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# Standard Guide for Corrosion Testing of Aluminum-Based Spent Nuclear Fuel in Support of Repository Disposal[1]

This standard is issued under the fixed designation C1431; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε1 NOTE—Editorial corrections were made throughout in June 2010.

## 1. Scope

1.1 This guide covers corrosion testing of aluminum-based spent nuclear fuel in support of geologic repository disposal (per the requirements in 10 CFR 60 and 40CFR191). The testing described in this document is designed to provide data for analysis of the chemical stability and radionuclide release behavior of aluminum-based waste forms produced from aluminum-based spent nuclear fuels. The data and analyses from the corrosion testing will support the technical basis for inclusion of aluminum-based spent nuclear fuels in the repository source term. Interim storage and transportation of the spent fuel will precede geologic disposal; therefore, reference is also made to the requirements for interim storage (per 10 CFR 72) and transportation (per 10 CFR 71). The analyses that will be based on the data developed are also necessary to support the safety analyses reports (SARs) and performance assessments (PAs) for disposal systems.

1.2 Spent nuclear fuel that is not reprocessed must be safely managed prior to transportation to, and disposal in, a geologic repository. Placement in an interim storage facility may include direct placement of the irradiated fuel or treatment of the fuel prior to placement, or both. The aluminum-based waste forms may be required to be ready for geologic disposal, or road ready, prior to placement in extended interim storage. Interim storage facilities, in the United States, handle fuel from civilian commercial power reactors, defense nuclear materials production reactors, and research reactors. The research reactors include both foreign and domestic reactors. The aluminum-based fuels in the spent fuel inventory in the United States are primarily from defense reactors and from foreign and domestic research reactors. The aluminum-based spent fuel inventory includes several different fuel forms and levels of $^{235}U$ enrichment. Highly enriched fuels ($^{235}U$ enrichment levels >20 %) are part of this inventory.

1.3 Knowledge of the corrosion behavior of aluminum-based spent nuclear fuels is required to ensure safety and to support licensing or other approval activities, or both, necessary for disposal in a geologic repository. The response of the aluminum-based spent nuclear fuel waste form(s) to disposal environments must be established for configuration-safety analyses, criticality analyses, PAs, and other analyses required to assess storage, treatment, transportation, and disposal of spent nuclear fuels. This is particularly important for the highly enriched, aluminum-based spent nuclear fuels. The test protocols described in this guide are designed to establish material response under the repository-relevant conditions.

1.4 The majority of the aluminum-based spent nuclear fuels are aluminum clad, aluminum-uranium alloys. The aluminum-uranium alloy typically consists of uranium aluminide particles dispersed in an aluminum matrix. Other aluminum-based fuels include dispersions of uranium oxide, uranium silicide, or uranium carbide particles in an aluminum matrix. These particles, including the aluminides, are generally cathodic to the aluminum matrix. Selective leaching of the aluminum in the exposure environment may provide a mechanism for redistribution and relocation of the uranium-rich particles. Particle redistribution tendencies will depend on the nature of the aluminum corrosion processes and the size, shape, distribution and relative reactivity of the uranium-rich particles. Interpretation of test data will require an understanding of the material behavior. This understanding will enable evaluation of the design and configuration of the waste package to ensure that unfilled regions in the waste package do not provide sites for the relocation of the uranium-rich particles into nuclear critical configurations. Test samples must be evaluated, prior to testing, to ensure that the size and shape of the uranium-rich particles in the test samples are representative of the particles in the waste form being evaluated.

1.5 The use of the data obtained by the testing described in this guide will be optimized to the extent the samples mimic the condition of the waste form during actual repository exposure. The use of Practice C1174 is recommended for guidance. The selection of test samples, which may be unaged or artificially aged, should ensure that the test samples and

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conditions bound the waste form/repository conditions. The test procedures should carefully describe any artificial aging treatment used in the test program and explain why that treatment was selected.

