



NUREG-2216

Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material

Final Report

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Standard Review Plan for Transportation Packages for Spent Fuel and Radioactive Material

Final Report

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ABSTRACT

This Standard Review Plan (SRP) provides guidance to the U.S. Nuclear Regulatory Commission (NRC) staff for reviewing an application for package approval issued under Title 10 of the *Code of Federal Regulations* (10 CFR), Part 71, "Packaging and Transportation of Radioactive Material." NRC approval of a package design typically results in issuance of a certificate of compliance (CoC) or a letter amendment for a transportation package.

The objectives of this SRP are to assist the NRC staff in its reviews by

- providing a basis that promotes uniform quality and a consistent regulatory review of an application for a CoC for a transportation package
- presenting a basis for the review's scope
- identifying acceptable approaches to meeting regulatory requirements
- suggesting possible evaluation findings that can be used in the safety evaluation report

This SRP was published for public comment, and the responses to those comments are available at ML20023A361. This SRP may be revised and updated as the need arises on a chapter-by-chapter basis to clarify the content, correct errors, or incorporate modifications approved by the Director of the NRC Division of Spent Fuel Management. Comments, suggestions for improvement, and notices of errors or omissions should be sent to and will be considered by the Director, Division of Spent Fuel Management, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001.

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ABBREVIATIONS AND ACRONYMS

ADAMS	Agencywide Documents Access and Management System
Ag	silver
AISC	American Institute of Steel Construction
ALARA	as low as is reasonably achievable (radiation exposure)
Am	americium
ANL	Argonne National Laboratory
ANS	American Nuclear Society
ANSI	American National Standards Institute
ASNT	American Society for Nondestructive Testing
APSR	axial power shaping rod
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
AWRE	Atomic Weapons Research Establishment
B ₄ C	boron carbide
B&PV	Boiler and Pressure Vessel (ASME Code)
BPR	burnable poison rod
BPRA	burnable poison rod assembly
BWR	boiling-water reactor
CE	Combustion Engineering
CE-PWR	Combustion Engineering System 80+ Pressurized-Water Reactor
CFR	Code of Federal Regulations
c.g.	center of gravity
CH ₄	methane
CISCC	chloride-induced stress corrosion cracking
CMS	computational modeling software
CoC	certificate of compliance
CR	control rod
CRC	commercial reactor critical
Cs	cesium
CSI	criticality safety index
CVCM	collected volatile condensable materials
D	deuterium (chemical symbol)
D ₂	deuterium gas
D ₂ O	deuterium oxide, heavy water
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DSFM	Division of Spent Fuel Management (NRC)
DT	deuterium tritium
DTO	tritiated heavy water
EALF	energy of average neutron lethargy-causing fission
EIA	Energy Information Administration
EPR	ethylene propylene rubber
EPRI	Electric Power Research Institute
Er	erbium

Er ₂ O ₃	erbium oxide
Eu	europium
FG	fuel grade
GBC	generic burnup credit cask
GCI	grid convergence index
Gd	gadolinium
Gd ₂ O ₃	gadolinium oxide
GE	General Electric
H	hydrogen, protium (chemical symbol)
H ₂	hydrogen gas
H ₂ O	water
HD	hydrogen deuteride
HDO	hydrogen-deuterium oxide
HPS	Health Physics Society
HT	tritium gas
HTC	Haut Taux de Combustion
HTO	tritiated water vapor, tritium oxide
H/X	hydrogen-to-fissile atom ratios
IAEA	International Atomic Energy Agency
IBA	integral burnable absorber
ICRP	International Commission on Radiological Protection
IHECSBE	International Handbook of Evaluated Criticality Safety Benchmark Experiments
IN	information notice (NRC)
INMM	Institute for Nuclear Materials Management
ISG	interim staff guidance
<i>k_{eff}</i>	“k” effective-neutron multiplication factor or effective thermal conductivity
LEU	low-enriched uranium
lfpm	linear feet per minute
LiAlO ₂	lithium aluminate
LSA	low specific activity
LWR	light-water reactor
MMC	metal matrix composite
MNOP	maximum normal operating pressure
Mo	molybdenum
MOX	mixed oxide
N ₂	nitrogen gas
NASA	National Aeronautics and Space Administration
Nd	neodymium
NDE	nondestructive examination
NDT	nondestructive testing
NFH	nonfuel hardware
NIST	National Institute of Standards and Technology

