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design criteria for consolidation of LWR spent fuel

an American National Standard

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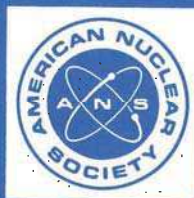
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**American National Standard
Design Criteria for Consolidation
of LWR Spent Fuel**

Secretariat
American Nuclear Society

Prepared by the
**American Nuclear Society
Standards Committee
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American National Standard

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Foreword

(This Foreword is not a part of American National Standard Design Criteria for Consolidation of LWR Spent Fuel, ANSI/ANS-57.10-1996.)

This standard provides design criteria for the equipment and systems comprising the rod consolidation process for commercial light water reactor (LWR) spent fuel assemblies. The criteria are applicable to wet and dry, and horizontal and vertical, consolidation concepts.

The standard does not include storage of the spent nuclear fuel either prior to consolidation or upon completion of the process. There is a section in the standard which identifies interface considerations of the process with the facility or installations in which consolidation will take place.

The rod consolidation process is intended to produce canisters filled with full-length fuel rods that have been removed from spent nuclear fuel. The process removes those components that maintain rod spacing and, thereby, allows the individual fuel rods to be reconfigured into a close packed array. This is intended to result in more efficient spent fuel management.

The standard is intended to be consistent with the requirements of the regulations in Title 10, "Energy," Code of Federal Regulations, Part 50, "Domestic Licensing of Production and Utilization Facilities," and Part 72, "Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation (ISFSI)."

The revision was part of periodic, routine maintenance. It includes updated references and clarifications.

The membership of Working Group ANS-57.10 of the Standards Committee of the American Nuclear Society, during the development of this revision, was as follows:

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Design Criteria for Consolidation of LWR Spent Fuel

1. Introduction and Scope

1.1 Introduction. This standard is intended to be used by: a) those involved in specifying the requirements for the equipment and systems necessary to consolidate light water reactor (LWR) spent nuclear fuel (rod consolidation); b) the designer of consolidation equipment and systems to define the minimum requirements; c) regulatory agencies in their evaluation of applications to perform rod consolidation.

This standard continues the set of similar American National Standards on the subject of spent nuclear fuel storage and handling.¹ The complementary standards are: Design Criteria for an Independent Spent Fuel Storage Installation (Water Pool Type), ANSI/ANS-57.7-1992 [1],² and Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type), ANSI/ANS-57.9-1992 [2].

1.2 Scope. This standard provides design criteria for the process of consolidating LWR spent nuclear fuel in either a wet or a dry environment. It addresses processes for consolidating fuel either horizontally or vertically. The standard sets forth requirements for utilizing equipment and systems to perform consolidation, handle fuel rods and nonfuel-bearing components, and handle broken fuel rods. This standard also contains requirements for facility or installation interfaces, nuclear safety, structural design, thermal design, accountability, safeguards, decommissioning, and quality assurance.

The standard is not concerned with the storage of the spent fuel either before or after the consolidation process. These areas are covered in the following American National Standards:

Design Requirements for Light Water Reactor Spent Fuel Facilities at Nuclear Power Plants, ANSI/ANS-57.2-1992 [3].

Design Criteria for an Independent Spent Fuel Storage Installation (Water Pool Type), ANSI/ANS-57.7-1992 [1].

Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type), ANSI/ANS-57.9-1992 [2].

1.3 Limits of Application. This standard applies to the process of rod consolidation. It is intended that the process be performed at commercial LWR nuclear power plants, reprocessing facilities, or other installations which receive, store, or dispose of LWR spent fuel. Other limits of application are that the spent nuclear fuel to be consolidated is commercial LWR fuel and has a minimum of one year of cooling after discharge from the reactor core.

1.4 Overall Design Consideration. This standard is based on the following factors that reduce the potential hazards of the rod consolidation process:

- (a) Short lived, high specific activity radionuclides, particularly those of iodine and xenon, are no longer present in significant quantities because of the minimum one year cooling time after discharge from the reactor core;
- (b) Very little remaining radioactivity is in a dispersible form;
- (c) Decay heat is greatly reduced because of the minimum one year cooling time after discharge from the reactor; and
- (d) Nuclear reactivity is reduced because of burnup.³

¹ Similar Standards as defined in American National Standards Institute Executive Standards Council-525, "ANSI Guide to Resolving Similar/Duplicate Standards Problems."

² Numbers in brackets refer to corresponding numbers in Section 7, References.

³ Most fuels decrease monotonically in reactivity with burnup; certain fuels initially increase in reactivity during the first cycle, then decrease.

