Designation: E853 − 23

Standard Practice for Analysis and Interpretation of Light-Water Reactor Surveillance Neutron Exposure Results[1]

This standard is issued under the fixed designation E853; 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 the methodology, summarized in Annex A1, to be used in the analysis and interpretation of neutron exposure data obtained from LWR pressure vessel surveillance programs and, based on the results of that analysis, establishes a formalism to be used to evaluate present and future condition of the pressure vessel and its support structures[2] (**1-74**).[3]

1.2 This practice relies on, and ties together, the application of several supporting ASTM standard practices, guides, and methods (see Master Matrix E706) (**1**, **5**, **13**, **48**, **49**).[2] In order to make this practice at least partially self-contained, a moderate amount of discussion is provided in areas relating to ASTM and other documents. Support subject areas that are discussed include reactor physics calculations, dosimeter selection and analysis, and exposure units.

1.3 This practice is restricted to direct applications related to surveillance programs that are established in support of the operation, licensing, and regulation of LWR nuclear power plants. Procedures and data related to the analysis, interpretation, and application of test reactor results are addressed in Practice E1006, Guide E900, and Practice E1035.

1.4 *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.*

1.5 *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:*[4]

E185 Practice for Design of Surveillance Programs for Light-Water Moderated Nuclear Power Reactor Vessels
E482 Guide for Application of Neutron Transport Methods for Reactor Vessel Surveillance
E509 Guide for In-Service Annealing of Light-Water Moderated Nuclear Reactor Vessels
E706 Master Matrix for Light-Water Reactor Pressure Vessel Surveillance Standards
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
E900 Guide for Predicting Radiation-Induced Transition Temperature Shift in Reactor Vessel Materials
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
E1006 Practice for Analysis and Interpretation of Physics Dosimetry Results from Test Reactor Experiments
E1018 Guide for Application of ASTM Evaluated Cross Section Data File
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
E2006 Guide for Benchmark Testing of Light Water Reactor Calculations

[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] ASTM Practice E185 gives reference to other standards and references that address the variables and uncertainties associated with property change measurements. The referenced standards are A370, E8, E21, E23, and E208.

[3] The boldface numbers in parentheses refer to the list of references appended to this practice. For an updated set of references, see Master Matrix E706.

[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.

E2215 Practice for Evaluation of Surveillance Capsules from Light-Water Moderated Nuclear Power Reactor Vessels

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

2.2 *Other Documents:*

NUREG/CR-1861 HEDL-TME 80-87 LWR Pressure Vessel Surveillance Dosimetry Improvement Program: PCA Experiments and Blind Test[5]

ASME Boiler and Pressure Vessel Code, Sections III and IX[6]

Code of Federal Regulations, Title 10, Part 50, Appendixes G and H[7]

3. Significance and Use

3.1 The objectives of a reactor vessel surveillance program are twofold. The first requirement of the program is to monitor changes in the fracture toughness properties of ferritic materials in the reactor vessel beltline region resulting from exposure to neutron irradiation and the thermal environment. The second requirement is to make use of the data obtained from the surveillance program to determine the conditions under which the vessel can be operated throughout its service life.

3.1.1 To satisfy the first requirement of 3.1, the tasks to be carried out are straightforward. Each of the irradiation capsules that comprise the surveillance program may be treated as a separate experiment. The goal is to define and carry to completion a dosimetry program that will, a posteriori, describe the neutron field to which the material test specimens were exposed. The resultant information will then become part of a database applicable in a stricter sense to the specific plant from which the capsule was removed, but also in a broader sense to the industry as a whole.

3.1.2 To satisfy the second requirement of 3.1, the tasks to be carried out are somewhat complex. The objective is to describe accurately the neutron field to which the pressure vessel itself will be exposed over its service life. This description of the neutron field must include spatial gradients within the vessel wall. Therefore, heavy emphasis must be placed on the use of neutron transport techniques as well as on the choice of a design basis for the computations. Since a given surveillance capsule measurement, particularly one obtained early in plant life, is not necessarily representative of long-term reactor operation, a simple normalization of neutron transport calculations to dosimetry data from a given capsule may not be appropriate (**1-67**).

3.2 The objectives and requirements of a reactor vessel's support structure's surveillance program are much less stringent, and at present, are limited to physics-dosimetry measurements through ex-vessel cavity monitoring coupled with the use of available test reactor metallurgical data to determine the condition of any support structure steels that might be subject to neutron induced property changes (**1, 29, 44-58, 65-70**).

4. Establishment of the Surveillance Program

4.1 Practice E185 describes the criteria that should be considered in planning and implementing surveillance test programs and points out precautions that should be taken to ensure that: (*1*) capsule exposures can be related to beltline exposures, (*2*) materials selected for the surveillance program are samples of those materials most likely to limit the operation of the reactor vessel, and (*3*) the tests yield results useful for the evaluation of radiation effects on the reactor vessel.

4.1.1 From the viewpoint of the radiation analyst, the criteria explicated in Practice E185 are met by the completion of the following tasks: (*1*) Determine the locations within the reactor that provide suitable lead factors (see Practice E185) for each irradiation capsule relative to the pressure vessel; (*2*) Select neutron sensor sets that provide adequate coverage over the energy range and fluence range of interest; (*3*) Specify sensor set locations within each irradiation capsule to define neutron field gradients within the metallurgical specimen array. For reactors in which the end of life shift in RT_{NDT} of the pressure vessel beltline material is predicted to be less than 100 °F, gradient measurements are not required. In that case sensor set locations may be chosen to provide a representative measurement for the entire surveillance capsule; and (*4*) Establish and adequately benchmark neutron transport methodology to be used both in the analysis of individual sensor sets and in the projection of materials properties changes to the vessel itself.

4.1.2 The first three items listed in the preceding paragraph are carried out during the design of the surveillance program. However, the fourth item, which directly addresses the analysis and interpretation of surveillance results, is performed following withdrawal of the surveillance capsules from the reactor. To provide continuity between the designer and the analyst, it is recommended that the documentation describing the surveillance programs of individual reactors provide details of irradiation capsule construction, locations of the capsules relative to the reactor core and internals, and sensor set design that are adequate to allow accurate evaluations of the surveillance measurement by the analyst. Well-documented (*1*) metallurgical and (*2*) physics-dosimetry databases now exist for use by the analyst based on both power reactor surveillance capsule and test reactor results (**1, 12, 19-38, 58-64**).

4.1.3 Information regarding the choice of neutron sensor sets for LWR surveillance applications is provided in Master Matrix E706: Guide E844, Sensor Set Design; Test Method E1005, Radiometric Monitors; Test Method E854, Solid State Track Recorder Monitors; Test Method E910, Helium Accumulation Fluence Monitors; and Damage Monitors. Dosimeter materials currently in common usage and acceptable for use in surveillance programs include Cu, Ti, Fe, Ni, Nb, U^{238}, Np^{237}, U^{235}, and Co-Al. All radionuclide analysis of dosimeters should be calibrated to known sources such as those supplied by the National Institute of Standards and Technology (NIST) or the International Atomic Energy Agency (IAEA). All quality

[5] Available from NRC Public Document Room, 1717 H St., NW, Washington, DC 20555.

[6] Available from American Society of Mechanical Engineers, Three Park Ave., New York, NY 10016-5990.

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