



Standard Guide for Simulation of Helium Effects in Irradiated Metals¹

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1. Scope

1.1 This guide provides advice for conducting experiments to investigate the effects of helium on the properties of metals where the technique for introducing the helium differs in some way from the actual mechanism of introduction of helium in service. Simulation techniques considered for introducing helium shall include charged particle implantation, exposure to α -emitting radioisotopes, and tritium decay techniques. Procedures for the analysis of helium content and helium distribution within the specimen are also recommended.

1.2 Two other methods for introducing helium into irradiated materials are not covered in this guide. They are the enhancement of helium production in nickel-bearing alloys by spectral tailoring in mixed-spectrum fission reactors, and isotopic tailoring in both fast and mixed-spectrum fission reactors. These techniques are described in Refs (1-5).² Dual ion beam techniques (6) for simultaneously implanting helium and generating displacement damage are also not included here. This latter method is discussed in Practice E 521.

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.*

2. Referenced Documents

2.1 ASTM Standards:

C 859 Terminology Relating to Nuclear Materials³

E 170 Terminology Relating to Radiation Measurements and Dosimetry⁴

E 521 Practice for Neutron Radiation Damage Simulation by Charged-Particle Irradiation⁴

E 706 Master Matrix for Light-Water Reactor Pressure Vessel Surveillance Standards, E706(0)⁴

E 910 Test Method for Application and Analysis of Helium Accumulation Fluence Monitors for Reactor Vessel Surveillance, E706(IIIC)⁴

3. Terminology

3.1 Descriptions of relevant terms are found in Terminology C 859 and Terminology E 170.

4. Significance and Use

4.1 Helium is introduced into metals as a consequence of nuclear reactions, such as (n, α), or by the injection of helium into metals from the plasma in fusion reactors. The characterization of the effect of helium on the properties of metals using direct irradiation methods may be impractical because of the time required to perform the irradiation or the lack of a radiation facility, as in the case of the fusion reactor. Simulation techniques can accelerate the research by identifying and isolating major effects caused by the presence of helium. The word simulation is used here in a broad sense to imply an approximation of the relevant irradiation environment. There are many complex interactions between the helium produced during irradiation and other irradiation effects, so care must be exercised to ensure that the effects being studied are a suitable approximation of the real effect. By way of illustration, details of helium introduction, especially the implantation temperature, may determine the subsequent distribution of the helium (that is, dispersed atomistically, in small clusters in bubbles, etc.)

5. Techniques for Introducing Helium

5.1 Implantation of Helium Using Charged Particle Accelerators:

5.1.1 *Summary of Method*—Charged particle accelerators are designed to deliver well defined, intense beams of monoenergetic particles on a target. They thus provide a convenient, rapid, and relatively inexpensive means of introducing large concentrations of helium into thin specimens. An energetic alpha particle impinging on a target loses energy by exciting or ionizing the target atoms, or both, and by inelastic collisions with the target atom nuclei. Particle ranges for a variety of materials can be obtained from tabulated range tables (7-11).

5.1.1.1 To obtain a uniform concentration of helium through the thickness of a sample, it is necessary to vary the energy of the incident beam, rock the sample (12), or, more commonly, to degrade the energy of the beam by interposing a thin sheet or wedge of material ahead of the target. The range of monoenergetic particles is described by a Gaussian distribution around the mean range. This range straggling provides a means of implanting uniform concentrations through the thickness of a

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² The boldface numbers in parentheses refer to a list of references at the end of this guide.

³ *Annual Book of ASTM Standards*, Vol 12.01.

⁴ *Annual Book of ASTM Standards*, Vol 12.02.