NMSS	NRC Office of Nuclear Material Safety and Safeguards
Np	neptunium
NRC	U.S. Nuclear Regulatory Commission
NRR	Office of Nuclear Reactor Regulation (NRC)
NSA	neutron-source assembly
O	oxygen
O ₂	oxygen gas
OCRWM	Office of Civilian Radioactive Waste Management
OFA	optimized fuel assembly
ORNL	Oak Ridge National Laboratory
UO ₂	uranium dioxide
PEEK	polyetheretherketone
PG	power grade
PNNL	Pacific Northwest National Laboratory
Pu	plutonium
PVC	polyvinyl chloride
PWR	pressurized-water reactor
QA	quality assurance
QAPD	quality assurance program description
QARD	quality assurance requirements document
RAC	Respiratory Advisory Committee (DOE)
RAI	request for additional information
RAM	radioactive material
RCA	radiochemical assay
RES	Office of Nuclear Regulatory Research (NRC)
RG	regulatory guide (NRC)
Rh	rhodium
RIS	regulatory issue summary
RSICC	Radiation Safety Information Computational Center
Ru	ruthenium
SAR	safety analysis report
SBR	styrene-butadiene
SCO	surface contaminated object
SER	safety evaluation report
SFPO	Spent Fuel Project Office (NRC)
SI	International System of Units
Sm	samarium
SNF	spent nuclear fuel
SRP	standard review plan
SRS	Savannah River Site
SSCs	structures, systems, and components
STP	standard temperature and pressure
T	tritium (chemical symbol)
T ₂	molecular tritium, tritium gas

T ₂ O	tritium oxide
Tc	technetium
TI	transportation index
TML	total mass loss
TPBARs	Tritium-Producing Burnable Absorber Rods
TVA	Tennessee Valley Authority
U	uranium
UF ₆	uranium hexafluoride
UO ₂	uranium dioxide
UT	ultrasonic testing
WG	weapons grade
WREC	Westinghouse Reactor Evaluation Center
X/Q	atmospheric dispersion

UNITS

A/g	Specific activity per gram
atm	atmosphere
Bq	Becquerel
C	Celsius
°C	degrees Celsius
Ci	curie
Ci/cm ³	curies per cubic centimeter
Ci/liter	curie per liter
Ci/yr	curies per year
cm	centimeter
cm ⁻¹	per centimeter
cm ²	square centimeter
cm ³	cubic centimeter
dpm/100 cm ²	disintegrations per minute per 100 square centimeters
eV	electron volt
F	Fahrenheit
°F	degrees Fahrenheit
ft	foot
ft ²	square foot
ft ³	cubic foot
g	gravitational unit
gm	gram
GWd/MTU	gigawatt days per metric ton uranium
GWd/MTHM	gigawatt days per metric ton of heavy metal
Gy	gray
hr	hour
in.	inch
K	Kelvin
keV	kilo electron volt
kg	kilogram
km	kilometer
kPa	kilopascal
ksi	thousand pounds per square inch
L	liter
lb	pound
m	meter
m ²	square meter
m ³	cubic meter

mb	millibar
mCi	millicurie
mCi/hr	millicuries per hour
mCi/m ³	millicuries per cubic meter
mCi/(TPBAR-hr)	millicuries per TPBAR per hour
MeV	mega electron volt
mg	milligram (one-thousandth of a gram)
mg/cm ²	milligrams per square centimeter
mi	mile
mJ	millijoule
ml	milliliter
mm	millimeter (one-thousandth of a meter)
MPa	megapascal (million pascals)
mph	miles per hour
mrem	millirem
ms	millisecond
mSv	millisievert
MT	metric ton
MTHM	metric tons of heavy metal
MW	megawatt
MWd	megawatt days
MWd/MTU	megawatt days per metric ton uranium
MWd/MTHM	megawatt days per metric ton of heavy metal
N	newton
nCi	nanocurie
Pa	Pascal
PBq	petabecquerel
ppm	parts per million
psf	pounds per square foot
psi	pounds per square inch
psig	pounds per square inch gauge
rad	radiation-absorbed dose
s	second
Sv	sievert
Tbq	terabecquerel
μCi	microcurie
μm	micrometer
W	watt
wt%	weight percent
yr	year

