



Designation: E1005 – 21

Standard Test Method for Application and Analysis of Radiometric Monitors for Reactor Vessel Surveillance¹

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1. Scope

1.1 This test method describes 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 (1-5).² 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).

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 (6-26).

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 (2-5, 28-30).

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 (2-5, 28-30).

¹ This test 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.

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 (2-5, 28-30).

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

1.3 The procedures in this test 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 1-5 (see Table 1).

1.4 This test 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, except for the energy units based on the electron volt, keV and MeV, and the time units: minute (min), hour (h), day (d), and year (a).

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

TABLE 1 Radiometric Monitors Proposed for Reactor Vessel Surveillance

Dosimetry Reactions	Residual Nucleus			Target Atom Natural Abundance ^A Ref (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	14.958 (2) h	1368.630 (5) 2754.049 (13)	99.9934 (5) 99.862 (3)	1.00	NTR	(2-5, 28-32)
²⁷ Al(n,α) ²⁴ Na	14.958 (2) h	1368.630 (5) 2754.049 (13)	99.9934 (5) 99.862 (3)	1.00	TR	(32) E266
³² S(n,p) ³² P	14.284 (36) d	<E _p >=695.5 (3)	100.0	0.9499 (26)	TR	E265
⁴⁵ Sc(n,γ) ⁴⁶ Sc	83.787 (16) d	889.271 (2) 1120.537 (3)	99.98374 (25) 99.97 (2)	1.00	NTR	(2-5, 28-32)
⁴⁶ Ti(n,p) ⁴⁶ Sc	83.787 (16) d	889.271 (2) 1120.537 (3)	99.98374 (25) 99.97 (2)	0.0825 (3)	NTR	(32) E526
⁴⁷ Ti(n,p) ⁴⁷ Sc	3.3485 (9) d	159.373 (12)	68.1 (5)	0.0744 (2)	TR	E526
⁴⁸ Ti(n,p) ⁴⁸ Sc	43.67 (9) h	983.526 (12) 1037.522 (12) 1312.120 (12)	100.0 (3) 97.5 (5) 100.0 (5)	0.7372 (3)	TR	E526
⁵⁵ Mn(n,2n) ⁵⁴ Mn	312.19 (3) d	834.848 (3)	99.752 (5)	1.00	TR	E261, E263 (2-5, 28-30)
⁵⁴ Fe(n,p) ⁵⁴ Mn	312.19 (3) d	834.848 (3)	99.752 (3)	0.05845 (35)	TR	E263
⁵⁴ Fe(n,γ) ⁵⁵ Fe	2.747 (8) a	5.88765 5.89875 6.49045	8.45 (14) 16.57 (27) 3.40 (7)	0.05845 (35)	NTR	(2-5, 28-30)
⁵⁶ Fe(n,p) ⁵⁶ Mn	2.57878 (46) h	846.7638 (19) 1810.726 (4) 2113.092 (6)	98.85 (3) 26.9 (4) 14.2 (3)	0.91754 (36)	TR	(2-5, 28-30)
⁵⁸ Fe(n,γ) ⁵⁹ Fe	44.494 (12) d	1099.245 (3) 1291.590 (6) 1481.70 (12)	56.51 (31) 43.23 (33) 0.059 (6)	0.00282 (4)	NTR	(2-5, 28-30)
⁵⁹ Co(n,γ) ⁶⁰ Co	5.2711 (8) a 10.467 (6) min (meta)	1173.228 (3) 1332.492 (4) 58.603 (7) 826.10 (3) 1332.492 (4) 2158.57 (3)	99.85 (3) 99.9826 (6) 2.07 (3) 0.00775 (3) 0.25 (3) 0.00075 (3)	1.00	NTR	E262, E481
⁵⁸ Ni(n,p) ⁵⁸ Co	70.85 (3) d 9.10 (9) h (meta)	810.7602 (20) 863.958 (6) 1674.705 (6) 24.889 (21)	99.44 (2) 0.700 (22) 0.528 (13) 0.0397 (6)	0.68077 (9)	TR	E264
⁶⁰ Ni(n,p) ⁶⁰ Co	5.2711 (8) a 10.467 (6) min (meta)	1173.228 (3) 1332.492 (4) 58.603 (7) 826.10 (3) 1332.492 (4) 2158.57 (3)	99.85 (3) 99.9826 (6) 2.07 (3) 0.00775 (3) 0.25 (3) 0.00075 (3)	0.26223 (8)	TR	(2-5, 28-30)
⁶³ Cu(n,γ) ⁶⁴ Cu	12.7004 (20) h	1345.77 (6)	0.4748 (34)	0.6915 (15)	NTR	(2-5, 28-30)
⁶³ Cu(n,α) ⁶⁰ Co	5.2711 (8) a 10.467 (6) min (meta)	1173.228 (3) 1332.492 (4) 58.603 (7) 826.10 (3) 1332.492 (4) 2158.57 (3)	99.85 (3) 99.9826 (6) 2.07 (3) 0.00775 (3) 0.25 (3) 0.00075 (3)	0.6915 (15)	TR	E523
⁹³ Nb(n,n') ^{93m} Nb	16.12 (15) a	30.77 (2) 16.52 (K _{α1,2})	0.000591 (9) 9.25	1.00	TR	(1-5, 28-30)
¹⁰³ Rh(n,n') ^{103m} Rh	56.114 (20) min	39.755 (12)	0.0684 (35)	1.00	TR	(2-5, 28-30)
¹⁰⁹ Ag(n,γ) ^{110m} Ag	249.78 (2) d	116.48 (5) 884.6781 (13)	0.0080 (3) 74.0 (12)	0.48161 (8)	NTR	E481