



Designation: E1005 – 03^{ε1}

Standard Test Method for Application and Analysis of Radiometric Monitors for Reactor Vessel Surveillance, E 706(IIIA)¹

This standard is issued under the fixed designation E1005; 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—The Referenced Documents were updated editorially in July 2006.

1. Scope

1.1 This method describes general procedures for measuring the specific activities of radioactive nuclides produced in radiometric monitors (RMs) by nuclear reactions induced during surveillance exposures for reactor vessels and support structures. More detailed procedures for individual RMs are provided in separate standards identified in 2.1 and in Refs **11, 24-27**. The measurement results can be used to define corresponding neutron induced reaction rates that can in turn be used to characterize the irradiation environment of the reactor vessel and support structure. The principal measurement technique is high resolution gamma-ray spectrometry, although X-ray photon spectrometry and Beta particle counting are used to a lesser degree for specific RMs **(1-29)**.²

1.1.1 The measurement procedures include corrections for detector background radiation, random and true coincidence summing losses, differences in geometry between calibration source standards and the RMs, self absorption of radiation by the RM, other absorption effects, and radioactive decay corrections **(1-10, 12-22)**.

1.1.2 Specific activities are calculated by taking into account the time duration of the count, the elapsed time between start of count and the end of the irradiation, the half life, the mass of the target nuclide in the RM, and the branching intensities of the radiation of interest. Using the appropriate half life and known conditions of the irradiation, the specific activities may be converted into corresponding reaction rates **(24-30)**.

1.1.3 Procedures for calculation of reaction rates from the radioactivity measurements and the irradiation power time history are included. A reaction rate can be converted to neutron fluence rate and fluence using the appropriate integral

cross section and effective irradiation time values, and, with other reaction rates can be used to define the neutron spectrum through the use of suitable computer programs **(24-30)**.

1.1.4 The use of benchmark neutron fields for calibration of RMs can reduce significantly or eliminate systematic errors since many parameters, and their respective uncertainties, required for calculation of absolute reaction rates are common to both the benchmark and test measurements and therefore are self canceling. The benchmark equivalent fluence rates, for the environment tested, can be calculated from a direct ratio of the measured saturated activities in the two environments and the certified benchmark fluence rate **(24-30)**.

1.2 This method is intended to be used in conjunction with ASTM Guide **E844**. The following existing or proposed ASTM practices, guides, and methods are also directly involved in the physics-dosimetry evaluation of reactor vessel and support structure surveillance measurements:

Master Matrix for Light-Water Reactor Pressure Vessel Surveillance Standards, E706 (O)³

E853 Analysis and Interpretation of Light-Water Reactor Surveillance Results, E706 (IA)³

E560 Practice for Extrapolating Reactor Vessel Surveillance Dosimetry Results, E706 (IC)³

E693 Practice for Characterizing Neutron Exposures in Iron and Low Alloy Steels in Terms of Displacements Per Atom (DPA), E706 (ID)³

E185 Practice for Conducting Surveillance Tests for Light-Water Nuclear Power Reactor Vessels, E706 (IF)³

E1035 Practice for Determining Radiation Exposure for Nuclear Reactor Vessel Support Structures, E706 (IG)³

E636 Practice for Conducting Supplemental Surveillance Tests for Nuclear Power Reactor Vessels, E706 (IH)³

E944 Guide for Application of Neutron Spectrum Adjustment Methods in Reactor Surveillance, E706 (IIA)³

E1018 Guide for Application of ASTM Evaluated Cross Section and Data File, E706 (IIB)³

¹ This method is under the jurisdiction of ASTM Committee **E10** on Nuclear Technology and Applications and is the direct responsibility of Subcommittee **E10.05** on Nuclear Radiation Metrology.

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

³ The reference in parentheses refers to Section 5 as well as Figs. 1 and 2 of Matrix E706.