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

C1174 Practice for Prediction of the Long-Term Behavior of Materials, Including Waste Forms, Used in Engineered Barrier Systems (EBS) for Geological Disposal of High-Level Radioactive Waste

2.2 *Government Documents*

10 CFR 60 US Code of Federal Regulations Title 10, Part 60, Disposal of High Level Radioactive Wastes in Geologic Repositories

10 CFR 71 US Code of Federal Regulations Title 10, Part 71, Packaging and Transport of Radioactive Materials

10 CFR 72 US Code of Federal Regulations Title 10, Part 72, Licensing Requirements for the Independent Storage of Spent Nuclear and High-Level Radioactive Waste

## 3. Terminology

3.1 *Definitions:*

3.1.1 Terms used in this guide are defined in Practice C1174, by common usage, by Webster's New World Dictionary, or as described in 3.2, or combination thereof.

3.2 *Definitions:*

3.2.1 *aluminum-based spent nuclear fuel*—irradiated nuclear fuel or target elements or assemblies, or both, that are clad in aluminum or aluminum-rich alloys. The microstructures contain a continuous aluminum-rich matrix with uranium-rich particles dispersed in this matrix.

3.2.2 *aluminum-based spent nuclear fuel form or waste form*—any metallic form produced from aluminum-based spent nuclear fuel and having a microstructure containing a continuous aluminum-rich matrix with uranium-rich particles dispersed in this matrix. This term may include the fuel itself.

3.2.3 *artificial aging*—any short time treatment that is designed to duplicate or simulate the material/property changes that normally occur after prolonged exposure and radioactive decay.

3.2.4 *attribute test*—a test conducted to provide material properties that are required as input to behavior models, but that are not themselves responses to the environment.

3.2.5 *bounding*—a test, sample condition or calculation designed to provide an evaluation of the limits to material behavior under relevant conditions.

3.2.6 *characterization test*—in high-level radioactive waste management, any test conducted principally to furnish information for a mechanistic understanding of alteration.

3.2.7 *corrosion product*—an ion or compound formed during the interaction of the aluminum-based spent nuclear fuel with its storage or disposal environment. The corrosion product may be the result of aqueous corrosion, oxidation, reaction with moist air, or other types of chemical interaction.

3.2.8 *interim storage installation*—a facility designed to store spent nuclear fuels for an extended period of time that meets the intent of the requirements of an independent spent fuel storage installation or a monitored retrievable storage facility, as described in 10 CFR 72.

3.2.9 *melt-dilute process*—a process to lower the fraction of $^{235}U$ in highly enriched, aluminum-based spent nuclear fuel by melting and adding depleted uranium to the waste from.

3.2.10 *performance assessment*—an analysis that identifies the processes and events that might affect a disposal system, examines the effects of those processes and events on the performance of the disposal system, and estimates the cumulative releases of radionuclides considering the associated uncertainties caused by all significant processes and events.

3.2.11 *safety analysis*—an analysis to determine the risk to the public health and safety associated with the storage, treatment, transportation, or disposal, or combination thereof, of aluminum-based spent nuclear fuel.

3.2.12 *service condition test*—a test of a material conducted under conditions in which the values of the independent variables characterizing the service environment are in the range expected in actual service.

## 4. Significance and Use

4.1 Disposition of aluminum-based spent nuclear fuel will involve:

4.1.1 Removal from the existing storage or transfer facility,

4.1.2 Characterization or treatment, or both, of the fuel or the resulting waste form, or both,

4.1.3 Placement of the waste form in a canister,

4.1.4 Placement of the canister in a safe and environmentally sound interim storage facility,

4.1.5 Removal from the interim storage facility and transport to the repository,

4.1.6 placement in a waste container,

4.1.7 Emplacement in the repository, and

4.1.8 Repository closure and geologic disposal. Actions in each of these steps may significantly impact the success of any subsequent step.

4.2 Aluminum-based spent nuclear fuel and the aluminum-based waste forms display physical and chemical characteristics that differ significantly from the characteristics of commercial nuclear fuels and from high level radioactive waste glasses. For example, some are highly enriched and most have heterogeneous microstructures that include very small, uranium-rich particles. The impact of this difference on repository performance must be evaluated and understood.

4.3 The U.S. Nuclear Regulatory Commission has licensing authority over public domain transportation and repository disposal (and most of the interim dry storage) of spent nuclear fuels and high-level radioactive waste under the requirements established by 10 CFR 60, 10 CFR 71, and 10 CFR 72. These requirements outline specific information needs that should be

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.