Designation: ~~E705 – 08~~ E705 – 13

Standard Test Method for Measuring Reaction Rates by Radioactivation of Neptunium-237[1]

This standard is issued under the fixed designation E705; 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.

1. Scope

1.1 This test method covers procedures for measuring reaction rates by assaying a fission product (F.P.) from the fission reaction ^{237}Np(n,f)F.P.

1.2 The reaction is useful for measuring neutrons with energies from approximately 0.7 to 6 MeV and for irradiation times up to 30 to 40 years.

1.3 Equivalent fission neutron fluence rates as defined in Practice E261 can be determined.

1.4 Detailed procedures for other fast-neutron detectors are referenced in Practice E261.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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:*[2]

E170 Terminology Relating to Radiation Measurements and Dosimetry
E181 Test Methods for Detector Calibration and Analysis of Radionuclides
E261 Practice for Determining Neutron Fluence, Fluence Rate, and Spectra by Radioactivation Techniques
E262 Test Method for Determining Thermal Neutron Reaction Rates and Thermal Neutron Fluence Rates by Radioactivation Techniques
E320 Test Method for Cesium-137 in Nuclear Fuel Solutions by Radiochemical Analysis (Withdrawn 1993)[3]
E393 Test Method for Measuring Reaction Rates by Analysis of Barium-140 From Fission Dosimeters
E704 Test Method for Measuring Reaction Rates by Radioactivation of Uranium-238
E844 Guide for Sensor Set Design and Irradiation for Reactor Surveillance, E 706 (IIC)
E944 Guide for Application of Neutron Spectrum Adjustment Methods in Reactor Surveillance, E 706 (IIA)
E1005 Test Method for Application and Analysis of Radiometric Monitors for Reactor Vessel Surveillance, E 706 (IIIA)
E1018 Guide for Application of ASTM Evaluated Cross Section Data File, Matrix E706 (IIB)

3. Terminology

3.1 *Definitions:*

3.1.1 Refer to Terminology E170.

4. Summary of Test Method

4.1 High-purity ^{237}Np (<40 ppm fissionable impurity) is irradiated in a fast-neutron field, thereby producing radioactive fission products from the reaction ^{237}Np(n,f)F.P.

[1] This test method is under the jurisdiction of ASTM Committee E10 on Nuclear Technology and Applicationsand is the direct responsibility of Subcommittee E10.05 on Nuclear Radiation Metrology.

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[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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

4.2 Various fission products such as ^{137}Cs-^{137m}Ba, ^{1140}Ba-^{140}La, ^{95}Zr, and ^{144}Ce can be assayed depending on the length of irradiation, purpose of the experiment, etc.

4.3 The gamma rays emitted through radioactive decay are counted and the reaction rate, as defined in Practice E261, is calculated from the decay rate and the irradiation conditions.

4.4 The neutron fluence rate for neutrons with energies from approximately 0.7 to 6 MeV can then be calculated from the spectral-weighted neutron activation cross section as defined in Practice E261.

4.5 A parallel procedure that uses ^{238} U instead of ^{237}Np is given in Test Method E704.

5. Significance and Use

5.1 Refer to Practice E261 for a general discussion of the determination of fast-neutron fluence rate with fission detectors.

5.2 ^{237}Np is available as metal foil, wire, or oxide powder. For further information, see Guide E844. It is usually encapsulated in a suitable container to prevent loss of, and contamination by, the ^{237}Np and its fission products.[4]

5.3 One or more fission products can be assayed. Pertinent data for relevant fission products are given in Table 1 and Table 2.

5.3.1 ^{137}Cs-^{137m}Ba is chosen frequently for long irradiations. Radioactive products ^{134}Cs and ^{136}Cs may be present, which can interfere with the counting of the 0.662 MeV ^{137}Cs-^{137m}Ba gamma ray (see Test Methods E320).

5.3.2 ^{140}Ba-^{140}La is chosen frequently for short irradiations (see Test Method E393).

