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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 E1214; 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 Practices E185 and E2215.

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.

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1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

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 and health practices and determine the applicability of regulatory limitations prior to use.* (See Note 1.)

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E185 Practice for Design of Surveillance Programs for Light-Water Moderated Nuclear Power Reactor Vessels
E706 Master Matrix for Light-Water Reactor Pressure Vessel Surveillance Standards, E 706(0)
E794 Test Method for Melting And Crystallization Temperatures By Thermal Analysis
E900 Guide for Predicting Radiation-Induced Transition Temperature Shift in Reactor Vessel Materials, E706 (IIF)
E2215 Practice for Evaluation of Surveillance Capsules from Light-Water Moderated Nuclear Power Reactor Vessels

3. Significance and Use

3.1 Temperature monitors are used in surveillance capsules in accordance with Practice E2215 to ~~verify~~estimate the ~~estimated~~maximum value of the surveillance specimen irradiation temperature. Temperature monitors are needed to give evidence of overheating of surveillance specimens beyond the expected temperature. Because overheating causes a reduction in the amount of neutron 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. Guide E900 provides an accepted method for quantifying the temperature 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~~temperature monitors alone. Indication of overheating 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 E706 that relates several standards used for irradiation surveillance of light water reactor vessel materials. It is intended primarily to amplify the requirements of Practice E185 in the design of temperature monitors for the surveillance program. It may also be used in conjunction with Practice E2215to evaluate the post-irradiation test measurements..

[1] This guide is under the jurisdiction of ASTM Committee E10 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 E706.

4. Selection and Calibration of Monitor Materials

4.1 *Selection of Monitor Materials*:

4.1.1 Materials selected for thermaltemperature 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 ±3°C (±5°F) of the recognized melting temperature. Transmutation-induced changes of the monitor materials suggested in 4.1.2 are not considered significant for fluence exposures up to 1×10^{20} n/cm^2(E > 1 MeV) relative to the goal of these thermaltemperature 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 (511 to 621°F). 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.

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 E794. 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 ensure that the maximum temperature of the surveillance specimens is determined within ±10°C (±18°F).

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

5.3 The design of the monitor and its container shall ensure 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 (18°F) up to the highest potential temperature, such as 330°C (626°F). It is recommended that monitors be selected to measure temperature at intervals of 5 to 12°C (9 to 22°F). At least one monitor shall remain intact throughout the service life; therefore the highest temperature monitor mustshall 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 thermaltemperature monitor and its ability to respond by melting at the environmental temperature of the surveillance specimens corresponding to the monitors' melting temperature. Design The monitors and fabrication must ensure that the monitor in the assembled container does containers shall be designed, fabricated and assembled to ensure that the monitors melt at a temperature within ±3°C (5°F) of the 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 mustshall be maintained. Provision for means of verification shall be done by design.

6. Post-Irradiation Examination

6.1 Following irradiation, the temperature monitors shall be examined for evidence of melting to establish the maximum

TABLE 1 Monitor Material Melting Temperatures

Monitor Material, Weight %	Melting Temperature, °C	Melting Temperature, °F
Cd–17.4 Zn	266	
Cd–17.4 Zn	266	511
Au–20.0 Sn	280	
Au–20.0 Sn	280	536
Pb–5.0 Ag–5.0 Sn	292	
Pb–5.0 Ag–5.0 Sn	292	558
Pb–2.5 Ag	304	
Pb–2.5 Ag	304	579
Pb–1.5 Ag–1.0 Sn	309	
Pb–1.5 Ag–1.0 Sn	309	588
Pb–1.75 Ag–0.75 Sn	310	
Pb–1.75 Ag–0.75 Sn	310	590
Cd–1.2 Cu	314	
Cd–1.2 Cu	314	597
Cd	321	
Cd	321	610
Pb	327	621