E482 Guide for Application of Neutron Transport Methods for Reactor Vessel Surveillance, E706 (IID)³

E2005 Guide for the Benchmark Testing of Reactor Vessel Dosimetry in Standard and Reference Neutron Fields

E2006 Guide for the Benchmark Testing of Light Water Reactor Calculations

E854 Test Method for Application and Analysis of Solid State Track Recorder (SSTR) Monitors for Reactor Vessel Surveillance, E706 (IIB)³

E910 Test Method for Application and Analysis of Helium Accumulation Fluence Monitors for Reactor Vessel Surveillance, E706 (IIIC)³

E1214 Application and Analysis of Temperature Monitors for Reactor Vessel Surveillance, E706 (IIIE)³

1.3 The general procedures in this method are applicable to the measurement of radioactivity in RMs that satisfy the specific constraints and conditions imposed for their analysis. More detailed procedures for individual RM monitors are identified in 2.1 and in Refs **11, 24-27** (see Table 1).

1.4 This method, along with the individual RM monitor standard methods, are intended for use by knowledgeable persons who are intimately familiar with the procedures, equipment, and techniques necessary to achieve high precision and accuracy in radioactivity measurements.

1.5 *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.*

TABLE 1 Radiometric Monitors Proposed for Reactor Vessel Surveillance

Dosimetry Reactions	Residual Nucleus			Target Atom Natural Abundance ^A [31]	Detector Response ^B	ASTM Standard or Ref.
	Half-life ^{C,A,D}	E _γ ^D (keV)	Yield ^D (%) γ/Reaction			
²³ Na(n,γ) ²⁴ Na	0.62356 (17) d	1368.633 2754.030	99.9936 99.855	1.00	NTR	(24-30)
²⁷ Al(n,α) ²⁴ Na	0.62356 (17) d	1368.633 2754.030	99.9936 99.855	1.00	TR	E266
³² S(n,p) ³² P	14.262 (14) d	<E _β >=694.9	100.	0.9502 (9)	TR	E265
⁴⁵ Sc(n,γ) ⁴⁶ Sc	83.79 (4) d	889.277 1120.545	99.9844 99.9874	1.00	NTR	(24-30)
⁴⁶ Ti(n,p) ⁴⁶ Sc	83.79 (4) d	889.277 1120.545	99.9844 99.9874	0.0825 (3)	TR	E526
⁴⁷ Ti(n,p) ⁴⁷ Sc	3.3492 (1) d	159.381	68.3	0.0744 (2)	TR	E526
⁴⁸ Ti(n,p) ⁴⁸ Sc	43.67 (9) h	983.526 1037.522 1312.120	100.0 97.5 100.0	0.7372 (3)	TR	E526
⁵⁵ Mn(n,2n) ⁵⁴ Mn	312.11 (5) d	834.843	99.9758	1.00	TR	E261, E263 (24-30)
⁵⁴ Fe(n,p) ⁵⁴ Mn	312.11 (5) d	834.843	99.9758	0.05845 (35)	TR	E263
⁵⁴ Fe(n,γ) ⁵⁵ Fe	2.73 (3) y	5.888 5.899 6.490	8.2 16.2 2.86	0.05845 (35)	NTR	(24-30)
⁵⁶ Fe(n,p) ⁵⁶ Mn	2.5789 (1) hr	846.754 1810.72 2113.05	98.87 27.18925 14.33615	0.91754 (36)	TR	(24-30)
⁵⁸ Fe(n,γ) ⁵⁹ Fe	44.472 (8) d	1099.251 1291.596 1481.7	56.5 43.2 0.059	0.00282 (4)	NTR	(24-30)
⁵⁹ Co(n,γ) ⁶⁰ Co	1925.5 (5) d 10.467 (6) m (meta)	1173.238 1332.502 58.603 826.28 1332.501 2158.77	99.857 99.983 2.01 0.00768 0.24 0.00072	1.00	NTR	E262, E481
⁵⁸ Ni(n,p) ⁵⁸ Co	70.82 (3) d 9.15 (10) h (meta)	810.775 863.959 1674.730 24.889	99.45 0.69 0.519 0.0369	0.68077 (9)	TR	E264

