INTERNATIONAL

Designation: E264 – 19

Standard Test Method for Measuring Fast-Neutron Reaction Rates by Radioactivation of Nickel[1]

1. Scope

1.1 This test method covers procedures for measuring reaction rates by the activation reaction ^{58}Ni(n,p)^{58}Co.

1.2 This activation reaction is useful for measuring neutrons with energies above approximately 2.1 MeV and for irradiation times up to about 200 days in the absence of high thermal neutron fluence rates, provided that the analysis methods described in Practice E261 are followed. If dosimeters are analyzed after irradiation periods longer than 200 days, the information inferred about the fluence during irradiation periods more than 200 days before the end of the irradiation should not be relied upon without supporting data from dosimeters withdrawn earlier.

1.3 With suitable techniques fission-neutron fluence rates densities above 10^7 cm^{-2}·s^{-1} 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, 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.*

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

E844 Guide for Sensor Set Design and Irradiation for Reactor Surveillance

E944 Guide for Application of Neutron Spectrum Adjustment Methods in Reactor Surveillance

E1005 Test Method for Application and Analysis of Radiometric Monitors for Reactor Vessel Surveillance

E1018 Guide for Application of ASTM Evaluated Cross Section Data File

3. Terminology

3.1 *Definitions:*

3.1.1 Refer to Terminology E170.

4. Summary of Test Method

4.1 High-purity nickel is irradiated in a neutron field, thereby producing radioactive ^{58}Co from the ^{58}Ni(n,p)^{58}Co activation reaction.

4.2 The gamma rays emitted by the radioactive decay of ^{58}Co are counted in accordance with Test Methods E181 and the reaction rate, as defined by Practice E261, is calculated from the decay rate and irradiation conditions.

4.3 The neutron fluence rate above about 2.1 MeV can then be calculated from the spectral-weighted neutron activation cross section as defined by Practice E261.

5. Significance and Use

5.1 Refer to Guide E844 for the selection, irradiation, and quality control of neutron dosimeters.

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[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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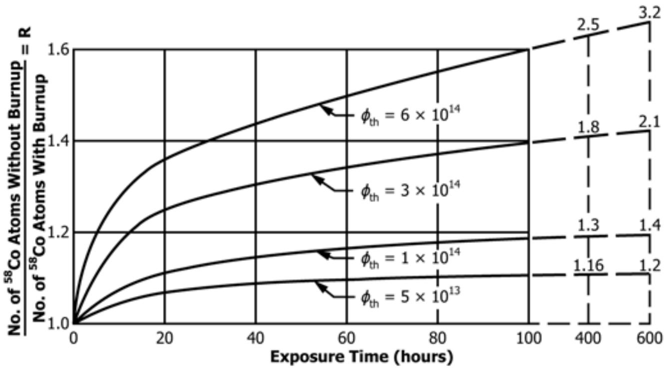
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.



NOTE 1—The burnup corrections were computed using effective burn-up cross sections of 1650 b for ^{58}Co(n,γ) and 1.4E5 b for ^{58m}Co(n,γ).