1.5 Format of Standard. For purposes of presentation, the rod consolidation process has been divided into seven subfunctions:⁴

- (a) End Fitting Removal
- (b) Rod Removal
- (c) Rod Array Reconfiguration
- (d) Consolidated Rod Packing
- (e) Nonfuel-Bearing Component Handling
- (f) Off-Normal Rod Handling
- (g) Auxiliary Operations.

Separate pieces of equipment are not necessarily required for each subfunction. For each unit operation, the design requirements include:

- (a) Codes and Standards
- (b) Requirements
- (c) Interfaces
- (d) Testing, Inspection, and Maintenance
- (e) Design Documentation.

Design requirements have also been established to address seven areas of concern which impact all aspects of the rod consolidation process:

- (a) Facility or Installation Interfaces
- (b) Nuclear Safety and Radiological Protection
- (c) Structural Analysis
- (d) Thermal Criteria
- (e) Accountability and Safeguards
- (f) Decommissioning
- (g) Quality Assurance.

2. Definitions

This section defines terms applicable to this standard.

broken rod. A rod that has been severed into two or more pieces and requires special handling.

canister. A container or restraints used to hold rods in a close-packed array. The canister may or may not have grids and may or may not act as a confinement barrier.

confinement. The structure, system, or component provided for the purpose of controlling the release of radioactive particulate matter; it may be either a physical barrier or a high efficiency filtration system.

commercial grade item. An item that satisfies the following:

- (a) is not subject to design or specification requirements that are unique to the nuclear industry,
- (b) is used in applications other than nuclear facilities,
- (c) is to be ordered from the manufacturer or supplier on the basis of specifications set forth in the manufacturer's published product description.

crud. The deposits on a spent fuel assembly that result primarily from mass transfer processes operating on the corrosion/erosion products from the various structural materials in contact with the reactor coolant in a LWR.

damaged rod. A rod in which the fuel cladding exhibits visible evidence of structural change that would compromise the rod consolidation process or fuel confinement.

design events. Postulated occurrences used to establish design requirements to satisfy operational and safety criteria of the rod consolidation system. Evaluation of the consequences of such occurrences are used to specify the performance requirements of the rod consolidation system.

design event I. An event that is expected to occur regularly or frequently in the course of normal operation of the rod consolidation system. Examples are:

- Loading of the spent fuel assembly into the consolidation machine;
- Removal of the end fittings;
- Removal of the rods;
- Rod array reconfiguration;
- Transfer of the canister of consolidated rods from the consolidation machine back to storage;

⁴ Six of these subfunctions comprise the separate unit operations which are performed and which are depicted in Figure A-1, Rod Consolidation Process Illustrative Flow Diagram, in Appendix A.

Confinement and control of debris (e.g., crud); and
Consolidation of nonfuel-bearing components.

design event II. An event that, although not occurring regularly, can be expected to occur with moderate frequency or on the order of once during any calendar year of rod consolidation system operation. A calendar year of rod consolidation operation is considered to be the processing of approximately 25 metric tons of uranium (MTU). Examples are:

- A loss of external power supply (single failure in the electrical system) for a limited duration;
- Handling of stray rod(s) and broken rod(s);
- Spurious operation of active components; and
- A single operator error followed by corrective action.

design event III. An infrequent event that could reasonably be expected to occur once during the lifetime of the rod consolidation system. Examples are:

- A loss of power for an extended interval;
- Dropping of a canister of consolidated rods;
- Failure of a major component of the rod consolidation system that cannot be repaired on site;
- Spilling of rods from a canister of consolidated rods; and
- Incorrect characterization of the spent fuel assembly to be consolidated.

design event IV. A low-probability event that, because of its consequences, may result in the maximum potential impact on the immediate environs. Examples are:

- Natural phenomena such as earthquakes, tornadoes, tornado-induced missiles, fires, and floods; and
- Man-induced, low-probability events such as aircraft impact, flammable material explosions, and explosion-induced missiles.

end fittings (nozzles). The portions of the spent fuel assembly which define the upper and lower extremities. Removal of an end fitting allows access to individual rods.

handling equipment. Manually or power operated devices used for performing relocation operations on rods, spent fuel assemblies, or canisters.

nonfuel-bearing components (NFBC). All components of a spent fuel assembly except the fuel rods, such as: end fittings, spacer grids, control rod guide tubes, water rods, and springs.

rod. That portion of a spent fuel assembly which is a long, thin walled tube closed by end caps. A rod may contain either fuel (uranium, plutonium, and fission products) or nonfuel material.

rod consolidation. The process of reducing the spacing between rods (also referred to as reconfiguration).

rod removal. Pulling or pushing a rod out of a spent fuel assembly. Rods can be removed from a spent fuel assembly singularly, in groups, in rows, or all simultaneously.