5.3.3 ^{95}Zr can be counted directly, following chemical separation, or with its daughter ^{95}Nb, using a high-resolution gamma detector system.

5.3.4 ^{144}Ce is a high-yield fission product applicable to 2- to 3-year irradiations.

5.4 It is necessary to surround the ^{237}Np monitor with a thermal neutron absorber to minimize fission product production from trace quantities of fissionable nuclides in the ^{237}Np target and from ^{238}Np and ^{238}Pu from (n,γ) reactions in the ^{237}Np material. Assay of ^{238}Pu and ^{239}Pu concentration is recommended when a significant contribution is expected.

5.4.1 Fission product production in a light-water reactor by neutron activation products ^{238}Np and ^{238}Pu has been calculated to be insignificant (1.2 %), compared to that from ^{237}Np(n,f), for an irradiation period of 12 years at a fast neutron ($E > 1$ MeV) fluence rate of 1×10^{11} cm^{-2} ·s^{-1}, provided the ^{237}Np is shielded from thermal neutrons (see Fig. 2 of Guide E844).

5.4.2 Fission product production from photonuclear reactions, that is, (γ,f) reactions, while negligible near-power and ~~researchreactor~~ research reactor cores, can be large for deep-water penetrations (**1**).[5]

[4] The sole source of supply of Vanadium-encapsulated monitors of high purity known to the committee at this time in the United States is Isotope Sales Div., Oak Ridge, TN 37830. In Europe, the sole source of supply is European Commission, JRC, Institute for Reference Materials and Measurements (IRMM) Reference Materials Unit Retieseweg 111, B-2440 Geel, Belgium. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

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

TABLE 1 Recommended Nuclear Parameters for Certain Fission Products

Fission Product	Parent Half-Life^A **(6)**	Primary Radiation^A **(7)** (keV)	γ Probability of Decay^A **(7)**	Maximum Useful Irradiation Duration
^{95}Zr	64.032 (6) d	724.192 (4)	0.4427 (22)	6 months
		756.725 (12)	0.5438	
~~^{99}Mo~~	~~2.7489 (6) d~~	~~739.500 (17)~~	~~0.1213 (22)~~	~~300 hours~~
^{99}Mo	65.94 (1) hr	739.500 (17)	0.1213 (22)	300 hours
		777.921 (20)	0.0426 (8)	
~~^{103}Ru~~	~~39.26 (2) d~~	~~497.084 (6)~~	~~0.910 (12)~~	~~4 months~~
^{103}Ru	39.26 (2) d	497.085 (10)	0.910 (12)	4 months
~~^{137}Cs~~	~~30.3 (5) yr~~	~~661.657 (3)^B~~	~~0.8510^B~~	~~30–40 years~~
^{137}Cs	30.05 (8) yr	661.657 (3)^B	0.8499 (20)^B	30–40 years
~~^{140}Ba–^{140}La~~	~~12.752 (5) d~~	~~537.261 (9)~~	~~0.2439 (23)~~	~~1–1.5 months~~
^{140}Ba–^{140}La	12.7527 (23) d	537.261 (3)	0.2439 (22)	1–1.5 months
		~~1596.21 (4)~~	~~0.954 (14)^C~~	
		1596.21 (4)	0.9540 (8)^C	
			1.1515^D	
~~^{144}Ce~~	~~289.91 (5) d~~	~~133.515 (2)~~	~~0.1109 (10)~~	~~2–3 years~~
^{144}Ce	28.91 (5) d	133.515 (2)	0.1109 (19)	2–3 years

^{A}The lightface numbers in parentheses are the magnitude of plus or minus uncertainties in the last digit(s) listed.

^{B}With ^{137m}Ba (2.552 min) in equilibrium.

^{C}Probability of daughter ^{140}La decay.

^{D}With ^{140}La ~~(1.6781~~ d) in transient equilibrium.