INTRODUCTION

Purpose of the Standard Review Plan

The Standard Review Plan for Transportation Package Approval (referred to herein as the SRP) provides guidance to the U.S. Nuclear Regulatory Commission (NRC) staff for reviewing applications for approval of package designs used for the transport of radioactive materials under Title 10 of the U.S. *Code of Federal Regulations* (10 CFR) Part 71. It is not intended as an interpretation of NRC regulations. Nothing contained in this SRP may be construed as having the force and effect of NRC regulations (except where the regulations are cited), or as indicating that applications supported by safety analyses and prepared in accordance with Regulatory Guide (RG) 7.9, “Standard Format and Content of Part 71 Applications for Approval of Packages for Radioactive Material,” will necessarily be approved, or as relieving any person from the requirements of 10 CFR Part 71 as well as other pertinent regulations, including but not limited to the following:

- 10 CFR Part 20, “Standards for Protection Against Radiation”
- 10 CFR Part 30, “Rules of General Applicability to Domestic Licensing of Byproduct Material”
- 10 CFR Part 40, “Domestic Licensing of Source Material”
- 10 CFR Part 60, “Disposal of High-Level Radioactive Wastes in Geologic Repositories”
- 10 CFR Part 70, “Domestic Licensing of Special Nuclear Material”

Three major objectives of this SRP include the following:

- summarize the regulatory requirements for package approval
- describe the procedure by which the staff determines that the requirements have been satisfied
- document the practices the NRC developed in previous package certifications

This SRP complements RG 7.9, which provides guidance to applicants on the standard format and content of applications for package approval. Unless specified, all acceptance criteria and review guidance in this SRP is applicable to all packages. Appendix A, “Description, Safety Features, and Areas of Review for Different Types of Radioactive Material Transportation Packages,” to this SRP describes different types of packages for different types of contents and provides specific information on reviewing each package type. Note that Appendix A does not contain guidance specific to spent nuclear fuel packages.

Applicability

This SRP provides guidance for the NRC staff’s review and approval of certificates of compliance for packaging used to transport radioactive materials (RAM).

Appendix E, “Description and Review Procedures for Irradiated Tritium-Producing Burnable Absorber Rods Packages,” to this SRP provides supplemental general information and

guidance for reviewing applications for packaging used in the shipment of irradiated tritium-producing burnable absorber rods (TPBARs).

Organizational Structure

The SRP is organized to correlate with the recommended content for an application, as detailed in RG 7.9, which will be revised in the future to harmonize with this SRP. The individual sections of each chapter address the matters that are reviewed, the basis for the review, how the review is accomplished, and the conclusions that are sought and follow a common outline of subsections, as described below. In conjunction with the SRP, the NRC staff developed several interim staff guidance (ISG) documents related to package approvals under 10 CFR Part 71. An ISG addresses emergent review issues. This SRP combines and updates NUREG-1609, “Standard Review Plan for Transportation Packages for Radioactive Material,” issued September 1997, and NUREG-1617, “Standard Review Plan for Transportation Packages for Spent Nuclear Fuel,” issued March 2000, and their supplements and incorporates applicable ISGs, as shown in Table 1.

Table 1 Interim Staff Guidance (ISGs) Incorporated Into This Standard Review Plan		
ISG # & Rev.	Title	Affected Chapter(s)
ISG 1 Rev. 2	Damaged Fuel	2, 4, 5, 6, 7
ISG 6	Establishing Minimum Initial Enrichment for the Bounding Design Basis Fuel Assembly(s)	5
ISG 7	Potential Generic Issue Concerning Cask Heat Transfer in a Transportation Accident	3
ISG 8 Rev. 3	Burnup Credit in the Criticality Safety Analyses of PWR Spent Fuel in Transport and Storage Casks	6
ISG 11 Rev. 3	Cladding Considerations for the Transportation and Storage of Spent Fuel	7
ISG 15	Materials Evaluation	5, 6, 7
ISG 19	Moderator Exclusion Under Hypothetical Accident Conditions and Demonstrating Subcriticality of Spent Fuel Under the Requirements of 10 CFR 71.55(e)	1, 3, 6
ISG 20	Transportation Package Design Changes Authorized Under 10 CFR Part 71 Without Prior NRC Approval	1, 3, 5, 6, 8, 9
ISG 21	Use of Computational Modeling Software	2, 3
ISG 22	Potential Rod Splitting Due to Exposure to an Oxidizing Atmosphere During Short-Term Cask Loading Operations in LWR or Other Uranium Oxide Based Fuel	3, 8
ISG 23	Application of ASTM Standard Practice C1671-07 When Performing Technical Reviews of Spent Fuel Storage and Transportation Packaging Licensing Actions	3, 5, 6, 7, 9