TABLE 1 *Continued*

Dosimetry Reactions	Residual Nucleus			Target Atom Natural Abundance ^A [31]	Detector Response ^B	ASTM Standard or Ref.
	Half-life ^{C, A, D}	E _γ ^D (keV)	Yield ^D (%) γ/Reaction			
⁶⁰ Ni(n,p) ⁶⁰ Co	1925.5 (5) d	1173.238	99.857	0.26223 (8)	TR	(24-30)
		1332.502	99.983			
	10.467 (6) m	58.603	2.01			
	(meta)	826.28	0.00768			
		1332.501	0.24			
		2158.77	0.00072			
⁶³ Cu(n,γ) ⁶⁴ Cu	12.700 (2) h	1345.77	0.47336	0.6917 (3)	NTR	(24-30)
⁶³ Cu(n,α) ⁶⁰ Co	1925.5 (5) d	1173.238	99.857	0.6917 (3)	TR	E523
		1332.502	99.983			
	10.467 (6) m	58.603	2.01			
	(meta)	826.33	0.0058			
		1332.501	0.25			
		2158.86	0.00088			
⁹³ Nb(n,n') ^{93m} Nb	5.89 (5) × 10 ³ d	30.77 16.52 (K _{α1,2})	0.000549 9.25	1.00	TR	(11, 24-30)
¹⁰³ Rh(n,n') ^{103m} Rh	56.114 (9) m	39.755	0.0684	1.00	TR	(24-30)
¹⁰⁹ Ag(n,γ) ^{110m} Ag	249.76 (4) d	116.48	0.00799	0.48161 (8)	NTR	E481
		884.685	72.192			
		937.493	34.1314			
		1384.300	24.1204			
		1505.040	12.9532			
		1475.788	3.96868			
¹¹⁵ In(n,γ) ^{116m} In	54.29 (17) m	1293.54	84.4	0.9571 (5)	NTR	E261, E262
		1097.3	56.2104			
		818.7	11.4784			
		2112.1	15.5296			
¹¹⁵ In(n,n') ^{115m} In	4.486 (4) h	336.241	45.9	0.9571 (5)	TR	(24-30)
		497.370	0.047			
¹⁸¹ Ta(n,γ) ¹⁸² Ta	114.43 (3) d	1121.3008	34.9	0.99988 (2)	NTR	E262
		1189.0503	16.225			
		1221.4066	26.9777			
¹⁹⁷ Au(n,γ) ¹⁹⁸ Au	2.69517 (21) d	1087.6904	0.159045	1.00	NTR	E261, E262 (24-30)
		675.8874	0.8038278			
		411.804	95.57			
²³² Th(n,γ) ²³³ Th	22.3 (1) m	890.1	0.14	1.00	NTR	(24-30)
		490.80	0.17			
		499.02	0.21			
		699.901	0.68			
		764.4	0.120			
... ⇒ ²³³ Pa	26.967 (2) d	312.17	38.6			
FM(n,f) ¹⁴⁴ Ce	284.893 (8) d	133.515 80.120	11.09 1.36407 (see Table 2)	— ^E	NTR, TR	E704, E705 (24-30)
FM(n,f) ¹⁴⁰ Ba	12.752 (3) d	537.261	24.4 (see Table 2)	— ^E	NTR, TR	E393, E704, E705
¹⁴⁰ Ba ⇒ ¹⁴⁰ La	1.6781 (3) d	1596.21 815.772 487.021	95.4 23.2776 45.5058 (see Table 2)			(24-30)
FM(n,f) ¹³⁷ Cs	30.07 (3) y	661.660	85.1 (see Table 2)	— ^E	NTR, TR	E320, E704, E705
¹³⁷ Cs ⇒ ^{137m} Ba	2.552 (1) m	661.660	90.11 (see Table 2)			(24-30)
FM(n,f) ¹⁰⁶ Ru	373.59 (15) d	—	—	— ^E	NTR, TR	E704, E705