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Standard Guide for Use of Melt Wire Temperature Monitors for Reactor Vessel Surveillance, E 706 (IIIE)[1]

This standard is issued under the fixed designation E 1214; 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 guide describes the application of melt wire temperature monitors and their use for reactor vessel surveillance of light-water power reactors as called for in Practice E 185.

1.2 The purpose of this guide is to recommend the selection and use of the common melt wire technique where the correspondence between melting temperature and composition of different alloys is used as a passive temperature monitor. Guidelines are provided for the selection and calibration of monitor materials; design, fabrication, and assembly of monitor and container; post-irradiation examinations; interpretation of the results; and estimation of uncertainties.

1.3 *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.* (See Note 1.)

2. Referenced Documents

2.1 *ASTM Standards:*

E 185 Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels, (IF)[2,3]

E 706 Master Matrix for Light-Water Reactor Pressure Vessel Surveillance Standards[3]

E 794 Test Method for Melting and Crystallization Temperature by Thermal Analysis[4]

E 844 Guide for Sensor Set Design and Irradiation for Reactor Surveillance, (IIC)[2,3]

3. Significance and Use

3.1 Temperature monitors are used in surveillance capsules, in accordance with Practice E 185, to verify the estimated values of irradiation temperature of the surveillance specimens. Temperature monitors are needed to give evidence of overheating of surveillance specimens beyond the expected temperature. Since overheating causes a reduction in the amount of radiation damage to the surveillance specimens, this overheating could result in a change in the measured properties of the surveillance specimens that would lead to an unconservative prediction of damage to the reactor vessel material.

3.2 The magnitude of the reduction of radiation damage with overheating depends on the composition of the material and time at temperature; there is not yet an accepted method for quantifying the effect. Because the evidence from melt wire monitors gives no indication of the duration of overheating above the expected temperature as indicated by melting of the monitor, the significance of overheating events cannot be quantified on the basis of thermal monitors alone. Indication of an overtemperature does serve to alert the user of the data to further evaluate the irradiation temperature exposure history of the surveillance capsule.

3.3 This guide is IIIE of Master Matrix E 706 that relates several standards used for irradiation surveillance of light water reactor vessel materials. It is intended primarily to amplify the requirements of Practice E 185. It may also be used in conjunction with Guide E 844.

4. Selection and Calibration of Monitor Materials

4.1 *Selection of Monitor Materials*:

4.1.1 Materials selected for thermal monitors shall possess unique melting temperatures. Since composition, and particularly the presence of impurities, strongly influence melting temperature, the fabricated monitor materials shall consist of either metals of purity 99.9 % or greater or eutectic alloys such that the measured melting temperature is within $\pm$ 3°C of the recognized melting temperature. Transmutation-induced changes of the monitor materials suggested in 4.1.2 are not considered significant for fluences to 1×10^{20} n/cm2 (E > 1 MeV) relative to the goal of these thermal monitors in flagging deviations from expected temperatures.

4.1.2 The monitor materials in Table 1 provide temperature indications in the range of 266 to 327°C. Other metals or alloys may be selected for the temperatures of interest provided the monitor materials meet the technical requirements of this guide.

4.1.3 The chosen monitor materials shall be carefully evaluated for radiological health hazards.

NOTE 1—It is beyond the scope of this guide to provide safety and health criteria, and the user is cautioned to seek further guidance.

[1] This guide is under the jurisdiction of ASTM Committee E-10 on Nuclear Technology and Applications and is the direct responsibility of Subcommittee E10.02 on Behavior and Use of Metallic Materials in Nuclear Systems.

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[2] The reference Master Matrix designation in parentheses refers to Section 5, as well as Figs. 1 and 2 of Matrix E 706.

[3] *Annual Book of ASTM Standards*, Vol 12.02.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

TABLE 1 Monitor Material Melting Temperature

Monitor Material, Weight %	Melting Temperature, °C
Cd–17.4 Zn	266
Au–20.0 Sn	280
Pb–5.0 Ag–5.0 Sn	292
Pb–2.5 Ag	304
Pb–1.5 Ag–1.0 Sn	309
Pb–1.75 Ag–0.75 Sn	310
Cd–1.2 Cu	314
Cd	321
Pb	327

4.2 *Calibration of Monitor Materials*— Each lot of monitor materials shall be calibrated by melting tests to establish the actual melting temperatures. The melting temperature tests shall be conducted in accordance with Test Method E 794. If an alternate method of calibration is used, the procedure and equipment must be described, the resultant mean values and uncertainties must be reported, and traceability to standards must be declared.

5. Design, Fabrication, and Assembly of Monitor and Container

5.1 The design of the monitor and its container shall assure that the maximum temperature of the surveillance specimens is determined within ±10°C.

5.2 The design shall provide for a minimum of one set of monitors for each surveillance capsule. Additional sets of monitors are desirable to characterize the inservice axial temperature profiles necessary to determine the maximum temperature of each surveillance specimen.