Because of the large variety of packages and the many different approaches that can be taken to evaluate these package designs, no single review plan can address in detail every situation that might be applicable to a review. The staff may therefore need to modify or expand the guidance in this review plan to adapt to specific package designs. The following areas of 10 CFR Part 71 are not within the scope of this SRP:

- Qualification and shipment of low-specific-activity material and surface-contaminated objects
- Qualification of special form radioactive material
- Reports, records, notifications, violations, and criminal penalties
- Exemptions and general licenses
- Requirements incorporated into 10 CFR Part 71 by reference to other regulations, (e.g., 10 CFR Parts 20, 21, 30, 40, 70, 73, and DOT or U.S. Postal Service regulations)

Technical Review Oversight

Certificate holders are responsible for demonstrating that the package design meets the requirements in 10 CFR Part 71, Subparts D, “Application for Package Approval,” and E, “Package Approval Standards,” and performing the preliminary determination, as required by 10 CFR 71.85, “Preliminary Determinations.” Licensees are responsible for complying with the general license in accordance with 10 CFR 71.17, “General License: NRC-Approved Package,” for safe operation and for complying with appropriate regulations during shipment. The NRC mission as the regulator is to confirm that the package design provides adequate protection of public health and safety and the environment. The value of the NRC review team is its independent expertise in identifying and ensuring the resolution of potential design or operational deficiencies, analytical errors, nonconservatisms or significant uncertainties in novel design approaches, or other issues that hinder the NRC’s ability to ensure compliance with the regulations. If otherwise left unchecked by the licensee and the regulator, these issues could potentially lead to the unsafe or noncompliant use of the package.

Several considerations may influence the depth and rigor that is needed for a reasonable assurance determination of both safety and compliance. These include, but are not limited to, the novelty of the design (as compared to existing designs), safety margins, operational experience, and defense-in-depth. Any aspect of the design or procedures that the NRC determines the certificate holder should not change, without prior NRC approval, should be placed as a condition in the certificate. The design is specified in the certificate of compliance (CoC) (by reference) with drawings, operating procedures, acceptance tests and maintenance programs, and with other relevant documentation as needed. The staff and applicant should ensure that the CoC conditions include the appropriate level of detail that could also allow for appropriate minor changes to the package but still be within the design specified in the CoC (e.g., tolerances that are bounding of variations that can be seen in package fabrication).

Review Process

The reviews of the application are performed by reviewers with expertise in the technical areas described in this SRP. Because of the dependence between technical information in different sections of the application, coordination among the different disciplines is important to ensure a consistent, uniform, and high-quality review. As shown in the flow charts contained in each chapter of this SRP, technical issues are interwoven among the disciplines, and many rely on input from multiple areas.

When reviewing an amendment to a package design, the staff should consult the SERs of previous amendments, if applicable, as well as the SERs for similar, approved packages to

understand past NRC determinations regarding analyses affecting or similar to those in the application under review. In conducting reviews, the staff should confirm that the application properly applies NRC regulatory guidance, when endorsed by reference. While applicants are not required to comply with NRC guidance, the use of NRC guidance facilitates the staff's review process in evaluating package designs and confirming compliance with NRC regulations.

For amendments, the staff should review the entire amendment to ensure that the applicant has identified all the changes to the certificate of compliance. Amendments may range from minor changes in the design, contents, or operations to adding new major component designs or contents. Some amendments are based upon the design and methodologies the NRC previously reviewed for that package. Evaluations of amendment changes are often based on the performance of the package as an integrated system. As a result, the staff may reexamine portions of previously approved components, contents, or methodologies in the application to ensure that the design and operations, as modified under the amendment proposal, meet 10 CFR Part 71 requirements. During the audit review of an amendment, the staff may occasionally find errors or other safety questions that affect part of the previously approved design. The staff may need to review that part of the application and ask questions to assure the design remains safe and compliant with applicable regulations. The questions should be limited to understanding and resolving the specific technical issue and should consider past precedents, regulatory guidance, and risk significance, as appropriate. The staff should also consider other processes (e.g., inspections, enforcement actions, generic issue program) to resolve these types of potential safety questions with a previously approved design.