shall, should, and may. "Shall" denotes a requirement; "should" denotes a recommendation; "may" denotes permission, neither a requirement nor a recommendation.

spacer grids. Components that maintain the rods in a specific array in spent fuel assemblies and are axially located between the end fittings. The function of the spacer grids is to restrain the rod laterally from bowing and vibrating.

spent fuel assembly. A single fabricated unit discharged from a commercial light water power reactor, still in the same mechanical configuration as when irradiated, containing rods and nonfuel-bearing components.

stray rod. A rod in either of the following conditions during the rod consolidation process: (a) partly inserted into a canister, or (b) in a position or situation (e.g. severely bowed) not normal for the process.

stuck rod. A rod which cannot be removed from the spent fuel assembly during the normal operation of rod removal.

3. Process Functions

The function of the rod consolidation process is to reduce safely the volume taken up by a spent

fuel assembly. The following activities will typically take place during the rod consolidation process:

- (a) Consolidation equipment is prepared for operation,
- (b) Spent fuel assembly identification and reactivity is confirmed,
- (c) A spent fuel assembly is placed into the consolidation equipment,
- (d) An end fitting is removed to allow access to the rods,
- (e) The rods are removed from the spent fuel assembly through the use of multiple or single rod removal techniques,
- (f) The rod array is placed into a canister in a reconfigured form,
- (g) The remaining nonfuel-bearing components are processed to facilitate storage and disposal, and
- (h) The canisters are prepared for storage.

4. Process Description

The process of rod consolidation has been divided into subfunctions for the purpose of this standard. The following are the descriptions of the subfunctions and are the basis on which the design criteria are presented. This division of the process into subfunctions is for convenience in the presentation of the performance requirements and related design criteria, and is not intended to imply that separate and independent equipment systems are required for each subfunction.

4.1 End Fitting Removal. End fitting removal permits access to the fuel rods. Removal can be accomplished by cutting or mechanical unfastening of one or both of the end fittings from the fuel assembly. This portion of the rod consolidation process also provides for handling of the end fittings and associated hardware.

4.2 Rod Removal. The controlled separation of the individual fuel rods from the spacer grids and other nonfuel-bearing components is accomplished in the rod removal portion of the rod consolidation process. The spent fuel assembly is restrained as necessary. To facilitate fuel rod separation, the removal device may be attached to the rods by mechanical clamping or

by bonding. Rods may be removed either as a group or individually.

4.3 Rod Array Reconfiguration. Rod array reconfiguration is the transformation of the rod array from that found in the fuel assembly to a closer packed array required by the consolidated rod canister. A transition device may be used to accomplish reconfiguration.

4.4 Consolidated Rod Packaging. Packaging of fuel rods is performed in order to:

- (a) Maintain the reconfigured geometry,
- (b) Provide structural support for the rods, and
- (c) Facilitate handling and storage of the rods.

4.5 Nonfuel-Bearing Component (NFBC) Handling. NFBC handling provides for volume reduction, packaging, or other processing of residual spent fuel assembly structural materials and other nonfuel items. Examples of these components are end fittings, spacer grids, and guide tubes. This subfunction could include the following steps:

- (a) Cutting or shearing
- (b) Compaction
- (c) Component segregation, or material segregation, or both
- (d) Packaging.

4.6 Off-Normal Rod Handling. Off-normal rod handling is the capability to retrieve, transfer, and prepare for storage: stuck rods, stray rods, and portions of broken rods encountered during rod consolidation activities. Examples of these operations include remote removal of broken or stuck rods from spent fuel assemblies and consolidated rod canisters; and the collection of loose material, stray rods, and fuel pellets.

4.7 Auxiliary Operations. These are the operations that are necessary to support rod consolidation or that are for general use throughout the consolidation process. Examples of auxiliary operations are:

- (a) Decontamination
- (b) Radiation monitoring

- (c) Photographic or videotape recording
- (d) Maintenance
- (e) Lifting and transfer
- (f) Visual monitoring.

5. Process Performance

The equipment and subsystems that are used in the LWR rod consolidation process shall be designed to perform under the designated Design Events given below. Credit may be taken for existing facility or installation capabilities. The division of the process into subfunctions is for convenience in presenting the performance requirements and related design criteria, and is not intended to imply that separate and independent equipment systems are required for each subfunction.

5.1 End Fitting Removal. Equipment provided for end fitting removal shall meet the following performance requirements:

5.1.1 Produce no damaged rods during fastener removal or the cutting operations for Design Events I and II.

5.1.2 Preclude accidental dropping of end fittings during or following end fitting removal operations for Design Events I and II.