5.3 The design of the monitor and its container shall assure that the monitor will readily sense the environmental temperature of the surveillance specimens and yet not be subject to any influences from fabrication or assembly or even post-service examination. The monitors typically consist of melt wires positioned adjacent to or among the surveillance specimens.

5.4 The quantity of monitors within each set shall be adequate to identify any temperature excursion of 10°C up to the highest potential temperature, such as 330°C. It is recommended that monitors be selected to measure temperature at intervals of 5 to 12°C. At least one monitor shall remain intact throughout the service life; therefore the highest temperature monitor must possess a melting temperature greater than the highest anticipated temperature.

5.5 Fabrication and assembly of the monitors and containers shall protect and maintain the integrity of each thermal monitor and its ability to respond by melting at the environmental temperature of the surveillance specimens corresponding to the monitors' melting temperature. Design and fabrication must assure that the monitor in the assembled container does melt at a temperature within ±3°C of environmental temperature of the specimens.

5.6 Identification of each monitor, its material and melting temperature, and its orientation and location in the surveillance capsule must be maintained. Provision for means of verification shall be by design.

6. Post-Irradiation Examination

6.1 Following irradiation, the temperature monitors shall be examined for evidence of melting to establish the maximum exposure temperature of the encapsulated surveillance specimens. Precautions should be taken while recovering the monitors from the surveillance capsule and during subsequent examination.

6.1.1 The monitor design and method of encapsulation shall be considered in the recovery procedure to ensure that the monitors are not damaged and that the original identity of individual monitors and their location is maintained.

6.1.2 Recovery and examination of the monitors should be performed remotely or with sufficient shielding to protect the operator from unnecessary radiation exposure.

6.2 Evaluation of the temperature monitors after service for evidence of melting should be performed using suitable equipment that is dependent on the design of the monitor container and the examination facility. When visual inspection of the monitors is possible, such as with periscopes, each monitor shall be examined and the results recorded. When possible, photographic records should be made of each monitor or set of monitors. When visual inspection is not practical or conclusive, radiography or metallographic examination may be necessary. Destructive examination should be performed only if further confirmation of the melting temperature is necessary.

6.3 The monitors shall be evaluated on the following basis:

6.3.1 *Unmelted*—No evidence of melting of any portion of the monitor.

6.3.2 *Partially Melted*—Any evidence of any melting of any portion of the monitor.

6.3.3 *Fully Melted*—Evidence that all of the monitor was subject to melting.

6.4 If there is reason to question the results, monitors should be reevaluated after completion of the post-irradiation examination to ensure that there was no change in the melting temperature. This verification of melting temperature may be performed as described in 4.2.

7. Interpretation

7.1 The design of the melt wire configuration should prevent ambiguities as to incipient melting, however, there may be circumstances where melting is questionable. Change in shape, slumping, and segmenting are indications of melting. When initial examination results are uncertain, further nondestructive and destructive examinations should be performed to verify the condition of the monitor.

7.2 The condition of the monitors should be consistent according to axial position and expected relative temperatures.

7.3 Based upon the temperatures indicated by the thermal monitors, the temperature of surveillance specimens must be ascertained and documented. The temperature relationship should consider the design of the monitor and container, the configuration of specimens relative to the monitors, and potential thermal gradients.

7.4 Abnormalities between the thermal monitor results and historical service conditions shall be assessed and described.

8. Estimation of Uncertainties

8.1 Results should be given as best estimates with known uncertainties. Uncertainties arise from limitations in precision and bias in determining the initial melting temperatures of each monitor, the ability of the monitor to accurately indicate the environmental temperature, the relationship in temperature between the monitors and the specimens, and the bias in discriminating melting.

8.2 All known and estimated uncertainties, including a description of their determination, must be reported with the estimated maximum exposure temperatures.

8.3 Uncertainties resulting from unresolved ambiguities must be described. Probable causes and subsequent implications should be stated.

9. Report

9.1 In addition to the reporting requirements of Practice E 185, the following information shall be reported:

9.1.1 Description of the thermal monitors including chemical composition of the monitor melt wires and their respective melting temperatures with uncertainties, container design, identification, and location in the irradiation capsule.

9.1.2 Results of the post-service evaluation in which each monitor condition is characterized as fully melted, unmelted, or partially melted.

9.1.3 The estimated maximum exposure temperature of each specimen and the known and estimated uncertainties.

9.1.4 The agreement between the thermal monitor results and the historical service conditions and description of any anomalies found while recovering, examining, or evaluating the monitors.

9.1.5 Results of any additional examinations, if performed, to resolve inconsistent monitor results.

9.2 The following additional documentation should be reported if performed:

9.2.1 Photographs of each irradiated temperature monitor that document the visual observations.

9.2.2 Preirradiation test results used to certify melting temperatures of each monitor type.

9.2.3 Test results, if performed, verifying post-irradiation melting temperature for each monitor.