.7 Operations

(1) The aging overpack shall be designed to receive, age and discharge a loaded TAD canister in a vertical orientation.

Rationale: Current GROA concepts of operation allow for the vertical receipt, ageing and discharging of a loaded TAD canister. See *Yucca Mountain Project Conceptual Design Report*; TDR-MGR-MD-000014, Rev. 05.

(2) The loaded aging overpack shall be transportable on site in a vertical orientation.

Rationale: Current GROA concepts of operation allow for movement of an aging overpack in a vertical orientation. This specification is based on current operational concepts and technical baseline in the *Yucca Mountain Project Conceptual Design Report.* TDR-MGR-MD-000014, Rev. 05. This cited source was not developed under the OCRWM QA program. Qualification is not required due to the associated values representing a bounding MGDS operational concept; not a calculations or analyses that need to be preformed under the QARD.

(3) The loaded aging overpack shall be designed to remain in its transport orientation when set down on an essentially flat horizontal surface without use of auxiliary supports.

Rationale: OCRWM requirement for the loaded aging overpack to remain freestanding.

(4) The aging overpack shall have a vendor designed fixture(s) such that the loaded aging overpack can be handled via an overhead crane.

Rationale: Maximizes flexibility for transfer within GROA facilities.

(5) The loaded aging overpack shall be designed to be moved to the aging pad via site transporter using a pair of lift beams (e.g., forklift).

Rationale: Allows for transport via GROA aging overpack transporter.

(6) The aging overpack shall be capable of being transported by air pallet.

Rationale: Maximizes flexibility for transfer within GROA facilities. This specification is based on current operational concepts and technical baseline in the *Yucca Mountain Project Conceptual Design Report.* TDR-MGR-MD-000014, Rev. 05. This cited source was not developed under the OCRWM QA program. Qualification is not required due to the associated values representing a bounding MGDS operational concept; not a calculations or analyses that need to be preformed under the QARD.

3.3.8 Materials

No material requirements, prohibitions or restrictions have been identified for the aging overpack.

Rationale: None required.

4.0 GLOSSARY

The following section incorporates the definitions and descriptions of major “terms of art” used throughout this document.

Aging- Safely placing commercial CSNF in a site-specific overpack on an aging pad for a long period of time (years) for radioactive decay. Radioactive decay results in a cooler waste form to ensure thermal limits can be met. Safely aging CSNF is an integral part of GROA operations to ensure material has significantly decayed to meet licensed thermal limitations.

Burnup- A measure of nuclear reactor fuel consumption expressed either as the percentage of fuel atoms that have undergone fission or as the amount of energy produced per initial unit weight of fuel.

Canister- The structure surrounding the waste form that facilitates handling, storage, aging and/or transportation.

1. For CSNF, the canister may provide structural support for intact CSNF, loose rods, non-fuel components and confinement of radionuclides.
2. Canistered waste shall be placed in waste packages prior to emplacement.

Cladding- The metallic outer sheath of a fuel rod generally made of a zirconium alloy. It is intended to isolate the fuel from the external environment.

Design Bases- That information that identifies the specific functions to be performed by a structure, system, or component of a facility and the specific values or ranges of values chosen for controlling parameters as reference bounds for design. These values may be constraints derived from generally accepted “state-of-the-art” practices for achieving functional goals or requirements derived from analysis (based on calculation or experiments) of the effects of a postulated event under which a structure, system, or component must meet its functional goals. The values for controlling parameters for external events include:

1. Estimates of severe natural events to be used for deriving design bases that will be based on consideration of historical data on the associated parameters, physical data, or analysis of upper limits of the physical processes involved; and,
2. Estimates of severe external human-induced events to be used for deriving design bases, which will be based on analysis of human activity in the region, taking into account the site characteristics and the risks associated with the event. (10 CFR 63.2)

Event Sequence- A series of actions and/or occurrences within the natural and engineered components of a GROA that could potentially lead to exposure of individuals to radiation. An event sequence includes one or more initiating events and associated combinations of repository system component failures, including those produced by the action or inaction of operating personnel. Those event sequences that are expected to occur one or more times before permanent closure of the geologic repository operations area are referred to as Category 1 event sequences. Other event sequences that have at least one chance in 10,000 of occurring before permanent closure are referred to as Category 2 event sequences.

Fuel assembly- A number of fuel rods held together by plates and separated by spacers used in a reactor. This assembly is sometimes called a fuel bundle or fuel element.

Geologic Repository Operations Area (GROA)- A high-level radioactive waste facility that is part of a geologic repository, including both surface and subsurface areas, where wet handling activities are conducted. (10 CFR 63.2)

Hypothetical Accident Conditions- The sequential conditions and tests defined in 10 CFR part 71 subpart E (Package Approval Standards) and subpart F (Package, Special Form and LSA-III Tests) that a package (or array of packages) must be evaluated against.

High-Level Radioactive Waste (HLW)- (1) The highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; (2) Irradiated reactor fuel; and (3) Other highly radioactive material that the Commission, consistent with existing law, determines by rule requires permanent isolation. (10 CFR 63.2)

Important to Safety- In reference to structures, systems and components, means those engineered features of the GROA whose function is:

1. To provide reasonable assurance that high-level waste can be received, handled, packaged, stored, emplaced, and retrieved without exceeding the requirements of §63.111(b)(1) for Category 1 event sequences; or
2. To prevent or mitigate Category 2 event sequences that could result in radiological exposures exceeding the values specified at §63.111(b)(2) to any individual located on or beyond any point on the boundary of the site.

Important to Waste Isolation- With reference to design of the engineered barrier system and characterization of natural barriers, means those engineered and natural barriers whose function is to provide a reasonable expectation that high-level waste can be disposed of without exceeding the requirements of 10 CFR 63.113(b) and (c). (10 CFR part 63.2)

Neutron Absorber- A material (e.g., boron) that absorbs neutrons used in nuclear reactors, transportation overpacks and waste packages to control neutron multiplication.

Normal Conditions of Transport- The conditions and tests defined in 10 CFR part 71 subpart E (Package Approval Standards) and subpart F (Package, Special Form and LSA-III Tests) that all packages must be evaluated against.

Postclosure- The period of time after closure of the geologic repository.

Preclosure- The period of time before and during closure of the GROA disposal system.

Site- An area surrounding the GROA for which the DOE exercises authority over its use in accordance with the provisions of 10 CFR part 63.

Site Transporter- A self-powered vehicle designed to haul the TAD canister and contents while within either a shielded transfer cask or aging overpack between GROA surface facilities.

Shielded Transfer Cask (STC)- A cask that meets applicable requirements for safe transfer of a TAD canister and its contents between various surface facilities.

Spent Nuclear Fuel (SNF)- Fuel withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing.

Storage– For the purposes of this specification, the placement, by a licensees and/or purchasers, of spent nuclear fuel in independent spent fuel storage installations (ISFSI) certified under title 10 CFR part 72.

TAD System- The set of components consisting of one or more TAD canisters, transportation overpacks, transportation skids, ancillary equipments, shielded transfer casks, aging overpacks and site transporters used to facilitate handling of CSNF.

Total Effective Dose Equivalent- For purposes of assessing doses to workers, the sum of the deep-dose equivalent (for external exposures) and committed effective dose equivalent (for internal exposures).

Transportation Overpack- The assembly of components of the packaging intended to retain the radioactive material during transport.

Trunnion- Cylindrical protuberance for supporting and/or lifting located on the outside of a container or cask (e.g., waste package, aging overpack, etc.)

Waste package- The waste form and any containers, shielding, packing and other absorbent materials immediately surrounding an individual waste container.