



Standard Test Method for Atom Percent Fission in Uranium Fuel (Radiochemical Method)¹

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INTRODUCTION

Uranium atom percent fission in a nuclear fuel is frequently determined by measurement of a fission product to uranium (U) ratio in the irradiated U fuel **(1-7)**.²

Among radioactive fission products, cesium-137 (¹³⁷Cs) was among the first used for estimation of fuel burnup. It has a reasonably well-known decay scheme, a low capture cross section, a long half-life, a very low yield from ¹³⁶Cs by neutron capture, and a high-fission yield which is fairly accurately known and not greatly affected by the type of fissionable material or the neutron spectrum. Disadvantages are found in the volatility of Cs and its precursors at fuel operating temperature (which gives rise to migration within the fuel), interference in counting from ¹³⁴Cs and ¹³⁶Cs, some uncertainty in physical constants, and required knowledge of irradiation history.

Although this test method is of historical interest, test methods based on mass spectrometry are preferred as a basis for fuel-warranty settlements because they are more accurate.

1. Scope

1.1 This test method covers the determination of U atom percent fission that has occurred in U fuel from analysis of the ¹³⁷Cs to U ratio after irradiation.

1.2 The test method is applicable to high-density, clad U fuel (metal, alloy, ceramic compound) in which no separation of Cs and U has occurred.

1.3 The test method is best applied to fuels that have aged several months since irradiation. In such material, the 13-day ¹³⁶Cs activity is reduced to a small amount through decay **(3)**.

1.4 The test method should be restricted to low-exposure samples in which the activity of ¹³⁴Cs is less than that of ¹³⁷Cs. Cesium-134 is produced by neutron capture on fission product ¹³³Cs and grows at a rate proportional to the square of the exposure. This capture process limits the test method to samples exposed to less than 0.6×10^1 nvt. This exposure corresponds to burnups of 12 gigawatt days per metric ton of uranium (GWD/MTU) in Yankee Core I, and 5 GWD/MTU in Dresden Core I. Samples with higher exposures may require the use of a lithium-drifted germanium detector to obtain adequate resolution between ¹³⁴Cs and ¹³⁷Cs. The use of such a detector will extend the range of this test method by a factor of about 2. Mass spectrometric isotope dilution analysis of

¹³⁷Cs with ¹³³Cs as the isotopic diluent would also overcome ¹³⁴Cs interference.

1.5 The test method is best applied to fuels where overheating has not caused center melting or grain growth, since high temperatures cause ¹³⁷Cs to distill from the fuel and deposit on cooler regions, such as the cladding. Therefore, cladding should be leached in the dissolver solution or dissolved with the uranium to maintain the true ratio of fission product ¹³⁷Cs to U. Alternatively, burnup in a maximum flux region of a fuel element can be obtained from analyzing a low-flux region of the element. The burnup measured in this position can be related to the burnup in the peak-flux position by a gamma scan of the element. A gamma scan usually represents the distribution of zirconium-95 and is a reflection of the fission distribution integrated over only the most recent months. This is not always a serious disadvantage, since such studies may be made after short irradiations.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods³

E 180 Practice for Determining the Precision of ASTM

¹ This test method is under the jurisdiction of ASTM Committee C-26 on Nuclear Fuel Cycle.

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² The boldface numbers in parentheses refer to the list of references appended to this test method.

³ Annual Book of ASTM Standards, Vol 14.02.