



Designation: E1005 – 10

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.

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, radioactive decay corrections, and burn out of the nuclide of interest (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

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

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

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.

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 (IIC)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 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 (some already identified in 1.2), including those for individual RM monitors:

2.2 *ASTM Standards*:⁴

E181 Test Methods for Detector Calibration and Analysis of Radionuclides

E185 Practice for Design of Surveillance Programs for Light-Water Moderated Nuclear Power Reactor Vessels

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

E263 Test Method for Measuring Fast-Neutron Reaction Rates by Radioactivation of Iron

E264 Test Method for Measuring Fast-Neutron Reaction Rates by Radioactivation of Nickel

E265 Test Method for Measuring Reaction Rates and Fast-Neutron Fluences by Radioactivation of Sulfur-32

E266 Test Method for Measuring Fast-Neutron Reaction Rates by Radioactivation of Aluminum

E320 Test Method for Cesium-137 in Nuclear Fuel Solutions by Radiochemical Analysis (Withdrawn 1993)⁵

E393 Test Method for Measuring Reaction Rates by Analysis of Barium-140 From Fission Dosimeters

E481 Test Method for Measuring Neutron Fluence Rates by Radioactivation of Cobalt and Silver

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

E523 Test Method for Measuring Fast-Neutron Reaction Rates by Radioactivation of Copper

E526 Test Method for Measuring Fast-Neutron Reaction Rates by Radioactivation of Titanium

E636 Guide for Conducting Supplemental Surveillance Tests for Nuclear Power Reactor Vessels, E 706 (IH)

E693 Practice for Characterizing Neutron Exposures in Iron and Low Alloy Steels in Terms of Displacements Per Atom (DPA), E 706(ID)

E704 Test Method for Measuring Reaction Rates by Radioactivation of Uranium-238

E705 Test Method for Measuring Reaction Rates by Radioactivation of Neptunium-237

E844 Guide for Sensor Set Design and Irradiation for Reactor Surveillance, E 706 (IIC)

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

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

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

E944 Guide for Application of Neutron Spectrum Adjustment Methods in Reactor Surveillance, E 706 (IIA)

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

E1035 Practice for Determining Neutron Exposures for Nuclear Reactor Vessel Support Structures

E1214 Guide for Use of Melt Wire Temperature Monitors for Reactor Vessel Surveillance, E 706 (IIIE)

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

E2006 Guide for Benchmark Testing of Light Water Reactor Calculations

2.3 *ANSI Standard*:

N42.14 Calibration and Usage of Germanium Detectors for Measurement of Gamma-Ray Emission Rates of Radionuclides⁶

3. Terminology

3.1 *Definitions*:

3.1.1 *radiometric monitor (RM), dosimeter, foil*—a small quantity of material consisting of or containing an accurately known mass of a specific target nuclide. Usually fabricated in a specified and consistent geometry and used to determine neutron fluence rate (flux density), fluence and spectra by measuring a specific radioactive neutron-induced reaction

⁴ 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.

⁵ The last approved version of this historical standard is referenced on www.astm.org.

⁶ Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.



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			
$^{23}\text{Na}(n,\gamma)^{24}\text{Na}$	0.62356 (17) d	1368.633 2754.030	99.9936 99.855	1.00	NTR	(24-30)
$^{27}\text{Al}(n,\alpha)^{24}\text{Na}$	0.62356 (17) d	1368.633 2754.030	99.9936 99.855	1.00	TR	E266
$^{32}\text{S}(n,p)^{32}\text{P}$	14.262 (14) d	$<E_p>=694.9$	100.	0.9502 (9)	TR	E265
$^{45}\text{Sc}(n,\gamma)^{46}\text{Sc}$	83.79 (4) d	889.277 1120.545	99.9844 99.9874	1.00	NTR	(24-30)
$^{46}\text{Ti}(n,p)^{46}\text{Sc}$	83.79 (4) d	889.277 1120.545	99.9844 99.9874	0.0825 (3)	TR	E526
$^{47}\text{Ti}(n,p)^{47}\text{Sc}$	3.3492 (1) d	159.381	68.3	0.0744 (2)	TR	E526
$^{48}\text{Ti}(n,p)^{48}\text{Sc}$	43.67 (9) h	983.526 1037.522 1312.120	100.0 97.5 100.0	0.7372 (3)	TR	E526
$^{55}\text{Mn}(n,2n)^{54}\text{Mn}$	312.11 (5) d	834.843	99.9758	1.00	TR	E261, E263 (24-30)
$^{54}\text{Fe}(n,p)^{54}\text{Mn}$	312.11 (5) d	834.843	99.9758	0.05845 (35)	TR	E263
$^{54}\text{Fe}(n,\gamma)^{55}\text{Fe}$	2.73 (3) y	5.888 5.899 6.490	8.2 16.2 2.86	0.05845 (35)	NTR	(24-30)
$^{56}\text{Fe}(n,p)^{56}\text{Mn}$	2.5789 (1) hr	846.754 1810.72 2113.05	98.87 27.18925 14.33615	0.91754 (36)	TR	(24-30)
$^{58}\text{Fe}(n,\gamma)^{59}\text{Fe}$	44.472 (8) d	1099.251 1291.596 1481.7	56.5 43.2 0.059	0.00282 (4)	NTR	(24-30)
$^{59}\text{Co}(n,\gamma)^{60}\text{Co}$	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
$^{58}\text{Ni}(n,p)^{58}\text{Co}$	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
$^{60}\text{Ni}(n,p)^{60}\text{Co}$	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	0.26223 (8)	TR	(24-30)
$^{63}\text{Cu}(n,\gamma)^{64}\text{Cu}$	12.700 (2) h	1345.77	0.47336	0.6917 (3)	NTR	(24-30)
$^{63}\text{Cu}(n,\alpha)^{60}\text{Co}$	1925.5 (5) d 10.467 (6) m (meta)	1173.238 1332.502 58.603 826.33 1332.501 2158.86	99.857 99.983 2.01 0.0058 0.25 0.00088	0.6917 (3)	TR	E523
$^{93}\text{Nb}(n,n')^{93\text{m}}\text{Nb}$	5.89 (5) $\times 10^3$ d	30.77 16.52 ($K_{\alpha 1,2}$)	0.000549 9.25	1.00	TR	(11, 24-30)
$^{103}\text{Rh}(n,n')^{103\text{m}}\text{Rh}$	56.114 (9) m	39.755	0.0684	1.00	TR	(24-30)
$^{109}\text{Ag}(n,\gamma)^{110\text{m}}\text{Ag}$	249.76 (4) d	116.48 884.685	0.00799 72.192	0.48161 (8)	NTR	E481