FIG. 1 *R* Correction Values as a Function of Irradiation Time and Neutron Flux

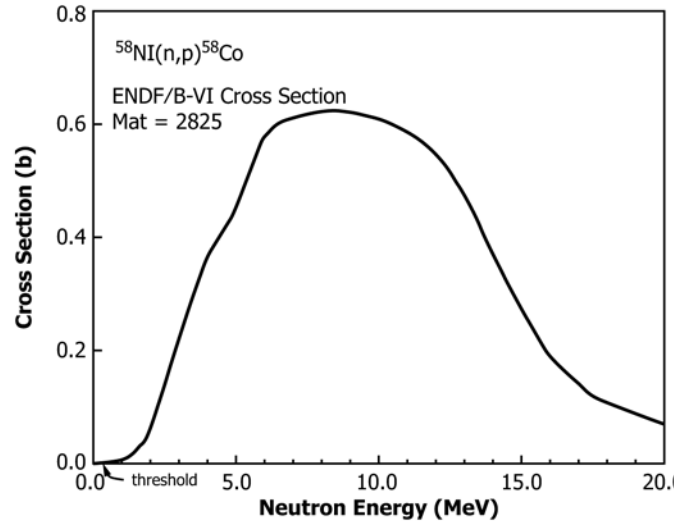


FIG. 2 ^{58}Ni(n,p)^{58}Co Cross Section

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

5.3 Pure nickel in the form of foil or wire is readily available, and easily handled.

5.4 ^{58}Co has a half-life of 70.85 (3) days (Refs (**1**) and (**2**))[3] and emits a gamma ray with an energy of 810.7602 (20) keV (Refs (**2**) and (**3**)).

5.5 Competing activities ^{65}Ni(2.5172 h) and ^{57}Ni(35.9 (3) h (Ref (**2**)) are formed by the reactions ^{64}Ni(n,γ) ^{65}Ni, and ^{58}Ni(n,2n)^{57}Ni, respectively.

5.6 A second 9.04 h isomer, ^{58m}Co, is formed that decays to 70.85-day ^{58}Co. Loss of ^{58}Co and ^{58m}Co by thermal-neutron burnout will occur in environments (Refs (**4**) and (**5**) having thermal fluence rates of 3×10^{12} $cm^{-2} \cdot s^{-1}$ and above. Burnout correction factors, *R*, are plotted as a function of time for several thermal fluxes in Fig. 1. Tabulated values for a continuous irradiation time are provided in Hogg, et al. (Ref (**5**))

5.7 Fig. 2 shows a plot of cross section (Ref (**6**)) versus energy for the fast-neutron reaction ^{58}Ni(n,p) ^{58}Co. This figure is for illustrative purposes only to indicate the range of response of the ^{58}Ni(n,p) reaction. Refer to Guide E1018 for descriptions of recommended tabulated dosimetry cross sections.

NOTE 1—The data is taken from the Evaluated Nuclear Data File, ENDF/B-VI, rather than the later ENDF/B-VII. This is in accordance with E1018, section 6.1, since the later ENDF/B-VII data files do not include covariance information. For more details see Section H of Ref (**7**).

6. Apparatus

6.1 *NaI (T1) or High Resolution Gamma-Ray Spectrometer.* Because of its high resolution, the germanium detector is useful when contaminant activities are present (see Test Methods E181 and E1005).

6.2 *Precision Balance,* able to achieve the required accuracy.

6.3 *Digital Computer,* useful for data analysis (optional).

7. Materials

7.1 The nickel metal must be low in contained cobalt to prevent the production of ^{60}Co by thermal-neutron capture. Nickel produced by the carbonyl (Mond) process is sufficiently free of cobalt for even the most adverse conditions. Whenever possible, all nickel should be tested for interfering impurities by neutron activation.

7.2 *Encapsulating Materials*—Brass, stainless steel, copper, aluminum, quartz, or vanadium have been used as primary encapsulating materials. The container should be constructed in such a manner that it will not create significant flux perturbation and that it may be opened easily, especially if the capsule is to be opened remotely (see Guide E844).

8. Procedure

8.1 Decide on the size and shape of nickel sample to be irradiated. This is influenced by the irradiation space and the expected production of ^{58}Co. Calculate the expected production rate of ^{58}Co from the activation equation described in Section 9, and adjust the sample size and irradiation time so that the ^{58}Co may be counted accurately.

8.2 Determine the level of thermal-neutron fluence rate by including a thermal-fluence rate monitor. Place the sample in a boron or cadmium shield if required.

8.3 Weigh the sample.

8.4 Irradiate the sample for the predetermined time period. Record the power level and any changes in power during the irradiation, the time at the beginning and end of the irradiation period, and the relative position of the monitors in the irradiation facility.

8.5 A waiting period of at least 4 days is recommended between termination of the exposure and start of counting. This allows the 9.04-h ^{58m}Co to decay entirely to the 70.85-day

[3] The boldface numbers in parentheses refer to a list of references at the end of this standard.