Designation: E1035 − 18 (Reapproved 2023)

Standard Practice for Determining Neutron Exposures for Nuclear Reactor Vessel Support Structures[1]

This standard is issued under the fixed designation E1035; 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 practice covers procedures for monitoring the neutron radiation exposures experienced by ferritic materials in nuclear reactor vessel support structures located in the vicinity of the active core. This practice includes guidelines for:

1.1.1 Selecting appropriate dosimetric sensor sets and their proper installation in reactor cavities.

1.1.2 Making appropriate neutronics calculations to predict neutron radiation exposures.

1.2 The values stated in SI units are to be regarded as standard; units that are not SI can be found in Terminology E170 and are to be regarded as standard. Any values in parentheses are for information only.

1.3 This practice is applicable to all pressurized water reactors whose vessel supports will experience a lifetime neutron fluence (E > 1 MeV) that exceeds 1×10^{17} neutrons/cm^2 or exceeds 3.0×10^{-4} dpa (**1**).[2] (See Terminology E170.)

1.4 Exposure of vessel support structures by gamma radiation is not included in the scope of this practice, but see the brief discussion of this issue in 3.2.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* (For example, (**2**).)

1.6 *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:*[3]

E170 Terminology Relating to Radiation Measurements and Dosimetry

E482 Guide for Application of Neutron Transport Methods for Reactor Vessel Surveillance

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

E844 Guide for Sensor Set Design and Irradiation for Reactor Surveillance

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

E910 Test Method for Application and Analysis of Helium Accumulation Fluence Monitors for Reactor Vessel 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

E2956 Guide for Monitoring the Neutron Exposure of LWR Reactor Pressure Vessels

2.2 *ASME Standard:*[4]

Boiler and Pressure Vessel Code, Section III

2.3 *Nuclear Regulatory Documents:*[5]

Code of Federal Regulations, Chapter 10, Part 50, Appendix G Fracture Toughness Requirements

Code of Federal Regulations, Chapter 10, Part 50, Appendix H Reactor Vessel Materials Surveillance Program Requirements

Regulatory Guide 1.99, Rev. 2 Effects of Residual Elements

[1] This practice 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 a list of references at the end of this practice.

[3] 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.

[4] Available from American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

[5] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

on Predicted Radiation Damage on Reactor Vessel Materials, U.S. Nuclear Regulatory Commission, May 1988

3. Significance and Use

3.1 Prediction of neutron radiation effects to pressure vessel steels has long been a part of the design and operation of light water reactor power plants. Both the federal regulatory agencies (see 2.3) and national standards groups (see 2.1 and 2.2) have promulgated regulations and standards to ensure safe operation of these vessels. The support structures for pressurized water reactor vessels may also be subject to similar neutron radiation effects (**1, 3-6**).[2] The objective of this practice is to provide guidelines for determining the neutron radiation exposures experienced by individual vessel supports.

3.2 It is known that high-energy photons can also produce displacement damage effects that may be similar to those produced by neutrons. These effects are known to be much less at the belt line of a light water reactor pressure vessel than those induced by neutrons. The same has not been proven for all locations within vessel support structures. Therefore, it may be prudent to apply coupled neutron-photon transport methods and photon-induced displacement cross sections to determine whether gamma-induced dpa exceeds the screening level of 3.0×10^{-4} used in this practice for neutron exposures. (See 1.3.)

4. Irradiation Requirements

4.1 *Location of Neutron Dosimeters*—Neutron dosimeters shall be located along the support structure in the region where the maximum dpa or fluence (E > 1 MeV) is expected to occur, based on neutronics calculations outlined in Section 5. Care must be taken to ensure that reactor cavity structures not modeled in the neutronics calculation offer no additional shielding to the dosimeters. The neutron dosimeters will be analyzed to obtain a map of the neutron fields within the actual location of the support structures. Considerations discussed in Guide E2956 (especially with regard to ex-vessel surveillance programs) apply.

4.2 *Neutron Dosimeters:*

4.2.1 Information regarding the selection of appropriate sensor sets for support structure application may be found in Guide E844, Test Method E1005, and Test Methods E854 and E910.

4.2.2 In particular, Test Method E910 also provides guidance for the additional possibility that operating plants may use existing copper-bearing instruments and cables within the reactor cavity as a retrospective passive dosimeter candidate.

5. Determination of Neutron Exposure Parameter Values

5.1 *Neutronics Calculations*—All neutronics calculations for (*a*) the analysis of integral dosimetry data, and (*b*) the prediction of irradiation damage exposure parameter values shall follow Guide E482, subject to these additional considerations that may be encountered in reactor cavities:

5.1.1 If the vessel supports do not lie within the core's active height, then an asymmetric quadrature set must be chosen for discrete ordinates calculations that will accurately reproduce the neutron transport in the direction of the supports. Care must be exercised in constructing the quadrature set to ensure that "ray streaming" effects in the cavity air gap do not distort the calculation of the neutron transport.

5.1.2 If the support system is so large or geometrically complex that it perturbs the general neutron field in the cavity, the analysis method of choice may be that of a Monte Carlo calculation or a combined discrete ordinates/Monte Carlo calculation. The combined calculation involves a two or three-dimensional discrete ordinates analysis only within the vessel. The neutron currents or fluences generated by this analysis may be used to create the appropriate source distribution functions in the final Monte Carlo analysis, or to develop bias (weighting) factors for use in a complete Monte Carlo model. For details of analyses in which discrete ordinates and Monte Carlo methods were coupled see Refs (**7-12**). Reference (**13**) provides a review of the available combined or hybrid discrete ordinates/Monte Carlo calculations. For hybrid calculations, the above caveats still hold for the discrete ordinates calculation, but in addition, the variance of the Monte Carlo results must now be included with the overall assessment of the variance of the dosimetry data.

5.2 *Determination of Damage Exposure Values and Uncertainties*—Adjustment procedures outlined in Guide E944 and Guide E1018 shall be performed to obtain damage exposure values dpa and fluence (E > 1 MeV) using the integral data from the neutron dosimeters and the calculation in 5.1. The cross sections for dpa are found in Practice E693. Dpa shall be determined for this application rather than just fluence (E > 1 MeV) because Ref (**1**) notes an increase in the ratio of dpa to fluence (E > 1 MeV) by a factor of two in going from the surveillance capsule position inside the reactor vessel to a position out in the reactor cavity.

6. Keywords

6.1 dosimetry; dpa; hybrid transport methods; neutron exposure; neutron fluence; radiometric monitor; reactor vessel supports; surveillance