5.1.3 Maintain support of the spent fuel assembly during Design Events I through III.

5.1.4 Provide local confinement of radioactive particulates during Design Events I and II.

5.1.5 Provide the ability to handle the spent fuel assembly following removal of the end fitting following Design Events II through IV.

5.2 Rod Removal. Equipment provided for rod removal operations shall meet the following performance requirements:

5.2.1 Prevent rod damage during Design Event I.

5.2.2 Preclude uncontrolled fuel rod movement during Design Events I and II.

5.2.3 Produce no damaged rods because of loads, distortions, displacements, or deflections

imposed on fuel rods by equipment during Design Events I and II.

5.2.4 Maintain fuel rods and spent fuel assemblies in a subcritical configuration for Design Events I through IV.

5.2.5 Provide local confinement of radioactive particulates during Design Events I and II.

5.2.6 Provide for fuel removal from equipment following Design Events II through IV.

5.3 Rod Array Reconfiguration. Equipment provided for reconfiguration of the fuel rod array shall meet the following performance requirements:

5.3.1 Produce no damaged rods because of loads, distortions, displacements, or deflections imposed on fuel rods by equipment during Design Events I and II.

5.3.2 Maintain fuel rods in a subcritical configuration for Design Events I through IV.

5.3.3 Preclude uncontrolled fuel rod movement for Design Events I and II.

5.3.4 Provide local confinement of radioactive particulates during Design Events I and II.

5.3.5 Provide for fuel removal from equipment following Design Events II and III.

5.4 Consolidated Rod Packaging. Packaging of rods or pieces thereof is accomplished through the use of canisters.

5.4.1 The canisters shall meet the following performance requirements:

5.4.1.1 Be dimensionally compatible with interfacing equipment for Design Events I and II.

5.4.1.2 Be structurally adequate to withstand handling and operating loads with a full complement of rods during Design Events I and II.

5.4.1.3 Allow for adequate cooling capability to protect the rods from temperatures that

would jeopardize the integrity of the fuel cladding for Design Events I through III.

5.4.1.4 If the selected canister design is of a sealed configuration, accommodate maximum anticipated pressure differential without collapse or permanent deformation during Design Events I through III.

5.4.1.5 Maintain a subcritical configuration throughout packaging during Design Events I through IV.

5.4.2 The packaging equipment shall meet the following performance requirements:

5.4.2.1 Preclude uncontrolled fuel rod movement during Design Events I and II.

5.4.2.2 Produce no damaged rods because of loads, distortions, displacements, or deflections imposed on fuel rods by equipment during Design Events I and II.

5.4.2.3 Provide for fuel removal from equipment following Design Events II and III.

5.4.2.4 Provide local confinement of radioactive particulates during Design Events I and II.

5.5 Nonfuel-Bearing Component Handling. Equipment used for nonfuel-bearing component handling may include component cutting, shearing, and compacting equipment; storage containers; tools; storage racks; and equipment stands. This equipment shall meet the following performance requirements:

5.5.1 Provide for the local confinement of debris during volume reduction operations for Design Event I.

5.5.2 Provide for the local confinement of radioactive particulates during Design Events I and II.

5.5.3 Provide for the withdrawal of nonfuel-bearing components and containers from the equipment following Design Event II.

5.6 Off-Normal Rod Handling. Off-normal rod handling includes the capability for damaged, stray, or broken rods to be retrieved,

transferred, and prepared for storage. See 5.4 for applicable performance requirements for off-normal rod storage containers. Equipment provided for off-normal rod handling shall meet the following performance requirements:

5.6.1 Remove and retrieve fuel rod sections and associated debris from fuel assemblies or work area following Design Event II.

5.6.2 Transfer fuel rods and associated debris to an appropriate storage container following Design Event II.

5.6.3 Maintain subcriticality during Design Events I through IV.

5.6.4 Provide local confinement of radioactive particulates during Design Events I and II.

5.7 Auxiliary Operations. Equipment, tools, fixtures, and associated systems that support rod consolidation operations shall perform their function during the Design Events applicable to the operation they support.

5.8 Facility or Installation Interfaces

5.8.1 Structural design of the rod consolidation process equipment, and of mating clearances with stands, racks, casks, and other supporting facility (or installation) structures, shall not prevent that facility (or installation) from performing its safety function during Design Events I through IV.

5.8.2 Subcriticality shall be maintained in the event of physical and nuclear interactions with adjacent activities for Design Events I through IV.

6. Process Design

The design requirements for the rod consolidation system are presented separately by subfunction. The Design Events to which these requirements apply are presented in Section 5.

6.1 End Fitting Removal

6.1.1 Codes and Standards. The end fitting removal equipment shall be designated