If the information provided in the application is not properly justified, the reviewer may develop and then forward to the applicant questions requesting clarification of technical issues via a request for additional information (RAI). The staff should review the applicant's response to the RAI, together with a supplemented application, for acceptability. The RAI process is repeated, as necessary, until the applicant demonstrates that the package design meets 10 CFR Part 71, or until the NRC terminates the application review or the applicant withdraws the application.

Safety Evaluation Report and Content

The NRC staff documents the results of an application review in a safety evaluation report (SER). Although the NRC Project Manager for the review will make the final determination of the organization of an SER, the SER typically is organized in the same manner as this SRP and contains the following information:

- a general description of the package, including the design and operational features, and content specifications
- a summary of the approach the applicant used to demonstrate compliance with the regulations, and a description of the reviews that the staff performed to confirm compliance
- comparison of systems, components, analyses, data, or other information important in the review analysis to the acceptance criteria, in addition to staff conclusions (including the bases for those conclusions) regarding the acceptability, suitability, or appropriateness of this information to provide reasonable assurance the acceptance criteria have been met

- summary of aspects of the review that were selected or emphasized, aspects of the design or contents that were modified by the applicant, aspects of the design that deviated from the criteria stated in the SRP, and the bases for any deviations from the SRP
- summary statements for evaluation findings at the end of each chapter

Content of this Standard Review Plan

Each chapter of the SRP is organized into the following sections:

- Review Objective
- Areas of Review
- Regulatory Requirements and Acceptance Criteria
- Review Procedures
- Evaluation Findings
- References

Review Objective This section provides the purpose and scope of the review and establishes the major review objectives for the chapter. The reviewer should obtain reasonable assurance during the review that the objectives are met.

Areas of Review This section lists the areas of review. Each area of review encompasses systems, components, analyses, data, or other information and provides the organizational structure for the rest of the chapter.

Regulatory Requirements and Acceptance Criteria The regulatory requirements portion of this section summarizes the regulatory requirements for 10 CFR Part 71 pertaining to the given chapter and can also list other significant regulatory requirements, such as those for 49 CFR Part 173, “Shippers—General Requirements for Shipments and Packagings.” This list is not all-inclusive, and the reviewer should refer to the regulations to ensure all relevant requirements are addressed in the application.

This subsection includes the regulatory requirements by reference and identifies other criteria to demonstrate that the package meets the regulatory requirements in 10 CFR Part 71 that apply to the given chapter. In most chapters, the acceptance criteria are organized similar to the review areas established in the “Areas of Review” section of the specific chapter and identify the type and level of information that should be in the application.

This section typically sets forth the solutions and approaches that staff reviewers have previously determined to be acceptable for demonstration of compliance with the regulations and addressing specific safety concerns or design areas that are important to safety. These solutions and approaches are discussed in this SRP so that the reviewers can implement consistent and well-understood positions as similar safety issues arise in future cases. These solutions and approaches are acceptable to the staff, but they are not the only possible method for meeting the regulations.

Substantial staff time and effort has gone into developing these acceptance criteria. Consequently, a corresponding amount of time and effort may be required to review and accept new or different solutions and approaches. Thus, applicants proposing new solutions and approaches to safety issues or analytical techniques other than those described in the SRP may

experience longer review times. An alternative for the applicant is to propose new methods on a generic basis, apart from a CoC. Such an alternative proposal could consist of a submittal of a topical report.

Review Procedures This section presents a general approach that reviewers typically follow to establish reasonable assurance that the applicable acceptance criteria have been met. As an aid to the reviewer, this section may also provide information on what has been found acceptable in past reviews. This section identifies standards that have been found acceptable in particular reviews, or that are desirable but not specifically identified in existing regulatory documents. Since many reviews of applications are interdisciplinary, the reviewers should coordinate with each other, as necessary, to identify issues in other chapters. The section includes a flow chart figure to depict the coordination that may be necessary to conduct reviews. In addition, the reviewer may provide discussions on conditions of the approval. In these cases, the reviewer should include a discussion of each condition and the reasons for the addition of the condition in the relevant sections of the SER.

Evaluation Findings This section provides example evaluation findings and summary statements to be incorporated into the SER. The reviewer prepares the evaluation findings based on the applicant's satisfaction of the regulatory requirements. The findings are published in the SER.

References This section lists the NRC documents, codes, specifications, standards, regulations, and other technical documents referenced in the chapter.